TATA-CORNELL INSTITUTE ANNUAL REPORT

FIFTH ANNIVERSARY EDITION

2018

TATA-CORNELL INSTITUTE FOR AGRICULTURE AND NUTRITION (TCI)

College of Agriculture and Life Sciences Cornell University

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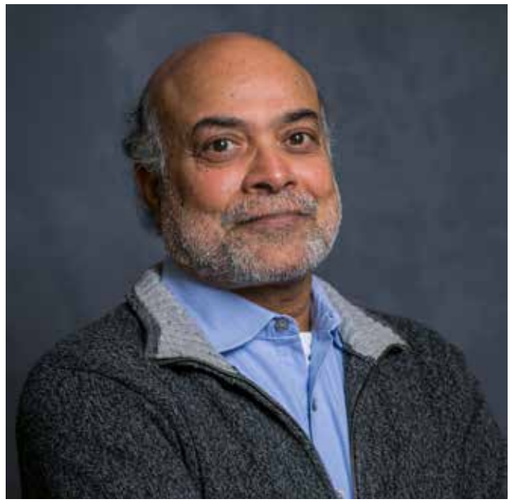
FROM THE DIRECTOR



We are five years old!

I am absolutely delighted with the amazing growth of the Tata-Cornell Institute (TCI) over the last five years. We are now an established Cornell entity, a center of excellence that provides high quality, multidisciplinary research and innovative technical and policy solutions for the intractable malnutrition problems in India. We are making significant progress in bringing agriculture and food systems back to the center of the discussion about the effective pathways to address malnutrition. TCI's analytical framework, its research methodologies and metrics, and its policy prescriptions are being applied beyond India. Through the Gates Foundation-funded TARINA project, we are building capacity in India for promoting nutrient-sensitive food systems.

As of the end of 2018, 10 TCI scholars had graduated, four with PhDs and 6 with master's degrees. We currently have 19 TCI scholars at work: 15 doctoral and 4 master's degree candidates. Our scholars come from various departments and schools across Cornell, including: the Dyson School of Applied Economics and Management, Division of Nutritional Sciences, as well as the departments of Food Science, Animal Science, Development Sociology and Economics. I am proud of the multidisciplinary mix of the TCI team and its commitment to interdisciplinary research. All of our PhD scholars spend a year or more conducting field-based research in rural India. Our scholars have successfully shown that the academic rigor expected of a world class university is absolutely compatible with field-based action research focused on the problems of rural communities in developing countries.

Over the years, we have built a committed core group of TCI "Faculty Fellows" that supervise our scholars' research. It is their commitment to excellence in applied research that makes us successful in achieving TCI's mission. We have also set up an excellent Postdoctoral and Research Associate program, with four having gone through the program in the last five years, and five currently participating. I am delighted with the quantity and quality of the research output of our Scholars and Postdoctoral Associates. To date, we have published 24 peer-reviewed journal articles and book chapters, with an additional six in the process of publication. That is roughly five articles per year. I am also excited about our forthcoming book, *Transforming Food Systems for a Rising India*, being published by Palgrave MacMillan Press. It is expected to be released by mid-2019, and will be available as a free, "open access" publication.

The TARINA project has helped us expand our work across India; we now operate in 6 states, covering 195 villages and 30,000 households. In collaboration with our nongovernmental organization (NGO) partners, we are promoting multisectoral strategies and innovative tools for enhancing the diversity of the food system and improving diet quality, thereby reducing the chronic problems of malnutrition in rural India. We look forward to continued collaboration with the Tata Trusts and the Bill & Melinda Gates Foundation in expanding our reach and impact in India and in providing solutions that can be applicable elsewhere in the developing world.

I hope you enjoy reading our TCI Annual Report for 2018.

Sincerely,
Dr. Prabhu Pingali
Director

TATA-CORNELL INSTITUTE RESEARCH TEAM

From left to right: Shubh Swain, Amrutha Jose Pampackal, Andaleeb Rahman, Jocelyn Boiteau, Sunaina Dhingra, Anaka Aiyar, Vidya Bharathi Rajkumar, Anna David Thottappilly, Kathryn Merckel, Kavya Krishnan, Prabhu Pingali, Naveen Sunder, Vidya Vemireddy, Kiera Crowley, Shiuli Vanaja, Abhinav Choudhry, Anshuman Gupta, Mathew Abraham, Mark Constas, Karuna Salve, Bindvi Arora, Kasim Saiyyad, Chanchal Pramanik, Brenda Daniels-Tibke, Qi Liu, Rohil Sahai Bhatnagar, Vanisha Sharma, Natasha Jha, Jessica Ames.

Not pictured: Mary-Catherine French, Srilakshmi Raj, Payal Seth, Anthony Wenndt

The Tata-Cornell Institute for Agriculture and Nutrition (TCI), founded in 2013, completed five years in 2018. As a long-term research initiative based at Cornell University in Ithaca, New York, with offices in Mumbai and New Delhi, we have grown and expanded our research profile over these years. The TCI team, consisting currently of applied economists; nutritionists; food, plant, soil, and animal scientists; sociologists; engineers; and more, are working to create, test, and scale up sustainable and effective solutions for reducing poverty and improving malnutrition and livelihoods in rural India.

We uniquely combine field-based projects, academic research, and policy analysis to generate and share knowledge relevant to Indian policymakers, research institutions, and development agencies. Our institutional partners have deep field experience and extensive knowledge of the local context; by working together, we share our strengths, mutually build our capacity, and refine the quality of our joint projects. Founded with a generous gift from the Tata Trusts, we are well on our way to making meaningful discoveries and developing innovative technologies and policy solutions to address the agriculture-nutrition nexus in India.

PATHWAYS FOR LINKING AGRICULTURE AND NUTRITION

Although there are many approaches to improving health and nutrition outcomes, TCI believes that the pathways that link agriculture and nutrition can create the most profound and lasting impacts for good health. As such, we have identified and oriented our applied research along four key pathways (Figure 1):

1. The **income pathway**, where gains in household income can translate to better food affordability and other impacts;
2. The **food access pathway**, including a household's access to sufficient, diverse, and quality food year round;
3. The **positive nutrition behavior pathway**, where interventions attempt to equalize food allocation among individuals within a common household and optimize early childhood care practices; and
4. The **health–environment pathway**, which effects improvements in nutrient absorption by linking access to clean water and improved sanitation and hygiene practices to better nutritional health.

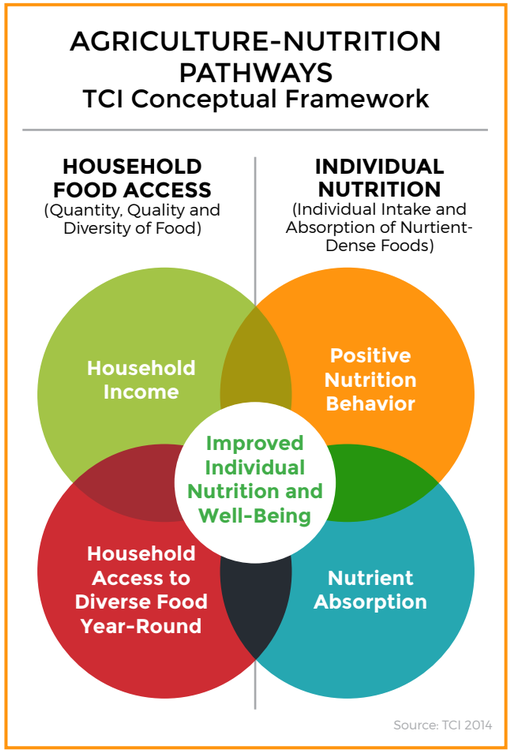


Figure 1: TCI believes that pathways that link agriculture and nutrition can create the most profound and lasting impacts for good health.

TCI's research and projects in India consider the factors that influence both a household's ability to access food—such as income, employment, and the ability to afford safe, high quality, and diverse foods in sufficient quantities—and the individual's ability to absorb and utilize his or her share of the household's total food/nutrient basket, which could vary, depending on the individual's age, gender, level of empowerment, household dynamics, cultural practices, and even physiological life stage (for example, pregnancy and infancy require different diets and care practices).

In this Annual Report we highlight the major research that TCI is currently pursuing or has completed in the year 2018. Many TCI projects concern the food systems pathways, while others encompass the overarching themes around food and nutrition on which the institute works. This section provides a snapshot of the major research and findings, while the different chapters give more detailed descriptions of the various research and findings.

INCOME PATHWAY AND FOOD ACCESS PATHWAY

Improving household-level incomes and ensuring availability of nutritious foods year round is essential to enabling better access to nutritious foods. The Tata-Cornell Institute works with the Cornell departments , such as Food Science, Animal Science, and Soil Sciences, on the topics of food fortification, soil health, and small ruminant production, which can improve access to nutritious foods and raise incomes and productivity at the farm level.

TCI has been involved with pioneering field- and lab-based fortification projects to ensure better access to nutritious food. In 2016, TCI in partnership with BAIF Development Research Foundation, MS University of Baroda, and DSM Nutritional Products Ltd., initiated the Sustainable Flour Fortification Initiative (Sfurti). This program trained Self-Help Group (SHG) members to sell sachets of multiple-micronutrient powder to millers and community members to fortify wheat flour to improve year-round access to nutritious foods. This project has been a great success, with an adoption rate of 70% in the villages in which the project was implemented, and has been instrumental in raising awareness of micronutrient deficiencies and creating demand for fortified food. Inspired by this success, Tata-Cornell Scholar Rohil Bhatnagar, a Food Science PhD candidate, is working on identifying and developing suitable iron-fortifying agents with highly bioavailable iron to fortify foods. Iron Deficiency Anemia (IDA) is one of the most dominant forms of nutritional disorders, disproportionately affecting women and children in countries like India. Bhatnagar has developed and encapsulated defatted green microalgae (DGM) as a potential iron fortificant in wheat flour and is currently carrying out studies with mice to establish its safety as a fortificant. If the viability of DGM as a fortificant is established, it can be used in a range of food items in India.

Soil health, like human health, is also conditioned on the availability of nutrients; healthy soil grows healthy, productive plants. The TCI Soil Health Project is headed by Dr. Harold van Es and PhD scholars Kavya Krishnan and Fatma Rekik. The project aims to bring a more holistic understanding to soil health assessment, going beyond the focus on chemical enhancements (use of synthetic fertilizers) and addresses issues that influence the physical, biological, and chemical attributes of soil to increase agricultural productivity and nutrition. The TCI Soil Health Project works on two fronts. First, it aims to build awareness and capacity, among India-based institutions and NGOs, of Cornell's framework for the Comprehensive Assessment of Soil Health. Second, the project is developing a soil health testing infrastructure, which includes laboratories and mobile tool kits.

Small ruminants are an important source of family income, especially for marginal farmers and the landless. The goat sector in India is constrained by feed shortages because of limited fodder cultivation, insufficient crop residues, and dependence on common property resources, which are small in size and increasingly degraded in vegetative quality and soil fertility. Addressing these issues can help promote small ruminant production and improve rural incomes. Dr. Maureen Valentine, a TCI scholar completed her PhD in Animal Sciences in 2018. Dr. Valentine conducted a field experiment in the Kandhamal District of Odisha to test the effects, on animal feed efficiency and goat health, of shifting from an open-grazing system

to a semi-intensive, stall-feeding system. This was a significant finding that points to the benefit of semi-stall-fed goat rearing and its potential to improve incomes through reduced kid fatalities.

POSITIVE NUTRITION BEHAVIOR PATHWAY

Women play key roles in agricultural activities, which is reflected in their overall time commitments toward agriculture. Time is a key resource used to carry out productive and nonproductive activities, and yet, within the scope of agriculture and nutrition linkages, the direct implications of changes in time allocation of women on nutrition outcomes are not well understood.

Vidya Vemireddy's work at TCI, examines the effects of women's agricultural work burdens on nutrition at the household level. Using multiple surveys, collecting high frequency data detailing time use and dietary intakes across seasons from June 2016 to February 2018, she finds that women contribute to both agriculture and domestic work, while men do not participate in domestic work. During peak seasons, these commitments translate to increased work burdens for women. The research shows that trade-offs in time lead to lower intake of nutrients, and given that women already face major micronutrient deficiencies, any more reduction in micronutrient intakes can be detrimental.

Orange-fleshed sweet potatoes (OFSP) are rich in nutrients, particularly vitamin A, which is essential during late pregnancy and for lactation and is necessary for eye, lung, and immune system functions. TCI, with our TARINA Consortium partner Grameen Development Services, introduced OFSP in the Maharajganj district of Eastern Uttar Pradesh, where diets are low in vitamin A. Kathryn Merckel, a PhD candidate in International Nutrition, is leading a study to understand the role that nutrition knowledge has on influencing decisions to cultivate and consume OFSP. As the crop is new to the region, TCI works to train farmers on how best to cultivate OFSP and inform mothers of the benefits of OFSP in children's diets, through activities such as recipe demonstrations of how OFSP can be used in traditional dishes. The study finds that OFSP adoption increased by an average of 95% in villages that received both agriculture and nutrition messaging interventions, and increased by an average of 50% in villages that received agricultural programming only.

HEALTH-ENVIRONMENT PATHWAY

Water sanitation and hygiene (WASH) practices, along with issues of food safety and waste, impact the availability of foods and nutrition absorption, establishing the importance of the health-environment pathway in the food system. TCI is working toward improving nutritional outcomes through a targeted approach, linking behavior changes around water, sanitation, and hygiene in the states of Uttar Pradesh, Jharkhand, and Odisha. The link between open defecation (OD) and adverse nutritional outcomes in a country like India, where nearly 40% of its population defecate in the open, is critical to address.

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

TCI continues to support AguaClara, a Cornell University graduate-founded project, which has established four water treatment systems in Jharkhand state, serving 2,000 people. We are now supporting AguaClara's expansion into the state of Odisha. Shiuli Vanaja, a PhD candidate in Applied Economics, is looking at the time-saving effects of piped water and the determinants of waterborne diseases in villages with AguaClara interventions, as compared to those without AguaClara's infrastructure. The research finds that in the AguaClara villages, on average, households spent 60 minutes less on water collection compared to the households in the control (non-AguaClara) villages. This has led to increased time spent by women in their primary occupations, whether agricultural work or household chores (including childcare). Ms. Vanaja also found that choice of drinking water source and hygiene practices at home, like handwashing, are important determinants of drinking water quality and a better source of drinking water has lowered the risk of diarrhea at the household level.

Postharvest loss is one of the major challenges affecting not only the adequacy of food supply, but also the quality of household diets, particularly in areas that employ predominantly traditional agriculture. Food that is diverted away from the value chain before it reaches the consumer, known as food loss, reduces food on the supply side. Perishable food groups, such as fruits and vegetables, are micronutrient-rich and contribute to quality diets, but also have greater food loss compared to more durable foods, such as staple grains. Among durable foods, mycotoxins are potent contaminants that can result in diverse health and nutrition deficits, both chronic and acute, in humans and livestock. In addition to the reduced physical and nutritive quality of contaminated food, infestation by mycotoxin-producing fungi can reduce yield and marketability of commodities. TCI Scholar Jocelyn Boiteau is carrying out a study to develop metrics for measuring quantity and quality food loss of perishable vegetables, with a focus on tomatoes. The objective of this work is to adopt a value-chain approach, which considers diet quality, to investigate food loss from a food- and nutrition-security perspective.

TCI Scholar Anthony Wenndt, a PhD candidate in Plant Pathology and Plant-Microbe Biology, is conducting a household-level longitudinal survey of mycotoxin contamination, across a range of susceptible commodities, in the Unnao District of Uttar Pradesh. Given the prevalence of sack-based grain storage systems in the study area and their demonstrated susceptibility to spoilage, the research approach has elevated the use of hermetic (airtight) storage systems as a user-friendly intervention for introduction into enrolled households. The farmer-oriented training program has been successfully administered to 98% of participating households, and preliminary findings indicate an overall positive usage experience.

OTHER ONGOING RESEARCH

Stunting, or height-for-age that falls 2 standard deviations below the mean value for universal growth curves, impacts nearly 142 million children worldwide. Most discussion on stunting centers on the environmental causes. However, the relative contribution of genetics, given environment and environmental change, to explaining the high prevalence of stunting has not been adequately addressed. Dr. Srilakshmi (Sri) Raj, TCI Research Associate, has been working on the design of a strategy to understand stunting in India, given the diversity of its causes and consequences. The project is at its beginning stages of setting up field studies and a genetic survey. The results from this study will help to evaluate current strategies for reducing stunting, and to identify better ways of distinguishing stunting from short stature in India.

Education, especially women's education, is shown to have significant positive effects on outcomes related to health, nutrition, and empowerment (themes that are central to TCI's research agenda). Tata-Cornell Scholar Naveen Sunder (PhD candidate in Economics) examines the direct and intergenerational benefits of the District Primary Education Programme (DPEP) in India. DPEP was a school construction program implemented by the Government of India, in collaboration with international partners. The findings show that school infrastructure programs had substantial

intergenerational impacts, as children of direct beneficiaries performed better on standardized tests of reading, math, and English.

By the year 2050, India will become the most populous country in the world. Current regional inequality in economic development has created a major challenge for the future. Due to differences in initial resource endowments and nationalized policies that placed states on different structural transformation pathways, some states today resemble poor countries in sub-Saharan Africa, while rapidly developing states resemble counterparts in Latin America. Unequal development has also led to the simultaneous prevalence of undernourishment, overnutrition, and micronutrient deficiencies in the country. These conundrums reflect the major paradoxes of the Indian growth story, one in which we see the simultaneous existence of regional inequality, rural and urban food insecurity, and the growing incidence of a triple burden of malnutrition. To address the current challenges in the Indian development paradox and in light of future challenges faced by the country, researchers at the Tata-Cornell Institute have authored the book, *Transforming Food Systems for a Rising India*, to be published by Palgrave Macmillan in 2019. In the book, TCI examines the nexus of economic development, agricultural production, and nutrition through the lens of a "Food Systems Approach (FSA)." Central to our vision for a robust food system is a nutrition-secure future where individuals have the capability and the opportunity to access a balanced and affordable healthy diet and whose health outcomes do not reflect their ability (or lack thereof) to access these diets.

TARINA AND RESEARCH DISSEMINATION

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 the Tata-Cornell Institute, 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. In the last three years, TARINA has made significant progress in bringing about tangible changes in people's lives, gathering evidence about best practices, capacity building, and engaging policymakers to take note of field-based evidence that can inform policy. In Section 4 of this report, one can read about the research and progress that TARINA has made thus far. Dissemination of research findings and engagement with the policy community is a central goal of the Tata-Cornell Institute. Research that is carried out is published in peer-reviewed books and journals. This year, we published six journal articles and book chapters. The publications section of this annual report provides a summary of TCI's publications in 2018.

TCI AT FIVE

TCI'S FIELD PROJECTS HAVE REACHED MORE THAN

30,000 HOUSEHOLDS

195 VILLAGES

6 STATES

OUR ACCOMPLISHED TEAM INCLUDES

29 TATA-CORNELL SCHOLARS TRAINED OR IN TRAINING

9 POSTDOCTORAL AND RESEARCH ASSOCIATES

6 FACULTY FELLOWS

WE HAVE PUBLISHED

3 BOOKS

23 JOURNAL ARTICLES, BOOK CHAPTERS, AND OTHER PUBLICATIONS

12 POLICY BRIEFS

RESEARCH HIGHLIGHTS

RESEARCHER SPOTLIGHT

Kathryn Merckel
Tata-Cornell Scholar and PhD Candidate, International Nutrition

Kathryn Merckel is a Tata-Cornell Scholar and PhD candidate in Nutritional Sciences with a concentration on International Nutrition and Development Economics. She first joined TCI in 2013, in the inaugural group of TCI interns, when she was completing her Master's degree in International Development at Cornell. Previously, she studied Food Science and Technology at the University of Nebraska-Lincoln, where she was awarded a David L. Boren Scholarship to study food security in Tanzania.

Her current research, supported by both TCI and a Fellowship for Foreign Language and Area Studies (FLAS), is on the effectiveness of nutrition and agricultural interventions to promote biofortified crops to farmers and families. Katy is interested in understanding how adoption of micronutrient-rich crops translates into diversified diets and improved nutrition for women and children, using aspects of social marketing and nutrition behavior change, to understand better how to design interventions that reach target audiences to effect lasting improvements in health.

In addition to the very practical skills of research design, data collection, and project management, Katy feels that the type of fieldwork done by TCI scholars is extremely beneficial in challenging and refining many of the assumptions that nutritionists and economists tend to make about diets and interventions to improve nutrition in developing regions. She is very interested in the ways that updating these paradigms and communicating ground-level findings to both the research community and policymakers can improve the relevancy and effectiveness of agricultural and nutrition programs, resulting in more diverse food systems and improved nutrition and health for vulnerable populations.

INCREASING PRODUCTION AND CONSUMPTION OF ORANGE-FLESHED SWEET POTATOES TO ADDRESS MICRONUTRIENT DEFICIENCIES

The Tata-Cornell Institute (TCI) is continuously gathering evidence on ways to increase the demand for cultivation and consumption of micronutrient-rich vegetables such as orange-fleshed sweet potatoes (OFSP). OFSP are rich in nutrients, particularly vitamin A, which is essential during late pregnancy and for lactation, and is necessary for eye, lung, and immune system functions. As the crop is new to the region, TCI works with our TARINA Consortium partner, Grameen Development Services, to train farmers on how best to cultivate OFSP. TCI also works at the household level to inform mothers of the benefits of OFSP in children's diets, through activities such as recipe demonstrations on how OFSP can be used in traditional dishes.

TCI-TARINA introduced OFSP in the Maharajganj district of Eastern Uttar Pradesh, where diets are frequently lacking in vitamin A. Tata-Cornell Scholar Kathryn Merckel, a PhD candidate in International Nutrition, is leading a study to understand the role that nutrition knowledge has in decision-making around the cultivation and consumption of OFSP. The study promotes OFSP as a crop in 10 villages, five of which were randomly selected to receive additional programs on nutrition behavior change and information on the importance of vitamin A in the diet. By assessing the differences in OFSP cultivation and consumption between the villages receiving only the agricultural promotion and those receiving additional nutrition information, we will learn how knowledge of nutrition motivates households to adopt more diverse crop systems and healthier diets.

At the start of the study, every household in each of the 10 villages had the opportunity to receive, at no cost, the orange-fleshed sweet potato vines if they attended an intensive field training on the basics of OFSP cultivation. The baseline adoption rate of orange-fleshed sweet potatoes was 18% in villages slated to receive only agriculture programming and 10% in villages that were to receive both agricultural and nutrition programming. The difference between the groups was attributable to earlier programs, which promoted OFSP in some of the villages that were randomized to receive agriculture promotion only, as well as differences in landholdings, factors that will be accounted

BENEFICIARY SPOTLIGHT

Project: Orange-Fleshed Sweet Potatoes for Nutrition in Uttar Pradesh

Name: Radhika

Village: Beloha, Maharajganj District, Uttar Pradesh

Quotes: Radhika, on why she chooses to grow this new crop: "It is healthy for us, so we grow."

Radhika, on eating orange-fleshed sweet potatoes: "It is the best, it has great taste."

The OFSP for Nutrition in Uttar Pradesh (ON-UP) Project aims to reduce the prevalence of vitamin A deficiency in communities in Maharajganj, Uttar Pradesh, through the introduction of orange-fleshed sweet potatoes, beta-carotene-rich tubers. This project builds on the success of similar OFSP introductions in sub-Saharan Africa. Farmers receive free vines and tubers for propagation, as well as agriculture support from our local partner, Grameen Development Services. Farmers trade vines, planting materials, and advice about growing OFSP between growing seasons.

Radhika is an OFSP farmer in Beloha, one of the agriculture intervention villages. The agricultural extension agents are quick to share how hard she works growing OFSP: her husband is an urban laborer, so most of the year she does everything by herself. She jokes that while other community members act indifferently to OFSP, she caught them stealing from her plot. The orange-fleshed sweet potato has "gone viral" in many villages, as it is delicious, easy to grow, and can be cultivated in all three Indian growing seasons. Radhika is expanding her area grown in OFSP next season.

RESEARCH HIGHLIGHTS

for in the final analysis. For the next five months, farmer field schools were conducted monthly in each village; and in villages receiving the nutrition messaging intervention, additional events were held to raise awareness about vitamin A deficiency, the role of orange-fleshed sweet potatoes in healthy diets, and proper diets for infants, young children, and mothers.

After the five-month intervention, we surveyed the villages to learn what impact OFSP were having. We found that 93% of people in the 10 villages had heard of OFSP, up from 23% at baseline, and that on average, people could name one more characteristic of OFSP than they could at baseline. These results were surprising, since only about half of the people in any given village had attended even one of our events. We also found an increase in the number of people growing OFSP, this time receiving vines from friends or neighbors who had first received their vines from us.

We found that OFSP adoption increased by an average of 95% in villages that received both agriculture and nutrition messaging interventions, and increased by an average of 50% in villages that received agricultural programming only. Future monitoring should tell us whether the difference in the rate of adoption is due to the effects of the intervention or to natural trends, in which rates of adoption begin to slow once a certain threshold of people are growing OFSP. We do not know what the saturation point is for OFSP in these rural villages. However, we do know that the main predictors for growing OFSP are awareness of its availability and having land for growing it. This finding speaks to how popular OFSP is and how eager Indian farmers are to try new crops and technologies.

When it comes to food choices, the nutrition intervention has motivated women to provide more vitamin A-rich foods to their children. We found that children in villages receiving the nutrition intervention ate more vitamin A-rich foods than children in villages who did not receive nutrition messages (Figure 1).

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

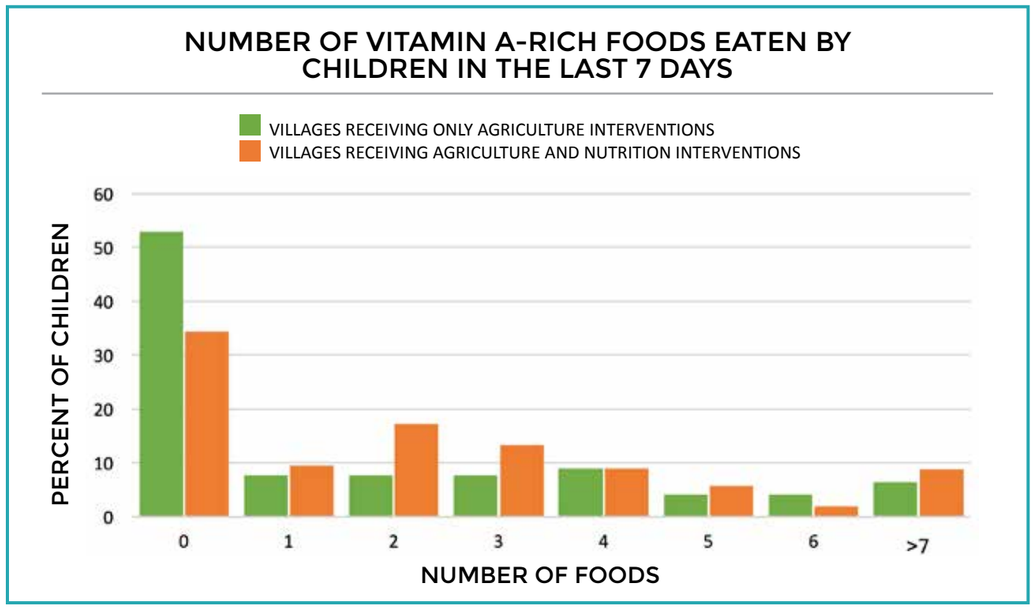


Figure 1: Children in the nutrition intervention ate more vitamin A-rich foods than children in villages who did not receive nutrition messages.

Diet diversification is a critical step in reducing micronutrient deficiencies and improving health outcomes, and projects like this one provide important data for understanding the underlying mechanisms that influence small farmer production systems and household decision-making around food selection. As a part of the TCI-TARINA project, this study contributes to the objective of increasing demand for nutritious foods and diversifying production of nutrient-rich crops. As we learn more about how individuals and households in rural Uttar Pradesh share information about food and agricultural innovation, and how interventions such as this one empower individuals to diversify their production and diets, we will be able to design policies and programs that are more effective and efficient at improving nutrition and health in rural India.

POSTHARVEST LOSS MANAGEMENT WITH A FOCUS ON MYCOTOXIN EXPOSURE: REDUCING NUTRITIONAL AND SOCIOECONOMIC BURDENS OF UNSAFE FOOD

Postharvest loss is one of the major challenges that affects not only the adequacy of food supply but also the quality of household diets, particularly, in areas that predominantly employ traditional agriculture. Among the many factors that lead to the postharvest loss in the rural food system, mycotoxins are potent fungal metabolites that contaminate food and feed chains worldwide. Exposure to mycotoxins can result in diverse health and nutrition deficits, both chronic and acute, in humans and in livestock. In addition to the reduced physical and nutritive quality of contaminated food, infestation by mycotoxin-producing fungi can reduce yield and marketability of commodities. In India, as in other parts of the developing world, local regulatory capacity is insufficient to adequately detect and ameliorate mycotoxin contamination, leaving many farmers' harvests unscreened and allowing potentially contaminated food and feed items into the diets of vulnerable people and animals.

The Tata-Cornell Institute has embarked upon a unique and intensive research effort, which uses a blend of strategies for farmer engagement along with laboratory-based analytical approaches, to assess the extent of mycotoxins in major crops, as well as create feasible and locally acceptable solutions and opportunities for reducing the nutritional and socioeconomic burdens of unsafe food.

In this study, TCI aims to optimize participatory research methods that can enable smallholders to autonomously regulate and reduce mycotoxin loads and other barriers to food safety in their own food systems.

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

Maize and groundnuts are most affected by aflatoxin, both in terms of frequency and magnitude, with some contamination exceeding 1,000 ppb (India's regulated limit for safe human consumption is 15 ppb). Sizable aflatoxin loads were detected in paddy (unmilled rice) and pearl millet. Preliminary comparisons between milled and unmilled rice from the same farms indicate that most of the toxin is in the husk and bran of the rice kernel and is, therefore, largely (but not completely) ameliorated by the milling process.

Deoxynivalenol (DON), a major wheat-affecting mycotoxin, and fumonisin, a major carcinogenic maize- and millet-affecting toxin, were largely absent in samples collected in the study area. This finding, coupled with the lack of associated crop diseases reported in the field, suggests that the fungal species responsible for fumonisin and DON contamination are absent or non-toxigenic in the

study area, a finding that can help in identifying priorities for mycotoxin risk management and in conceptualizing how mycotoxins fit among spoilage agents in household grain storage.

Time-point data from the longitudinal survey to date have revealed several important trends in mycotoxin accumulation across the target commodities (Figure 2). In groundnuts, the mean level of aflatoxin contamination has remained relatively constant over time. In maize, aflatoxin levels have been very high consistently across all time-points. Paddy, not traditionally considered highly susceptible to aflatoxin contamination, has yielded considerable levels of the toxin throughout the longitudinal survey. There was an unexpectedly dramatic leap in aflatoxin contamination in paddy in March 2018 (Time-point 3), and TCI is presently working to understand potential environmental and/or biological factors at play in this uptick at approximately 6 months postharvest. The lowest levels of aflatoxin contamination were observed in stored pearl millet and milled rice samples.

Efforts are ongoing to develop participatory data collection and problem-solving opportunities for the target village communities. Farmers are being successfully engaged in systematically documenting seasonal cultivation and food management behaviors, and in characterizing prominent grain storage pests and disease concerns.
Given the prevalence of sack-based grain storage systems in the study area and the sacks' demonstrated susceptibility to spoilage, our participatory research approach elevated hermetic (airtight) storage systems as a user-friendly intervention to introduce in enrolled households. The farmer-oriented training program has been successfully administered to 98% of participating households (180/184 total enrolled households). Hermetic storage sacks were distributed (2 per participating household) to participants for a household-level trial. Participants have been engaged in monitoring the quality of their grain and the storage environment, and qualitative interviews indicate an overall positive usage experience.

This study, with implications for policymakers, is demonstrating that supervised local self-monitoring, enabled by a structured and informative participatory process, can ideally

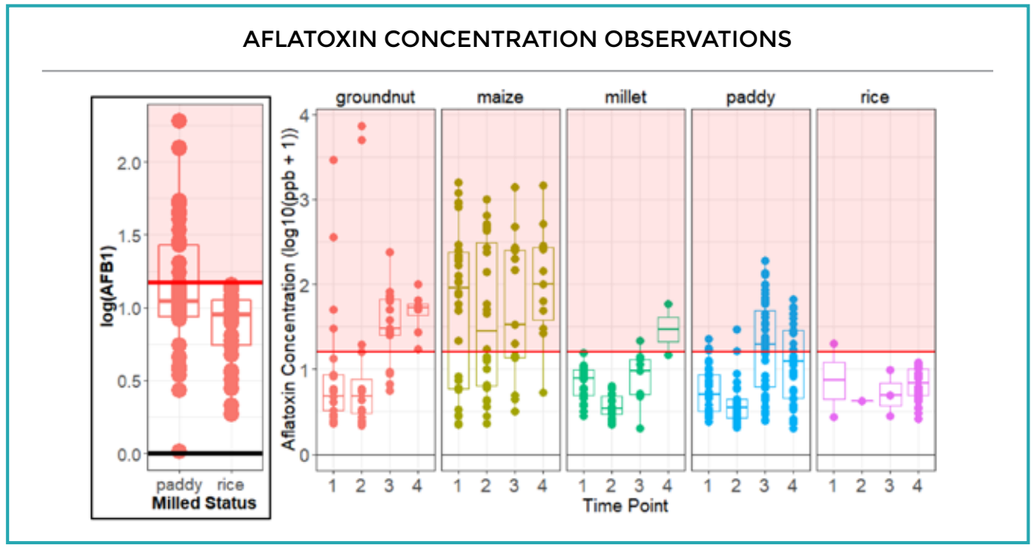


Figure 2: (Left) Aflatoxin concentration observed in milled and unmilled samples of the same rice batches, with samples having reduced, yet still quantifiable, levels of toxin post-milling. (Right) Time series progression of aflatoxin B1 contamination in enrolled household samples. Only samples with detectable (>1 ppb) levels of aflatoxin B1 are shown. The red line represents the regulated legal limit (15 ppb), and any points in the red-shaded portion of the figure represent samples with contamination in excess of that limit.

Guided participatory research activity with participants.

cultivate an indigenous sense of value of food safety and an understanding of the link between food quality and nutrition security, while lifting some of the burden from formal, but overburdened, regulatory oversight and also effectively mitigating mycotoxins and other agents of food spoilage and waste in a locally adapted manner. The process is also producing a toolkit and organizational model for community action, which could be adapted for other efforts to realize nutritional and social gains.

ROLE OF WOMEN'S TIME IN AGRICULTURE-NUTRITION LINKAGES: EVIDENCE FROM RURAL INDIA

Agricultural development has various implications for nutrition. From existing literature, we know that women play a key role in agricultural activities, which is reflected in their overall time commitments toward agriculture. Women in rural areas of developing countries not only engage in labor-intensive activities like agriculture and construction, but also are solely responsible for household chores like cooking and cleaning, collecting fuel and water, and caring for children and the elderly. As time commitments in agricultural activities fluctuate, the amount of time a female household member can allocate to food preparation, childcare, and rest is also affected. Time is a key resource used to carry out productive and nonproductive activities, and yet, within the scope of agriculture and nutrition linkages, the direct implications of changes in time allocation for women on nutrition outcomes are not well understood.

In recent discourse, there is a growing concern that increasing women's agricultural work can negatively impact their time for providing nutrition to the household. However, there are no studies that explore the impact of time constraints imposed by agriculture, across seasons, on nutrition. This study addresses the gap in the literature by looking at the relationship between women's time constraints and their nutrient intake in the context of agricultural-nutrition linkages.

Translating the Evidence to Action
Based on preliminary findings, TCI's TARINA initiative is piloting and scaling up improved storage technologies, like hermetic bags, grain storage drums, and moisture meters. These technologies have been introduced for pulses, such as chickpea, green gram, and black gram; vegetables; and staples, including wheat, in all TARINA village locations. Awareness is being generated through self-help groups and farmer field school platforms. Around 840 households have received benefits of these technologies and have been able to store approximately 60 tons of crop harvest for future consumption, selling in the market, or using for seed in the next sowing season.

Therefore, in order to clarify how time allocation in agriculture could affect nutritional outcomes, TCI conducted a study in the Chandrapur district of Maharashtra, India. The study spreads across 24 villages, located in three blocks of the Chandrapur district, each of which have different cropping patterns: Mul (paddy), Korpana (cotton), and Gondpipri (paddy and cotton). This has allowed for the necessary spread of agricultural activities to study time allocation patterns. A random sample of 40 households was chosen from each of the 24 villages per block, for a total of 960 households. Each household was visited 10 times throughout the year; a woman within the age range of 18-49 years and a representative man were interviewed in each household, thus, bringing the total sample of individuals to 1,920.

Led by Tata-Cornell Scholar Vidya Vemireddy, this overall effort, which includes multiple surveys across seasons and prerequisite recipe

RESEARCHER SPOTLIGHT

Anthony J. Wenndt
Tata-Cornell Scholar and PhD Candidate, Plant Pathology and Plant-Microbe Biology

Anthony J. Wenndt is a Tata-Cornell Scholar and PhD Candidate in the field of Plant Pathology and Plant-Microbe Biology. He received BA degrees in Biology and Russian Language, with an interdisciplinary concentration in Global Development Studies, from Grinnell College. His research sits at the intersection of science and society, and he is passionate about connecting smallholder farmers to livelihood-enhancing agricultural insights and technological innovations.

At TCI, he is working to develop a participatory action research (PAR) framework for capacity building and community mobilization against the accumulation of fungal toxins in foods that can be injurious to human and animal health. He is currently conducting a participatory survey of mycotoxin accumulation in household grain storage systems in Unnao District, Uttar Pradesh, and working to establish a Farmer Research Network geared toward facilitating locally specific food safety diagnostics and intervention options for target communities.

standardization, was conducted during the period of June 2016 to February 2018. To our knowledge, this is the first study that collected such high-frequency data on detailed time use and dietary intake, spanning multiple seasons.

Our findings show that women contribute significantly to agriculture as well as to domestic work and that they are time constrained. Figure 3 shows the average time spent, in minutes per day over a ten-month period, in agriculture, cooking time, domestic work, and socializing. In peak agriculture seasons (for example, during July-August planting and in October-November for harvest), women can spend up to 333 minutes in agriculture; thereby reducing their time spent on domestic work, personal care, and sleep-related activities.

The consequences of these time trade-offs are reflected in nutrient intake as well. We were able to calculate precise nutrient intakes for micronutrients, such as iron and zinc, and macronutrients, such as carbohydrates and proteins, through a 24-hour recall of dietary consumption. These nutrient intakes are calculated using a one-of-a-kind record of 502 local recipes, which we collected through a recipe standardization process. (The recipe standardization process documents the recipes prepared at home in terms of ingredients used and the time taken to prepare and cook them.) Using this detailed information, we find that working longer hours in agriculture during the peak season is associated with a lower intake of calories, proteins, fats, iron, zinc, and vitamin A.

One of the main challenges in studying the linkage between women's time allocation and nutrition outcomes is lack of appropriate time-use and dietary intake panel data that spans all agricultural seasons. This lack of data makes it almost impossible to analyze the nuances at play. We are able to address data and literature gaps related to seasonality. Using the rich time-use data, our study documents the types and extent of work burdens faced by women in agriculture. We also contribute methodologically, by providing novel methods of collecting nutrient information and time-use data.

There are several implications of this research. Our findings suggest that women contribute to both

AVERAGE TIME SPENT IN AGRICULTURE AND OTHER ACTIVITIES BY WOMEN

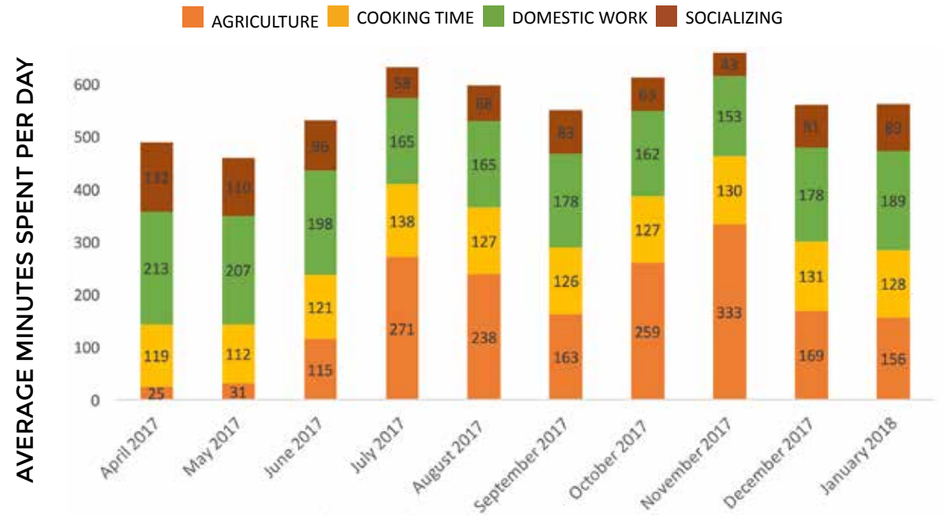


Figure 3: More time in agriculture means less time for self-care, cooking, cleaning, and sleep.

RESEARCH HIGHLIGHTS

agricultural and domestic work, while men do not participate in domestic work. During peak seasons, these commitments translate to increased work burdens for women. We also show that these trade-offs in time lead to lower intake of nutrients. Given that women already face major micronutrient deficiencies, more reduction in micronutrient intakes can be detrimental. From the perspective of agriculture-nutrition linkages, understanding the

Woman being interviewed by an enumerator while she is storing turmeric.

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

ACCESS TO PIPED WATER, TIME SAVINGS, AND HEALTH COSTS IN RURAL INDIA

Many of us living in cities and in developed countries take access to good quality drinking water for granted. However, for much of the world, especially in rural South Asia and Africa, access to clean water at home is a dream. In fact, in India, only about 40 percent of the population has piped water on tap in the premises of their homes. In the absence of this basic facility, family members (especially, women and girls) must travel outside their home to fetch water. They often carry water for drinking, cooking, bathing, and washing utensils and clothes. Sometimes, women make several trips a day, covering larger distances from their homes. Time spent in water collection is time not spent on other productive activities like agricultural work, income-generating activities, attending school or trainings, caring for family members such as small children or the elderly, or simply enjoying a bit of leisure time.

The Tata-Cornell Institute is working to quantify the effects of having piped water on tap on women's time use and time savings. We are also interested in understanding the determinants of water-borne illnesses, such as diarrheal disease. Diarrhea is a leading cause of death for children across the developing world. Furthermore, repeated bouts of diarrhea take a toll on nutritional outcomes, in that it is difficult for affected persons to absorb nutrients if their intestines are regularly diseased or inflamed. By working to improve access and make the availability of clean water inside the home a reality for more rural people in India, TCI is not only improving the quality of life and saving time and labor for women, we are also improving the nutrition and health of these households.

Results from Field Surveys in Jharkhand

The efforts to understand the time-saving effects of piped water and the determinants of waterborne diseases in rural India is being led by Shiuli Vanaja, a Tata-Cornell Scholar and PhD candidate in Applied Economics.

In the state of Jharkhand, working with our partner AguaClara (a Cornell-based R&D team), TCI established water treatment systems in four villages. After these systems became fully operational, Ms. Vanaja studied the time-saving effects of having access to piped water at home in three of these four villages. For this purpose, three control villages, which were similar in socioeconomic status to the AguaClara villages, were chosen for comparison. A yearlong field survey was conducted to measure the time spent in water collection in the AguaClara and control villages over different seasons of the year.

The purpose of this research was to explore how much time women in the households saved when

FROM RESEARCH TO REALITY: HOW AGUACLARA AND TCI ARE INCREASING WATER ACCESS IN INDIA

While we understand that safe water on tap has important economic and health benefits for communities; reliable, long-term water service in developing regions is a lingering challenge. Conventional water treatment technologies are not easily sustained in low-income communities, often becoming defunct within a few years of installation. Although household-level water treatment technologies, such as charcoal filters or reverse osmosis units, are a logical alternative, they are costly and do not achieve the same health outcomes as tap water at home. Our partner, AguaClara, seeks to push the boundaries of technology, inventing new systems that allow water treatment plants to be economic and long-lasting for increasingly smaller communities.

In partnership with AguaClara, TCI established four water treatment systems in Jharkhand state, serving 2,000 people in total. Now we are helping establish more water treatment facilities in the eastern state of Odisha. AguaClara technologies are unique in that they are gravity-powered, use local materials and labor, and achieve high performance with simple design. Community engagement, training, and empowerment are critical aspects of this technology transfer, which ensures ongoing maintenance and sustainability.

AguaClara technology is gravity-powered and achieves high performance with simple design.

The AguaClara program began as a student-based research program at Cornell University, which had the original goal of designing water treatment plants in resource-limited communities in Honduras. In 2013, AguaClara LLC, was founded by Cornell graduates to extend the implementation of the technology to underserved communities in India. Now, as a nonprofit organization AguaClara Rearch with the support of TCI is bringing clean drinking water on tap to communities in need. The community is treating the water using an invention called the Hydrodoser, developed by AguaClara Reach. The Hydrodoser is a gravity-based, sensor- and pump-free technology, which automatically adjusts the flow of a chlorine solution based on the flow of water to be treated. This feature ensures the disinfectant dose is neither too high nor too low. An accurate dose is critical for ensuring the safety of the water and is something that previous nonelectric disinfection systems had been unable to achieve. The simple yet sophisticated technology is built using pipes and tubes that can be found in any hardware store and can be operated and repaired by local community members.

The water service is administered by a local, democratically elected water board. The water board manages bill collection, pays the local operator, and commissions repairs. For around $1 per household per month, the communities can receive up to 120 liters of safe drinking water per person per day. This affordable solution makes it a viable option for the most remote communities.

Following the success of the Hydrodoser installation in Lahanda, AguaClara Reach is working with local NGO partner Gram Vikas to deploy the Hydrodoser across 60 villages. Together, they are training a team of local fabricators to manufacture the technologies. Then, they will install them initially in five communities and train local operators to run the systems. The Tata-Cornell Institute is committed to supporting AguaClara Reach and expanding the deployment of this life-changing technology.

they had access to in-house piped water on tap and how the women used their time freed from water collection. We found that in the AguaClara villages, on average, households are spending 60% less time in water collection per day compared to the households in the control (non-AguaClara) villages. In other words, the households in the control villages spent 100 minutes per day on average collecting water, while the households in the AguaClara villages spent only 40 minutes.

Shiuli Vanaja (right) speaking with a woman about the time spent on daily activities.

This has led to increased time spent in their primary occupation, which is either agricultural work or household chores (including childcare). On average, women in the AguaClara treatment villages are spending 20% of their extra time each day in their primary occupation.

Surprisingly, Ms. Vanaja also observed that even in households with piped water, family members were sometimes traveling outside their home to fetch water from other public water sources available in the community. 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 other more conveniently located water sources, such as the piped water they have on tap at home. The existing social norms and beliefs affect their perceptions and preferences regarding drinking water.

To understand 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. The drinking water quality at home 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. Our results found that both the chosen drinking water source and hygiene practices at home, like handwashing, are important determinants of drinking water quality in the 30 villages. Households that made better choices regarding sources of drinking water have lower risk of diarrhea from drinking water.

In sum, this work affirms the many benefits of having clean, piped water on tap. There is a continued need for building water infrastructure, like the AguaClara piped water systems, to provide water on tap to homes in rural India. This infrastructure would save time for women and other family members involved in water collection and increase the time spent in agricultural and care work. Access to a piped water tap at home, however, may not guarantee that households will use it for drinking purposes. The perception of quality plays an important role in determining the source choice, water-handling practices, water quality, and associated health costs. For reducing health costs associated with waterborne diseases, it is important to understand the drivers of the perceptions of rural women about the quality of drinking water and devise behavioral change programs to modify these perceptions favorably.

ACHIEVING AND SUSTAINING OPEN DEFECATION-FREE VILLAGES THROUGH COMMUNITY MOBILIZATION

The Tata-Cornell Institute is working toward improving nutritional outcomes through a targeted approach that links behavior changes around water, sanitation, and hygiene (WASH) practices. The link between open defecation and adverse nutritional outcomes in a country like India, where nearly 40% of its population defecate in the open, is critical to address (WHO and UNICEF 2017). The Indian policy response has been focused largely on the construction of toilets. Eliminating open defecation (OD) is one of the major challenges in building an enabling environment for better nutrient absorption.

A major unexplored factor behind the rampant practice of OD is the preference to do so, which

TCI-TARINA uses the CLTS approach with the aim of achieving open-defecation free villages in rural Uttar Pradesh.

the mere provision of toilets does not overcome. With the collaboration of our TARINA Consortium partner Grameen Development Services (GDS), we are building on the tenets of community-led total sanitation (CLTS): a behavioral change campaign methodology that stimulates community-level behavior to stop the practice of OD. Communities are facilitated to conduct their own appraisals and analyses of open defecation (OD) and take their own actions to become ODF (open defecation free). At the heart of CLTS lies the recognition that merely providing toilets does not guarantee their use, nor result in improved sanitation and hygiene.

Tata-Cornell Scholar Payal Seth, a PhD candidate in Applied Economics, is leading this important research. Our study aims to find out the causal contribution of behavioral change versus toilet construction approaches on outcomes, such as the use of toilets, child health, and safety of women. The research design has two treatment arms and one control arm. The two treatment arms (Clusters A and B) are presented with the option of toilet construction, in which each household would receive one toilet. Tata-Cornell Institute covers 75% of the cost, and the rest is borne by the households. Additionally, Cluster A receives a behavioral change intervention before the decision is made to have the toilet built. Around 1,000 households in 15 villages in the Maharajganj District of Uttar Pradesh are participants in this experiment.

Before the intervention, less than 3% of the households had access to toilets. After the behavioral change intervention was successfully disseminated in all Cluster A villages, almost all households readily accepted having the toilets built (Figure 4). In Cluster B, around 84% of the households agreed to toilet construction. The

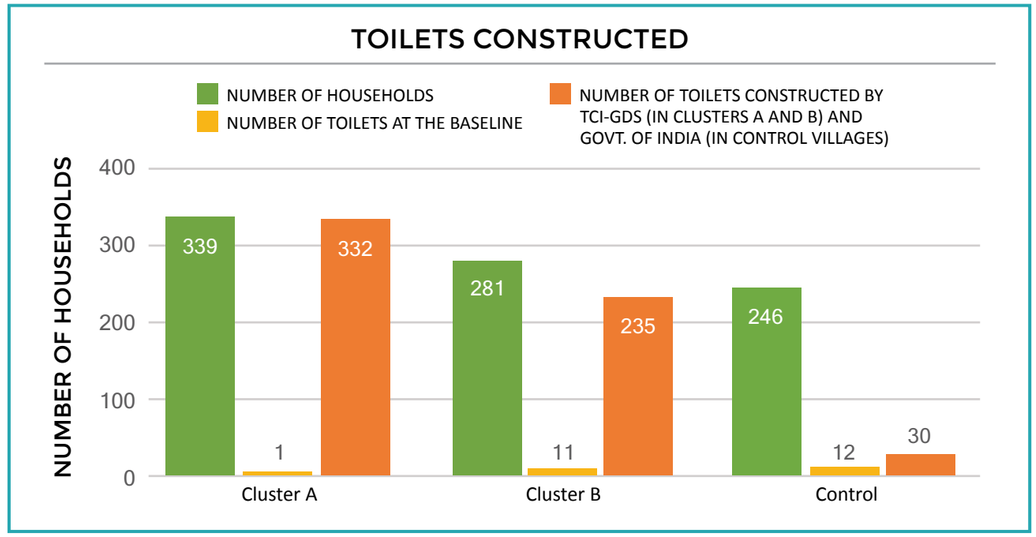


Figure 4: In cluster A villages, after the behavioral change intervention, almost all households readily accepted having the toilets built. In Cluster B, around 84% of the households agreed to toilet construction.

difference in the amount of toilet construction in Clusters A and B is statistically significant at p-value = 0.01[1].

Toilet Use

Designed to gain more insight into understanding toilet use among the different clusters, our study tracks the monthly toilet usage of the heads of the households and their spouses in all households participating in this study (Figure 5).

There is a discernible difference in the toilet usage of the two treatment arms in comparison to the control arm. Within the treatment arms, Cluster A, with the CLTS behavior change campaign shows a significant increase in toilet use across gender. Women's use of toilets is significantly higher than that of the men in both treatment arms. The qualitative findings from the semi-structured focus group discussions support the survey findings. The messages and demonstrations,[2] which prompt the community for a closer appraisal of the physical outcomes of open defecation are found as significant drivers for increasing toilet use. The interim results from the study indicate the feasibility of adapting or scaling up the intervention to other TCI-TARINA study areas.

ESTIMATING AND UNDERSTANDING THE QUANTITY AND QUALITY FOOD LOSS IN VEGETABLE VALUE CHAINS: A STUDY OF TOMATOES IN INDIA

India faces a continued prevalence of undernutrition as well as an increasing prevalence of overweight and obesity. Food systems that are delivering poor quality diets are among the contributors to this triple burden of malnutrition. Food production and consumption systems are related to the UN Sustainable Development Goals (SDGs) to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (SDG2); ensure healthy lives and promote wellbeing (SDG3); and ensure sustainable consumption and production patterns (SDG12). Food loss and waste have been recognized as a source of global concern under responsible production and consumption, with potential implications for food and nutrition security.

Food production systems cover the value chain from on-farm production, processing, and distribution to marketing and retailing. Production systems shape food environments, as they determine the foods that are available, affordable, and appealing to consumers. Foods that are available and accessible influence diet quality. Food that is diverted away from the value chain before it reaches the consumer, known as food loss, reduces food on the supply side. Perishable food groups, such as fruits and vegetables, are micronutrient rich and contribute to quality diets, but also have greater food loss compared to more durable foods, such as staple grains.

Opportunities within the food system exist to reduce fruit and vegetable losses and to improve their availability and affordability to consumers. However, there are no standard, validated methods to measure food loss. The knowledge gap in estimating the scope of quantity and quality food loss, as well as the determinants of loss, remains a challenge for designing evidence-based interventions. Many studies on food loss have focused on durable foods such as staples. Further, estimates continue to focus on quantity loss without as much attention given to quality loss.

[1] Please note that the toilets in Cluster C (our control group) were constructed by the Government of India and not by TCI-GDS.

[2] One such demonstration is the fecal-oral demonstration, found to be one of the crucial triggering activities for behavioral change. A strand of hair is dipped in a sample of old and foul-smelling excreta, and then in a glass of water, which is politely offered to the members of the community. Most indignantly refuse. Flies begin gathering around the feces and also sit atop a pile of rice, strategically placed next to the fecal matter. The community comes to understand that the fly, with 6 feet, is six times more likely to transfer infection from the feces to the rice, than a single hair dipped into the glass, which members rejected, with one refusing angrily. The community concludes that they must abandon OD and seeks aid to further this goal, the behavioral change that we have found to be significant in the acceptance of the toilets.

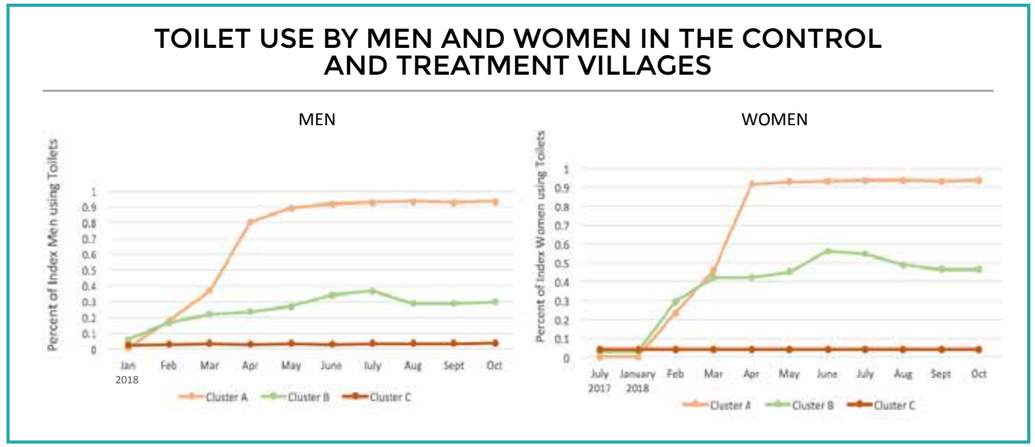


Figure 5: The graphs depict the monthly toilet usage of the representative (index) man and woman of the household. All responses are self-reported.

Therefore, TCI seeks to understand quantity and quality food losses along the perishable vegetable value chains in India.

We are working to adapt methods to estimate the magnitude and determinants of vegetable losses from farm to retail with the objective of identifying points of quantity and quality loss along the value chain, and final destinations of diverted food.

Beginning in October 2018, Tata-Cornell Scholar Jocelyn Boiteau initiated a study to develop metrics for measuring quantity and quality food loss of perishable vegetables, with a focus on tomatoes. The objective of this work is to adopt a value-chain approach that considers diet quality to investigate food loss from the perspective of food and nutrition security. Tomatoes were chosen as a case study vegetable because they are highly perishable, are grown during multiple seasons, and have both culinary and economic importance throughout India. Beyond India, tomatoes are an important vegetable globally, both in terms of production and consumption.

Setting up research sites in the Chittoor district, Andhra Pradesh, and Hyderabad, Telangana, we will use quantitative and qualitative methods to gain a comprehensive understanding of food loss along fresh tomato value chains. Andhra Pradesh is among the top tomato-producing states in India, and the Chittoor district has the greatest area under tomato cultivation in the state. Further, the Madanapalle tomato wholesale market, located in the Chittoor district, is among the largest tomato markets in Asia. Study participants in the Chittoor district site will include tomato farmers, wholesale buyers, and local retailers that purchase directly from farmers.

Tomatoes in Madanapalle are sent all over India, including Hyderabad, a major metropolitan area in India. Therefore, we will include Hyderabad as a second research site to give length to the tomato value chain and understand food loss of tomatoes at vegetable wholesale markets and retail stages. Study participants in the Hyderabad site will include tomatoes traders and retailers.

Data will be collected between January-September 2019. This data collection captures both low and peak harvest seasons, allowing us to determine any seasonal differences in food loss. Results from this study will provide estimates and determinants of quantity and quality loss along the studied tomato value chains. Additionally, using innovative field-based food quality assessment methods, we will compare sensory quality scaling with nutrient content estimates. Finally, this study will provide valuable information on how value chain actors perceive and describe their experiences of quantity and quality loss in vegetable value chains.

This work will contribute to the development and scope of food loss metrics and methods. Importantly, this study expands the scope of

BENEFICIARY SPOTLIGHT

Project: Igniting Change in Sanitation Behavior through Community-Led Total Sanitation

Name: Vidyawati

Village: Shivrajpur, Maharajganj District, Uttar Pradesh

Quote: Vidyawati, after the implementation of CLTS in her village states: "People used to defecate on the roads… It was bustling with vehicles and people, anyone could stare at us, and with so many people staring at us, our honor was at stake. [But now,] our village is protected, our kids use toilets, we use them... As you can see, the village is all clean now, there are no feces outside."

The sanitation project of TCI aims to study the effectiveness of a behavior change program called Community-Led Total Sanitation (CLTS) to end open defecation. Beyond the mere implementation of the project, CLTS has created an organic opportunity for village members, particularly, women to be leaders and catalysts for change in their own community.

Vidyawati is one of these women. She has taken this movement to heart; from the beginning, Vidyawati was determined to end open defecation.

Her vow to not let these unhygienic habits continue to affect her community motivated Vidyawati to encourage community members to attend CLTS meetings, save money for toilet construction, and to stop defecating in the open. Her dedication and energy have proven effective: the village of Shivrajpur has been declared open defecation free (ODF).

Vidyawati and other women just like her are providing what a program or plan simply cannot give: community-led conviction to improve their own health. Desire from within to stand behind CLTS is what has set apart these villages in our research and have helped them to become free of open defecation.

estimates to include not only quantity, but also quality loss. Further, we will contribute to the evidence on food loss of perishable food groups, looking across multiple value chains. Beyond estimates and determinants of food loss, this work will inform about food loss and waste definitions and priorities by delving into value-chain actor perspectives, experiences, and decision-making. Ultimately, this work will contribute to the evidence for food loss reduction interventions that leverage vegetable value chains to improve the food environment and diet quality.

Low quality tomatoes that will not be auctioned or sold at the Madanapalle market are packed into bags and given away for animal feed. On the day this photo was taken, the bags of tomatoes were free. However, depending on the market price, farmers might charge a small sum for bags of tomatoes meant for animal feed.

DEVELOPING A MICROALGAE-BASED IRON FORTIFICANT TO ADDRESS IRON MALNUTRITION IN INDIA

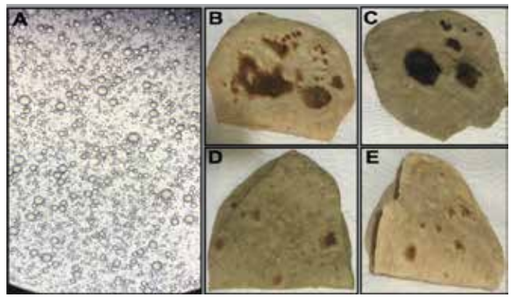
Iron deficiency affects up to 5 billion people worldwide. Although iron is one of the most abundant elements in the earth's crust, iron-deficiency anemia (IDA) is also one of the most frequent nutritional disorders. In the human body, the most important function of iron is the synthesis of the oxygen-transporting protein, hemoglobin. A shortage of iron depletes the body of hemoglobin, resulting in various detrimental health outcomes, such as impaired cognitive function and delayed physical growth in children, reduced working capacity, and many other manifestations that affect the quality of life. Excess iron in the body, however, also has equally devastating consequences (Papanikolaou and Pantopoulous 2005). This makes iron a highly problematic micronutrient.

Specifically, in India, anemia affects over 80% of children below the age of three, 58% of expectant mothers, 50% of nonpregnant and non-lactating women, and over 56% of adolescent girls (Kapil and Bhadoria 2014); with iron deficiency accounting for over 60% of anemia cases (Black et al. 2008). IDA was responsible for 24% of maternal mortality in India, and another 50% of maternal mortality has been indirectly associated with anemia (Anand et al. 2014). This has catastrophic consequences for the future generation and can eventually lead to a "double-burdened" society, with both mother and child being anemic. The economic implications of IDA in India are also severe, accounting for 5% gross domestic product (GDP) loss (Sharma 2003).

National surveys have shown that, except for staples, the consumption of other nutritionally dense commodities, such as pulses, milk, fruits, and vegetables, falls far below the recommended dietary allowances (RDA) (NIN 2011). With meat consumption among the lowest worldwide, IDA incidence is high in India (Delgado 2003). In such areas, fortification has been considered as a successful and cost-effective public health approach to compensate for nutritional iron inadequacy. However, iron fortificants with high relative bioavailability affect the sensory profile of foods, limiting their palatability. Meanwhile, the fortificants that do not cause these sensory issues suffer from low bioavailability (Hurrell 2002). Thus, ideal iron sources that can be effectively utilized in food products to improve iron nutrition remain elusive.

TCI has, therefore, made it a top priority to address the rising issue of IDA in India through the identification of suitable iron-fortifying agents. This requires not only understanding the drivers of IDA in India, but also determining what a culturally acceptable food product with competence for fortification, commercialization, and consumption could be. Tata-Cornell Scholar Rohil Bhatnagar is leading TCI's efforts on this front. Through fieldwork in the form of household surveys, focus group discussions, village-level market assessments, and interviews with local medical practitioners carried out in Gujarat, Jharkhand, and Bihar, wheat flour was identified as a potential vehicle for iron delivery, as it is widely consumed and available through the public distribution system.

As a potential wheat flour iron fortificant, we are studying the utility of biosustainable, defatted green microalgae (DGM), a byproduct of the biofuel industry. In cooperation with Cornell University's Field of Food Science, the preliminary work on this project was initiated in September 2016, as a proof-of-concept study, using rodent models. This study had two phases: first, to investigate the effectiveness of DGM to restore iron status of mice with diet-induced iron deficiency; and second, to assess the effect of high doses of continuous DGM supplementation on liver health.



A. Microcapsules in a water-in-oil-in-water emulsion; green droplets represent the encapsulated DGM. These microcapsules have an average particle size of 0.97 µm, and visually appear as cream colored; B. Roti control (no fortification); C. Roti fortified with 5% ferrous sulfate; D. Roti fortified with 5% DGM; E. Roti fortified with 5% encapsulated DGM. Unlike ferrous sulfate or DGM, encapsulated DGM did not contribute any color, taste, or aroma to the roti.

In Phase I, the inclusion of iron through DGM resulted in heavier mice, compared to the iron-deficient control mice. Mice fed the DGM diet also had elevated hemoglobin and storage iron. Since DGM is a rich source of iron, it can be suspected that consumption of large amounts of DGM may cause iron toxicity. However, in Phase II, repeated oral challenge through high doses of DGM did not induce any oxidative stress, iron bioaccumulation or inflammation. Our results suggest that DGM may be a safe and effective food ingredient in alleviating iron deficiency, while creating added value to the biofuel production of microalgae.

RESEARCH HIGHLIGHTS

The utilization of DGM in food products is difficult because of its strong green color and fishy aroma. Moreover, its use in staples poses additional challenges, since (1) the fortifying material has to be of the same color as the flour itself; and (2) the interaction of iron with lipids present in the flour over time may cause undesirable color development. Therefore, it is critical to identify strategies to mask the sensory attributes of DGM before it can be used in food products. To accomplish this, we have been developing encapsulation models, using conventional homogenization for use in wheat flour fortification.

Microcapsules developed using this technology were successful in overcoming the sensory limitations of DGM and were also stable at temperatures (~220°C) typically used to bake Indian bread (chapati/roti). With this project, we envision translating the novel technology into safe, viable, and dietary pattern-adherent fortified foods that optimize IDA-related health outcomes in the real world, without jeopardizing future resources of nourishment.

INTENSIFYING GOAT PRODUCTION THROUGH A SUSTAINABLE FEEDING SYSTEM

India's goat sector is constrained by feed shortages because of limited fodder cultivation, insufficient crop residues, and dependence on common property resources that are small in size and increasingly degraded in vegetative quality and soil fertility. Human and livestock populations' future growth is expected to increase pressure on the availability and productivity of grazing lands, resulting in fewer feed resources for goats and other animals. TCI is researching ways to address the widespread problem of feed scarcity that small ruminant producers face. Dr. Maureen Valentine, PhD in Animal Science and graduate of the Tata-Cornell Scholar program, conducted a study in the Kandhamal District of Odisha with goat-owning households in 2016. Research culminated into two main research questions:

- How do goat management decisions impact animal health and the environment?
- What are the effects of goat intensification through semi-stall-fed production on goat health, kid survival, and farmer adoption interest?

Results indicated that the metabolizable energy of pasture forages was low, and there was a high proportion of non-native species. Goats graze repeatedly in the same grazing areas, which was exacerbating land management concerns already complicated by deforestation and conversion to agricultural land. When comparing the traditional grazing management system to the semi-stall-fed research group, kid survivability was 4.26 times greater in the semi-stall-fed group. Kid mortality decreased by 22.5% in the semi-stall-fed group (9.1%), compared to the traditional grazing group. Sixty-three percent of participating

Reduction in goat kid mortality has a significant impact on increased community involvement in livestock.

farmers were interested in supplementing their goats after the project's conclusion. The interest and demand for more knowledge regarding best livestock management practices from participating farmers will be instructive for how local extension personnel and development organizations can involve farmers. Findings show the potential benefits of shifting to more intensive livestock production with improved feeds. Animal husbandry extension systems have immense potential to assist rural goat farmers with production system changes, but they require more direction about how to help small ruminant owners with preventative or advisory care, rather than the

current focus on larger ruminants and curative veterinary services.

This research furthers the Tata-Cornell goal to improve affordability of diet diversity for the rural poor by optimizing the productivity of livestock production systems to increase incomes. With improved incomes, rural farmers will be able to select more diverse diets. In the short term, it is expected that increasing the productivity of the goat industry will better meet the growing domestic demand for goat meat and provide income to rural farmers that are the primary owners of goats. In the long term, more market availability of goat meat would reduce the overall price and allow people with lower incomes the opportunity to purchase meat more frequently, which would drastically improve local diets. The results of this research have been drafted into publishable papers and will be submitted for publishing in the coming months.

GENETIC AND ENVIRONMENTAL CONTRIBUTORS TO STUNTING IN INDIA

The Tata-Cornell Institute is investigating the genetic and environmental contributors to stunting in India These research efforts are directed by Dr. Srilakshmi (Sri) Raj, TCI Research Associate. Stunting, or height-for-age that falls two standard deviations (SD) below the mean value for universal growth curves, impacts nearly 142 million children worldwide. Most discussion on stunting centers on environmental causes. However, the relative contribution of genetics, given the environment and environmental change, to explaining the high prevalence of stunting has not been adequately addressed.

The focus on environmental causes for stunting, itself a syndrome of other pathogenic childhood disorders and a predictor of future adverse health, means that biological mechanisms are less known. This lack of knowledge may hinder public efforts to reduce stunting. Thus far, attention to environmental causes of stunting have led to reductions in global prevalence, but reduction is slowing. By studying the biology of and natural variation in stunting and its outcomes, we can better understand how to further reduce its prevalence and its negative consequences.

The genome is the primary building block of all traits in all organisms. Therefore, to understand stunting, we need to begin by understanding the genes that are involved in stunting, the genetic

pathways that are disrupted in stunted individuals as compared to healthy ones, and variation in genetic basis and phenotypic outcome. A primary question to consider is whether there is a biological difference between short childhood height and stunting. This question energizes our current research efforts to understand the biological basis for stunting.

Height as a trait in humans is highly heritable, between 80-90%, as measured in European populations. Hundreds of genetic variants are associated with height, each having a small impact. The interaction among these genetic variants and the environment is responsible for the range of height variation we see. These interactions can vary by age and environmental context, and the actual variants that contribute to the trait may have different impacts on the heights of individuals from different families and populations (Figure 6). Thus far, most studies on the genetics of height have been carried out in adults of European descent. However, stunting is primarily a syndrome affecting young children of non-European descent. There is a strong need for genetic information on healthy linear growth in children from populations vulnerable to stunting.

India provides an optimal setting to elucidate the biological basis for stunting. India has one of the highest rates of stunting globally, with 38.4% of children under five stunted. Indian children also appear to have greater risk for stunting than do African children, despite better economic status. Furthermore, prevalence of stunting in India has vast regional and district-based differences, based

VARIABILITY IN GENE-ENVIRONMENT INTERACTIONS AND THEIR PHENOTYPIC CONSEQUENCES

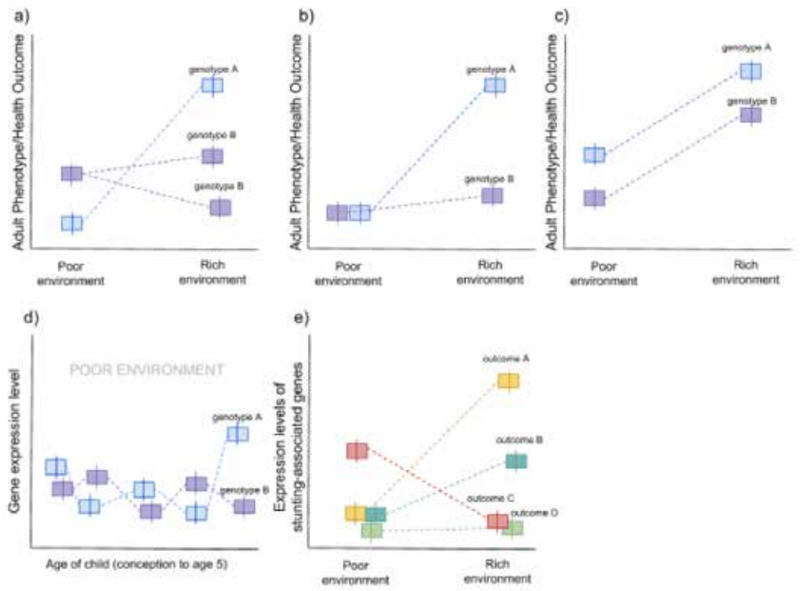


Figure 6: Figures 6a-6c depict the possible trajectories of two different genotypes in two different environments. Figure 6d depicts age-dependent variability in the phenotype of different genotypes. Gene expression can vary through age as well, and this can also depend on the underlying genotype. Finally, Figure 6e depicts the four possible outcomes of gene expression in two different environments. Taken together, these figures show how a single genotype, or two different genotypes, can have different consequences on phenotype, depending on age and environmental context. The colors refer to different genotypes and different outcomes.

on the latest National Family Health Survey (2016) results. In contrast, muscle wasting, another marker of poor childhood health, is at a uniformly high prevalence throughout every district in India. The diversity of stunting prevalence, risk factors, and generally high risk within India make it an ideal setting to study the biological basis for stunting.

Therefore, we have worked on designing a strategy to understand stunting in India, given the diversity of its causes and consequences. We are in the beginning stages of setting up the field studies and genetic survey. We will use our results to evaluate current strategies to reduce stunting and identify better ways of distinguishing stunting from short stature in India.

PARENTS' SCHOOLING AND CHILDREN'S LEARNING OUTCOMES

Although developing countries around the world have largely succeeded in raising school enrollment rates, there has not always been a commensurate improvement in learning outcomes (Glewwe and Muralidharan 2016). India has had near universal primary school enrollment rates since 2009, but learning levels remain abysmally low. Data from the Annual Status of Education Survey (ASER) for the year 2016 show that only about 2 out of 5 third graders in India could read a vernacular text, and only 1 of 3 could perform a two-digit subtraction.

Since education, especially women's education, has significant positive effects on outcomes related to health, nutrition, and empowerment (themes that are central to TCI's research agenda), it is critical to explore the mechanism(s) of how public investment in education (in this case, through a school construction policy) contributes to educational outcomes (and by proxy, other socioeconomic outcomes) across generations.

Therefore, research conducted by Tata-Cornell Scholar Naveen Sunder (PhD candidate in Economics) examines the direct and intergenerational benefits of the District Primary Education Programme (DPEP) in India. the DPEP was a school construction program implemented by the Government of India in collaboration with international partners. It was active from 1993 to 2004, across 271 districts in 18 states throughout the country. During this time, the program built over 100,000 primary and upper-primary schools and more than 50 million children benefited. He finds that the DPEP leads to higher access to schools, which increases school attendance and grades completed among direct beneficiaries.

Data from the Annual Status of Education Survey (ASER) for the year 2016 show that only about 2 out of 5 third graders in India could read a vernacular text, and only 1 of 3 could perform a two-digit subtraction.

Further, he finds substantial intergenerational impacts of the program; namely, children of direct beneficiaries learn better in school, as compared to children of non-beneficiaries.

The DPEP targeted districts with female literacy below the national average at the time (39.2%). This assignment rule meant that districts just below this threshold were more likely to receive the program than districts just above the threshold (Figure 7). Absent any other differences between these regions (as established in the study), any impacts on educational outcomes could be attributed to the DPEP. Results from a regression discontinuity design show that, during the time that the DPEP was in place, an average treatment district received 258 more government schools than a comparable non-DPEP district, which led to a relative increase of 0.21 government schools per 1,000 population in these districts.

Impact on Direct Beneficiaries

Using national household survey data from the District Level Household and Facilities Survey (DLHS-3 and DLHS-4), Naveen finds that enhanced availability of schools due to the DPEP

RESEARCHER SPOTLIGHT

Naveen Sunder
Tata-Cornell Scholar and PhD Candidate, Economics

Naveen is a Tata-Cornell Scholar and a PhD candidate in the Economics Department at Cornell University. Prior to pursuing his PhD, he completed his BA (Honors) in Economics at Shri Ram College of Commerce in New Delhi, his Masters in Economics from the Delhi School of Economics, and worked for three years on impact evaluation studies in the Indian states of Andhra Pradesh and Odisha.

He specializes in using microeconomics and econometrics to address policy-relevant questions in international development. His dissertation research focuses on the vital role of women's education in shaping nutrition, health, and education outcomes in low- and middle-income countries. Within TCI, he has helped collect detailed household survey data in TARINA intervention regions. Currently, he is using this unique data set to explore various questions related to dietary diversity in rural India. Examples include an empirical investigation of the presence and causes of a dietary gap between women and other household members, and the relative importance of self-production and the markets in determining diet diversity in rural India.

DPEP POLICY ASSIGNMENT

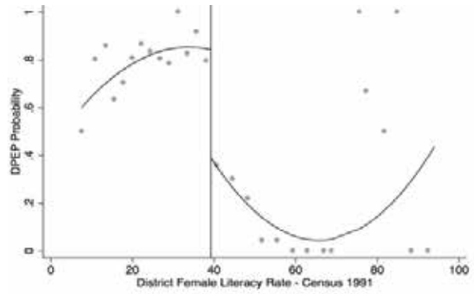


Figure 7: The figure shows the dramatic increase in the probability of receiving the school construction policy (DPEP) around the mean female literacy (39 percent).

led to increased enrollment (8 percentage points), years of education (0.8 years), primary school completion (7 percentage points) and literacy (8 percentage points) among the group of direct beneficiaries (similar to Khanna [2017]). The gains from the DPEP were similar for both male and female beneficiaries.

Intergenerational Effects

Additionally, using child test score data for all years between 2007 and 2014 (ASER), we learned that children of female the DPEP beneficiaries, on average, perform better on standardized tests of reading (0.19 SD), math (0.18 SD), and English (0.09 SD) than comparable children of non-beneficiaries (Figure 8). However, the performance of an average child of a male DPEP beneficiary is not statistically significantly different from that of an average child whose father was in a control district. Thus, the results indicate that mothers are able to transmit their human capital to the next generation.

Potential Mechanisms

1. Using school-level information from a government source (DISE data), there is suggestive evidence that the effects identified here were driven by the increased number of schools in treatment districts, and not by the potentially "superior" quality of schools in these regions.
2. Using information from other household surveys (IHDS and DLHS) to investigate, it was determined that there may be some household- and individual-level mechanisms behind the observed impacts of the DPEP. Results indicate that these findings are potentially mediated by:
   a. Higher bargaining power for women
   b. Increased educational investments in children
   c. Improved childcare practices
   d. Better health of mothers

IMPACT OF DPEP ON READING TEST SCORES OF CHILDREN OF BENEFICIARIES

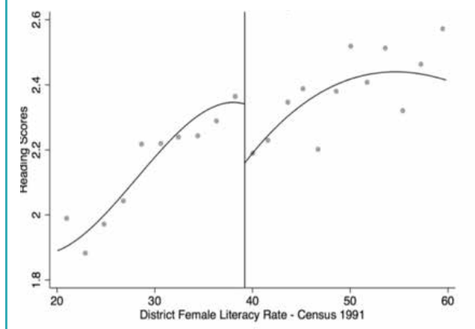


Figure 8: Impact of school construction policy on reading test scores, obtained through the difference between observations within the shaded region to the left of the threshold (treatment) and those to the right of the cut-off (control).

Contributions

1. While most previous analyses of school construction policies have focused on identifying effects on direct beneficiaries (Duflo 2001; Azam and Saing 2017; Khanna 2017, among others), the current study is one of the first papers to assess intergenerational impacts.
2. This study adds to the evidence on the important role of parents, especially mothers, in shaping child learning.
3. By examining performance on standardized tests, we are able to identify program

impacts on actual learning outcomes. This is uncommon in the school construction literature (Burde and Linden 2013).

4. Given that overall education measures in many countries in Central andWestern Africa and South Asia are comparable to those in India at the time of the DPEP implementation, the results of this analysis suggest the potential benefits that these countries could also experience from school construction policies.

Policy Implications

The findings from this analysis show that school infrastructure programs have substantial intergenerational impacts and that school infrastructure programs provide returns on investment that lead to gains not only for direct beneficiaries, but also across generations. This study provides evidence for the positive intergenerational impact of increasing school infrastructure and affirms that parents, particularly mothers, play an important role in shaping their children's learning abilities. This complements the finding of other studies [such as Andrabi, Das, and Khwaja (2012); Banerji, Berry, and Shotland (2017)] that show how increasing the skill sets of mothers could go a long way toward boosting children's academic performance. Other research shows that these effects extend beyond the classroom and can have considerable health, nutrition, and empowerment benefits for families across generations.

SOIL HEALTH PROJECT: DEVELOPING MOBILE AND LABORATORY TESTING PLATFORMS

The TCI Soil Health Project focuses on soil health enhancement to improve agricultural productivity, reduce malnutrition, and enhance the rural environment. In current production systems, it is very common to only focus on chemical enhancements (for example, use of synthetic fertilizers to increase production), but the soil health approach is more holistic and addresses the physical, biological, and chemical attributes of soil.

Earlier work by former Tata-Cornell Scholar Phil Frost in Jharkhand documented soil health challenges in India due to long-term intensive crop production. We believe farmers and agricultural extensionists need the tools and support to be able to measure and track indicators of soil health locally. Many farmers report that they have willingly shared soil samples with researchers and government or NGO agriculture extension agents to be analyzed in a distant laboratory, but they report (1) seldom hearing the results of the assessment; and (2) not knowing the proper actions to take in order to ameliorate their soil health issues.

As such, the TCI Soil Health Project is working along two fronts to improve soil management practices via agriculture extension services and knowledge transfer to farmers. First, we are building awareness and capacity among India-based institutions and NGOs on Cornell's framework for the Comprehensive Assessment of Soil Health, and second, we are developing a soil health testing infrastructure that includes laboratories and mobile toolkits.

The laboratories help quantify soil health status of regional soils and develop interpretation schemes, while the mobile toolkits are intended for use by extension and NGO consultants in the field and provide immediate results for farmers on the most critical metrics to address soil health. This will facilitate soil health assessment, education, and ultimately, conversation on soil health management practices.

Operationalizing simplified and affordable soil health measurements for the Indian agricultural environment and subsequently developing context-appropriate management advice for soil health improvement are efforts underway with our partners, including NGOs (such as PRADAN and SPARK), academic institutions (Dr. Rajendra Prasad Central Agricultural University [DRPCAU] in Pusa, Bihar), and global research organizations (International Maize and Wheat Improvement Center [CIMMYT]).

Dr. Harold van Es, a foremost expert in soil health and the 2016 President of the Soil Science Society of America and TCI Faculty Fellow, delivered a seminar in August 2017 at DRPCAU on "A Soil Health Assessment and Management Framework" (which was attended by more than 200 students and faculty), followed by discussions on ideas with the Honorable Vice Chancellor of the university and university staff in agronomy (Dr. Mritunjay

Kumar), soil science (Dr. Ranjan Laik), soil and water engineering (Dr. Ravish Chadra), and plant pathology (Dr. Bimla Rai and Dr. P. K. Jha). The university is supporting the Soil Health Program with existing staff, and several postgraduate students are doing thesis research related to soil health. The university also agreed to create a new soil health program and associated laboratory infrastructure, including space for setting up a soil health laboratory in a new building.

In the summer of 2018, equipment was purchased for new soil health measurements, and long-term agronomic trials were sampled by Ms. Krishnan. Laboratory analyses were performed to assess the effects of crop rotations, reduced tillage, and soil amendments. Additional samples are collected through a collaboration with regional CIMMYT staff and will be processed in the laboratory, and also used with reflectance spectroscopy measurements.

A second PhD student, Ms. Fatma Rekik, focuses on a largely unknown issue in India, the connection between soil health and human health through nutrition. She traveled to the state of Jharkhand in spring 2018 to survey local villagers and collect grain and human hair samples that were analyzed for nutrients, as well as possible toxic chemicals like heavy metals.

This project is making a push to get solutions for soil health more broadly available in India, thereby addressing concerns about severe soil degradation. So far, our interactions have fostered knowledge sharing, partnership development, and capacity building between India-based and Cornell-based scientists, NGOs, and research institutes that are in a position to bring soil health concepts to policymakers, extension service providers, and farmers in India.

Training Workshop on Soil Health Measurement Techniques

Tata-Cornell's Soil Health initiative organized a Soil Health Workshop at the Dr. Rajendra Prasad Central Agricultural University, from July 10-12, 2018. In a collaborative effort with DRPCAU, TCI intends to set up a fully functioning soil health laboratory in India that can be used by both Indian scientists and scholars from the Tata-Cornell Institute.

Kavya Krishnan, a Tata-Cornell Scholar and PhD student in Soil and Crop Science, and Zach Batterman, laboratory technician at the Cornell Soil Health Laboratory, set up and operationalized the lab at DRPACU in early July. They also organized and facilitated a workshop to train eight graduate students and five professors in soil testing techniques.

Current Indian soil testing focuses on the physical and chemical aspects of soil health, neglecting the biological. The workshop emphasized the importance of biological testing, as well as provided a complete overview of soil health. The workshop offered hands-on training on three tests: Soil Respiration, Active Carbon, and Soil Protein. This practical learning allowed the students to individually work through each of the tests until they were confident that they could do the tests independently and use these tests' results and observations in their own research.

Soil Health Indicators

Soil Respiration

Soil respiration is a measure of the metabolic activity of soil microbial populations. Soil respiration rate is determined by a 4-day incubation process. A sample of air-dried soil, sieved through an 8 mm sieve, is rewet and placed in an air tight jar for 4 days. The amount of carbon dioxide released is then quantified. Greater release of carbon dioxide is indicative of a larger, more active soil microbial community participating in nutrient cycling and organic matter (OM) decomposition.

The soil respiration station of the lab with sample incubations already set up so the students could gain experience with the entire process of the test.

Active Carbon

Active Carbon is often used as a proxy for readily available carbon that is a food and energy source for the soil microbial community. It can be measured colorimetrically after samples are oxidized with potassium permanganate. The color change is determined by using a spectrophotometer and is calibrated against standards of known concentration.

Soil Protein

Soil protein is estimated using the Autoclaved-Citrate Extractable (ACE) Protein Index. This is used as a proxy for the fraction of the soil organic matter pool that is present as proteins or protein-like substances. Soil protein content can be used as an indicator of the biological and biochemical quality of the soil and is very well associated with the overall soil health status, because it represents the largest pool of organically bound nitrogen in the soil. We determine protein content of soil samples following a sodium citrate extraction under autoclaving (high temperature and pressure), and the extracted proteins are the quantified using the colorimetric bicinchoninic acid assay (BCA).

ENABLING COOPERATION AMONG SMALLHOLDER FARMERS: AGGREGATION MODELS FOR AGRICULTURAL DEVELOPMENT

In the past two decades, demographic changes of increase in population and per capita income has led to rising demand for higher value agricultural commodities. This change in demand has provided an impetus for agricultural sector growth, which can lead to improved incomes and livelihoods. The agricultural development strategy of the Government of India currently aims to double farmers' incomes from the current average of 45,318 Rupees per hectare per year (as stated in the National Sample Survey [NSS]).

The national government has identified four strategies to bring development in the farm sector: (1) increase production through better soil and nutrition management and improving infrastructure such as irrigation; (2) improve marketing through interventions such as electronic sales platforms and the creation of more market infrastructure to improve market access; (3) implement risk management and mitigation strategies through insurance schemes and limiting climate change impacts; and (4) link agriculture and value addition through agroprocessing.

In India, a majority of agricultural production takes place on small and marginal farms with an average size of 1.15 hectares. Smallholder farming faces several disadvantages in accessing commodity markets, credit and extension services, technology, and lumpy inputs like management and asset-specific machinery due to weak economies of scale, limiting their ability to benefit from these interventions. Addressing the disadvantages of access is critical if agricultural strategies are to increase productivity and incomes in a smallholder-based agricultural economy. Organization of agricultural production and marketing activities that mitigate the disadvantages of economies of scale is not a new concept. The farm cooperative movement globally has had differing levels of success, depending on purpose and context. In countries like Japan, South Korea, and Taiwan that were founded upon small farms, cooperatives have been successful. In India and other developing countries, cooperatives have faced significant structural and incentive-based challenges.

The structural problems include political and bureaucratic interference, poor management and governance, and elite capture of the activities to their benefit. Cooperatives have also faced incentive problems, characterized by dormant membership and poor participation of members, hindering the growth of these organizations. This was due to the lack of percolation of benefits to members, especially for the demography that cooperatives meant to empower.

However, since early 2000, there has been a significant drive in India to promote aggregation models such as Farmer Producer Organizations (FPOs) and cooperatives. The amendment of the Companies Act in 2003 that enabled the formation of Producer Companies (PCs) was a significant step in this direction. By 2017, over 3,000 FPOs had been promoted in India, and over 5,000 are planned to be set up in the next five years. As FPO expansion continues, questions need to be answered of why they would succeed now when they have failed in the past, and what can be done to better promote and establish them to bring about growth in the agricultural sector.

The Tata-Cornell Institute (TCI) and International Food Policy Research Institute (IFPRI) organized a Policy Dialogue on "Aggregation Models in the Agricultural Sector in India" on August 10, 2018, in New Delhi. The policy dialogue aimed to first, explore the key issues and challenges of governance and self-management among the varying aggregation models; and second, to assess the significant challenges aggregation models face in market linkage, vertical coordination, and broader private sector participation and to suggest policies to link the small farmers to markets. Third, the dialogue sought to set a research agenda that can produce suggestions for policy change to enable better promotion of aggregation models. The participants for this dialogue were comprised of academics, policymakers, civil society organizations, agribusiness corporate entity representatives, and managers of aggregation models.

The Policy Dialogue defined a three-phase agenda to study aggregation models in India. In the first phase, a systematic literature review will be conducted to identify gaps in literature and research in relation to aggregation models. It will look to the experiences and lessons from the cooperative movement and other collective actions from India and around the developing world. Context specificity is an essential factor to consider when studying aggregation models. Similar to the case of cooperatives, success in one context may not translate the same results in another. In the second phase, a case study-based approach will help analyze phenomenon and context, their simultaneous interaction, and the influence they have on the promotion and success of small farm aggregation. In the final phase, the literature review and case studies will allow us to formulate hypotheses for testing and also enable us to develop metrics to evaluate the performance of various aggregation models. Evidence gathered through hypothesis testing will help identify problems faced by aggregation models in India and benefit policy formation to better promote these organizations.

FOOD POLICY REFORMS IN INDIA: STATE-LEVEL DIFFERENCE

Analyzing food policies, especially around social safety nets, comprise an essential part of the Tata-Cornell Institute's research agenda. Food and agricultural policies have a clear link with overall nutritional outcomes. At TCI, we have been arguing that the current predicament of the triple burden of malnutrition (where undernutrition as stunting and wasting, micronutrient deficiencies, and obesity simultaneously coexist) lies in the excessive focus on staple grains and lack of innovation in the safety net programs in India. Last year, in one of our papers, "The Bumpy Road from Food to Nutrition Security – Slow Evolution of India's Food Policy," (Pingali, Prabhu; Bhaskar Mittra and Andaleeb Rahman, 2017, Global Food Security 15: 77-84), we discussed the interlocked food distribution-stocking-procurement mechanism that has created perverse incentives for various political actors and stifled policy

reforms. Research by Dr. Andaleeb Rahman, TCI Postdoctoral Associate, has built upon this same theme in an effort to understand why some states have been able to reform their policies while others have not. His work explores the role of inherent political economy factors.

State-level differences in performance and pace of reforms around various social safety net programs are essential, given that the federal government has greater legislative power over this sector. Studying the political economy of food assistance programs in India, Dr. Rahman's work illustrates that, although changing political paradigms and priorities have affected agricultural policies, much of it continues to be determined by electoral arithmetic and political exigencies at the state level. Policy frameworks, rather than focus on nutritional security, continue to rally around the sentiments of hunger reduction, which were laid to rest some time ago. In recent years, the government has launched two major initiatives: the National Food Security Mission (NFSM) in 2007 to encourage food production, and the National Food Security Act (NFSA) in 2013. Schemes like the Public Distribution System (PDS), which was considered to be nonfunctional, have shown remarkable improvements over time. Reforms in the PDS, however, have come about as a result of spirited

PUBLICATION

Pingali, Prabhu, Bhaskar Mittra, and Andaleeb Rahman. 2017. "The Bumpy Road from Food to Nutrition Security – Slow Evolution of India's Food Policy." *Global Food Security* 15: 77–84.

initiatives by India's federal government, as it has used its legislative powers to reform agriculture. Food policy is now increasingly taking central stage in India's subnational politics, as these reforms have led to the emergence of a larger social policy architecture, which was absent earlier.

Food assistance programs have always been used for vote mobilization and electoral gains, especially in the South Indian states. These policies have now taken hold in other poorer states as well. Massive reduction in the subsidized price of grains in Chhattisgarh, Odisha, and Himachal Pradesh are clear examples. Improvements in PDS have led to successive terms in office for the Chief Ministers (CMs). These changes, however, have the potential to define what lies in store for the future of India's agriculture and its food policy. One can only speculate on whether it will be a break from the historical legacies of open-ended procurement, cereal-based schemes, and the distributional reforms, including moving away from in-kind subsidies in the future. This portion of TCI's research agenda has been explored further in a forthcoming paper in the Journal World Food Policy, "Food Security and Nutrition in Rural India: Understanding State Level Heterogeneity," in which Dr. Andaleeb Rahman, along with Drs. Prabhu Pingali and Bhaskar Mittra, link these state-level variations in food policy reforms with nutritional outcomes. The idea is to deliberate on the potential of these reforms to lead a new path of subnational development. Going forward, TCI's food policy work will continue to focus on ways to redesign food-based welfare policies in India.

PUBLICATION

Rahman, Andaleeb, Prabhu Pingali, and and Bhaskar Mittra. Forthcoming. "Food Security and Nutrition in Rural India: Understanding State Level Heterogeneity" *World Food Policy* Volume 4, Issue 2/Volume 5, Issue 1.

FOOD SYSTEMS FOR A RISING INDIA: ENABLING RURAL PROSPERITY AND NUTRITION SECURITY

The Green Revolution followed by the liberalization of the Indian economy has been credited with shepherding India onto a path of high growth. Over the last decade, increases in per capita incomes, greater urbanization rates, increase in literacy rates, population growth, and poverty reduction have characterized this high growth process. While agricultural development has brought about income generating opportunities to some in the farming sector, in a small farm-dominant country like India, poor infrastructure and a lack of institutional support has excluded many smallholders from benefiting from the growth. At the macro level, the growth process has been highly inequitable, benefiting some states more than others. At the consumer end, increases in income and income-generating opportunities continue to coexist with poor health outcomes. The latter is reflected in the simultaneous prevalence of undernourishment, overnutrition, and micronutrient deficiencies in the country. These conundrums reflect the major paradoxes of the Indian growth story, one in which we see the simultaneous existence of regional inequality, rural and urban food insecurity, and the growing incidence of a triple burden of malnutrition.

Aside from tackling these challenges, looking ahead to 2050 and beyond, we see important trends that threaten to derail the progress that India has made. Feeding a growing population that is both richer and more urban has significant implications for future food systems. Catering to the rise in demand for diverse diets will be a main goal, as we look ahead. Linking urban food demand with rural prosperity will also be essential to ensuring both urban and rural food security. As fertility rates in the country reach replacement levels and life expectancy increases, providing jobs to growing numbers of adults, and managing the risks of rising obesity and the rising incidence of noncommunicable diseases will be important for health systems.

Current regional inequality in economic development has also created a major challenge for the future. Due to differences in initial resource endowments and nationalized policies that placed states on different structural transformation pathways, some states today resemble poor countries in sub-Saharan Africa while rapidly developing states resemble counterparts in Latin America. Continuing down this policy pathway will have negative implications, for both national political stability and for economic development, as we look ahead. Finally, anthropogenic climate change has created major challenges for future food security. Through its negative impact on food availability, access, nutrition, and affordability, climate change will reduce the effectiveness of policies aimed at increasing food and nutrition security for the future.

Much of the prior literature has reflected on the importance of either the development of the agricultural sector, the role of economic growth, or the importance of food security for ensuring greater and more equitable economic development. Even works, which look at the intersection of these groups, focus only on increasing production as a means to increasing economic growth or focus on managing consumption as a means for improving health and productivity. They do not evaluate the intersectionality of these domains and their spillovers on the economic, ecological, or health systems within the country.

Thus, we see: the existence of policies that increase productivity in agriculture at the expense of the environment, policies that increase economic growth while also increasing regional inequality and hurting small farmers, and top-down policies that aim to reduce undernutrition without any discussion on how to tackle growing obesity. These policy recommendations remain palliative at best, often treating the symptoms but not the core problems in the economy. Most of these approaches also have not considered the implications of the changing economic, demographic, and climatic landscape of the future.

With a view to addressing the current challenges in the Indian development paradox and in light of the future challenges faced by the country, researchers at the Tata-Cornell Institute have authored the book, *Transforming Food Systems for a Rising India*, to be published by Palgrave in 2019. In this book, TCI examines the nexus of economic development, agricultural production, and nutrition through the lens of a "Food Systems Approach (FSA)." Central to our vision for a robust food system is a nutrition-secure future where individuals have the capability and the opportunity to access a balanced and affordable healthy diet and whose health outcomes do not reflect their ability (or lack thereof) to access these diets. Creation of new opportunities and capabilities for increasing farm production and productivity, reducing malnutrition, improving labor productivity, and facilitating greater structural transformation that also reduces inequality are the main goals of the approach.

In order to implement a holistic approach towards welfare development and nutrition security, we link the goals for agricultural development, health and nutrition, and economic development with each other (Figure 9). We bring together the latest data and scientific evidence from the country to map

RESEARCHER SPOTLIGHT

Dr. Anaka Aiyar
Postdoctoral Associate

Anaka is a Postdoctoral Associate at the Tata-Cornell Institute for Agriculture and Nutrition. She joined TCI in 2016, after completing her PhD in Economics at the University of California, Riverside. Her research interests are driven by her passion to positively impact the lives of less privileged individuals living in developing countries. At TCI, her research projects explore why states in India have had disparate experiences in achieving nutrition security.

As a health economist, she identifies the mechanisms that explain subnational differences in nutrition security, as well as identifies policies that are best suited to overcome these challenges. Her research will be published in TCI's latest book, *Transforming Food Systems for a Rising India*. The book will be published by Palgrave in 2019. Anaka's research has also been published in journals such as Economics Letters. She has also received several honors and awards, including the Taraknath Das Foundation Grant in Aid and the Dean's Distinguished Fellowship Award at the University of California, Riverside. Prior to her PhD, she worked in India on field-based action research projects. Her projects included conducting an impact evaluation of health policy in Karnataka and market research for social entrepreneurs in Tamil Nadu.

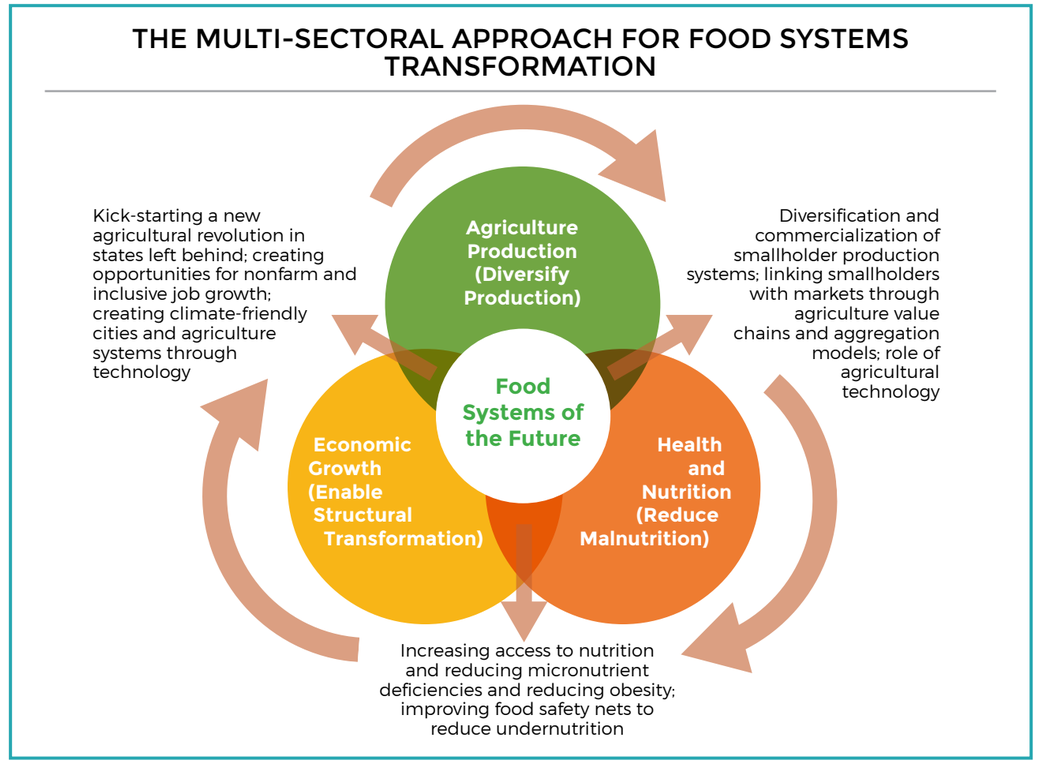


Figure 9: A holistic approach towards welfare development and nutrition security links agricultural development, health and nutrition, and economic development goals with each other.

out the current state of food systems. Therefore, we are able to:

1. Highlight the nature of food system challenges in India across the aforementioned domains;
2. Identify trends that create new opportunities or threats to progress;
3. Emphasize policy and institutional interventions that are needed to address these challenges; and
4. Provide goals and set a food systems agenda that interlinks each domain, as well as accounts for the specific subnational structural transformation experience that impacts policy effectiveness.

Our book not only aims to inform policymakers and practitioners on proper actions and respective consequences for future food systems, it also provides researchers new and exciting avenues to conduct research on nutrition security. Additionally, by providing a fresh and holistic perspective on the challenges for the future, and an overview of the policies that are available toward ensuring greater food security, this work aims to increase citizen awareness and engagement in developing food systems of the future.

PUBLICATION

Pingali, Prabhu, Anaka Aiyar, Mathew Abraham, and Andaleeb Rahman. Forthcoming. Transforming *Food Systems for a Rising India.* Agricultural Economics and Food Policy Series. Palgrave Publishers.

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 the Tata-Cornell Institute for Agriculture and Nutrition (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 (BMGF). The grant is largely centered on agricultural pathways to improving nutrition outcomes using a food systems approach. Three main objectives and nine intermediate results underwrite the grant's overarching goal to create a more nutrition-sensitive food system in India. Together, these components comprise TARINA's Results Framework. This framework is depicted in Figure 1, which shows the links between the components and how they align with the grant's primary goal.

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

Objective 1 of TARINA's Results Framework (Figure 1) 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 (Figure 2). Objectives 2 and 3 are more research- and policy-oriented goals.

Both of these 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 and from evidence based on research done by TCI scholars, TARINA research partners (IFPRI and Emory University), and microlevel studies undertaken by implementing partners, TARINA continues to strengthen its knowledge base for making the rural food system in intervention districts more nutrition sensitive.

TARINA is a unique program with a live connection between intervention, evidence, and advocacy (Figure 3). The field-level programs are continuously informed by TARINA's active monitoring, learning, and evaluation system. The robust qualitative and quantitative program monitoring through the Quarterly Progress Reports (QPR) from TARINA partners and the real-time Management Information System (MIS), coupled with strategic evidence-generating activities, including the TARINA baseline survey (TBS), midterm process documentation (PDs), and thematic research studies by TARINA partners and TCI scholars, inform and guide the intervention to assure its effectiveness. TARINA utilizes the collective evidence to influence policy through various advocacy platforms: by disseminating innovative research products through peer-reviewed publications, policy briefs, and training manuals; and through engagement in discourses, in the form of roundtables, workshops, and consultations with impact makers. The Center of Excellence (CoE) within TARINA leads and supports the generation of the evidence, in translating the findings into the high-value research products and utilizing the research products for building capacity and influencing policy around the food system and nutrition in India.

TARINA

TARINA RESULTS FRAMEWORK

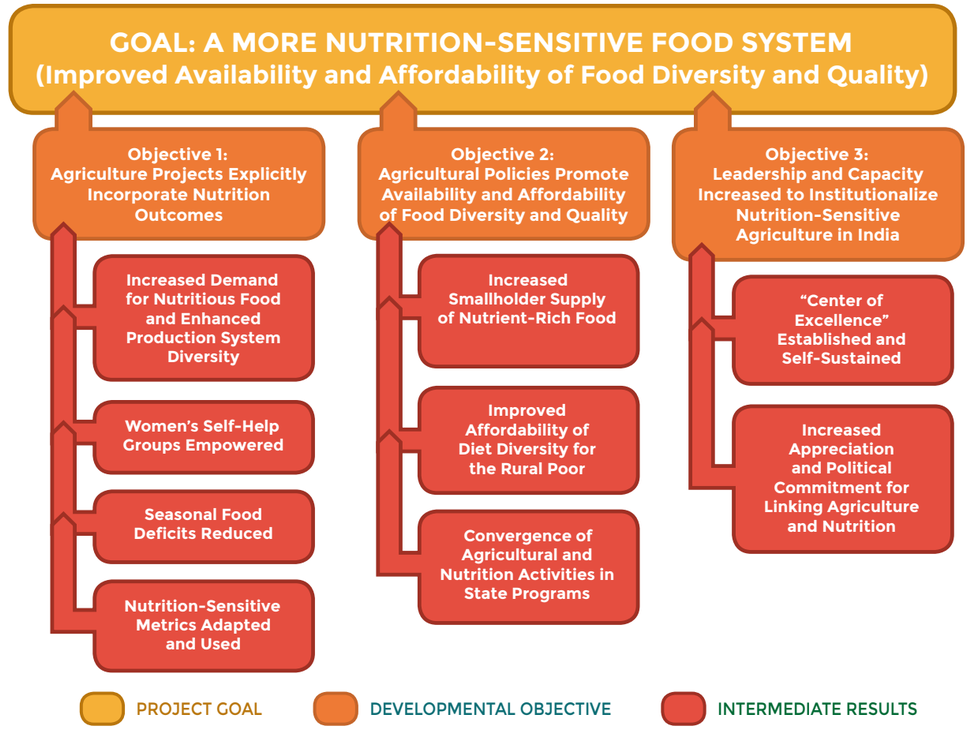
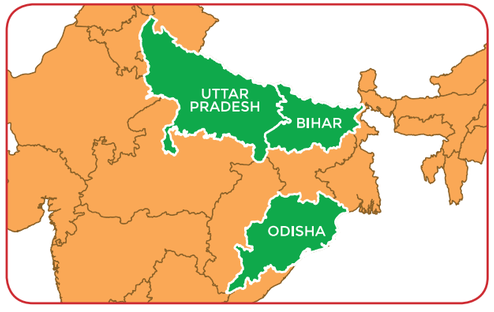


Figure 1. Three objectives and nine intermediate results make up TARINA's overarching goal to create a more nutrition-sensitive food system in India.

LOCATIONS AND PARTNERS



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

Figure 2. TARINA's NGO and development partners in three Indian states of Bihar, Odisha, and Uttar Pradesh

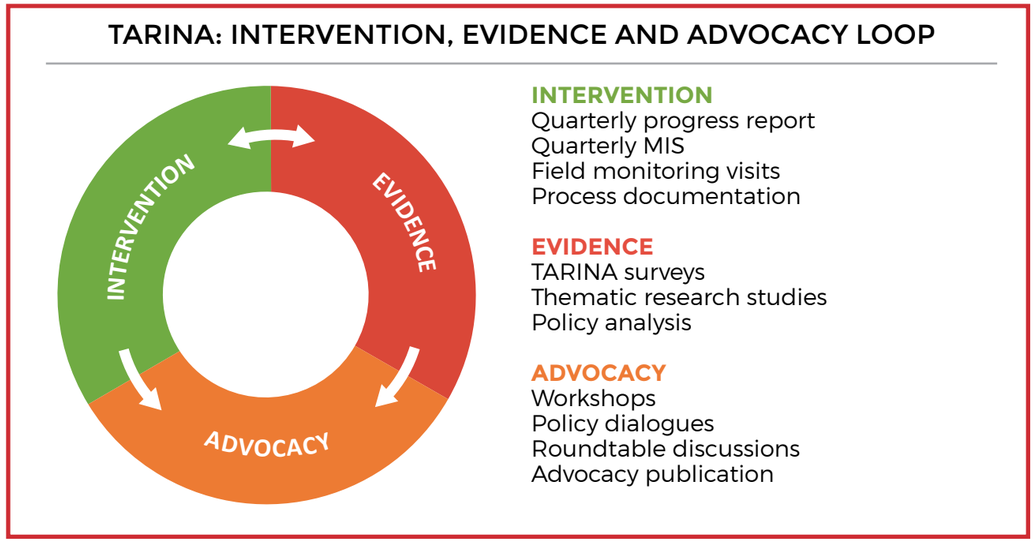


Figure 3: Live connection between intervention, evidence and advocacy is a critical component of TARINA.

TARINA'S FOOD SYSTEM APPROACH: YEAR 3 OF MOVING THE NEEDLE IN THE FIGHT AGAINST 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. The interconnected components of a food system are depicted in figure 4. TARINA's food systems approach 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. Our third year, 2018, was marked by moving the needle in the fight against malnutrition. We have made substantial progress in making agriculture more diverse and nutritious food more accessible through kitchen gardens and livestock promotion in the regions in which we work. In our projects, we have strived to enable the reduction in food loss, to empower women, and to bring about community behavior change toward better nutrition. We have also kept our commitment to enhancing the capacities of key players around food systems and nutrition through our Center of Excellence (CoE) and by engaging with the policy community to disseminate evidence and facilitate dialogue on strategic policy issues related to sustainable, nutrition-sensitive agriculture.

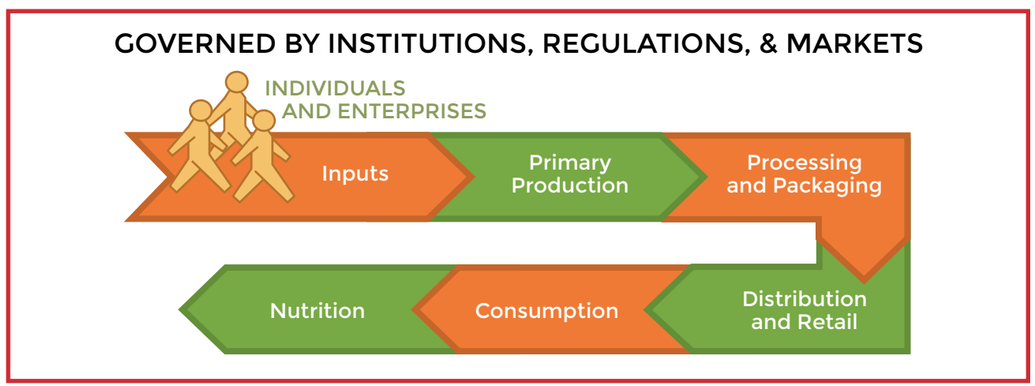


Figure 4: A food system includes all individuals, enterprises, and institutions that influence the supply, demand, consumption, and absorption of food micronutrients.

Making Agriculture More Diversified

The implementing partners of TARINA are promoting cultivation of vegetables, pulses, and oilseeds to diversify staple grain production. Diversification of production systems is aimed at increasing availability of and accessibility to nutritious food and household access to it. TARINA has registered crop diversification over a total of 3,800 acres, involving 12,700 farmers, across four implementing districts in Odisha, Bihar, and Uttar Pradesh. As of August 2018, TARINA has enabled about half of the farmers in its villages to diversify in favor of the cultivation of non-staples, compared to just a little over one-fifth at the start of the program.

Although methods and approaches to achieving this goal vary across the three states, all involve the provision of seeds, market linkages, and training on a recommended Package of Practices (PoP) for farmers.

RESEARCH UNDER TARINA

- "Role of Market Diversifying Agricultural Production: Spotlight on the APMC Act in India,"

Led by TARINA research partner IFPRI

Expanding Household Access to Food Diversity by Promoting Kitchen Gardens

In India, farmers traditionally cultivate vegetables and other nutrient-rich crops for home consumption, and they sell surpluses in the local markets. However, the production is limited to only a few vegetables and only during a few months of the year, which can lead to gaps in access and availability of nutritious food throughout the year. TARINA is finding innovative approaches to expand homestead horticulture, working to ensure that farmers have increased access and availability to diverse foods throughout the year. Through sustained intervention, TARINA has been able to encourage 7,777 households to set up kitchen gardens in Bihar, Uttar Pradesh, and Odisha. One out of 10 households in TARINA intervention areas had kitchen gardens at the outset, which has increased to one out of three households by the end of August 2018. Five thousand, one-hundred forty-four farmers are trained on PoP for better kitchen garden/wadi management (Figure 5).

Promoting Livestock to Enhance Food System Diversity

Promoting small ruminants like goats and poultry, dairy production through improved animal health services, and advanced livestock management are other strategies of TARINA for achieving better nutrition through a strengthened income pathway. As of August 2018, 6,966 goat-dewormings, 5,830 goat vaccinations, 721 poultry-dewormings, and 1,587 poultry vaccinations have resulted in improved animal health in TARINA villages. Improved breeding, feeding systems, preventive health care, and better market linkages are the pillars on which the intervention with small ruminants is designed and are mediated through the Buck User Groups (BUGs), and the women farmers' collectives. As of August 2018, BUGs had

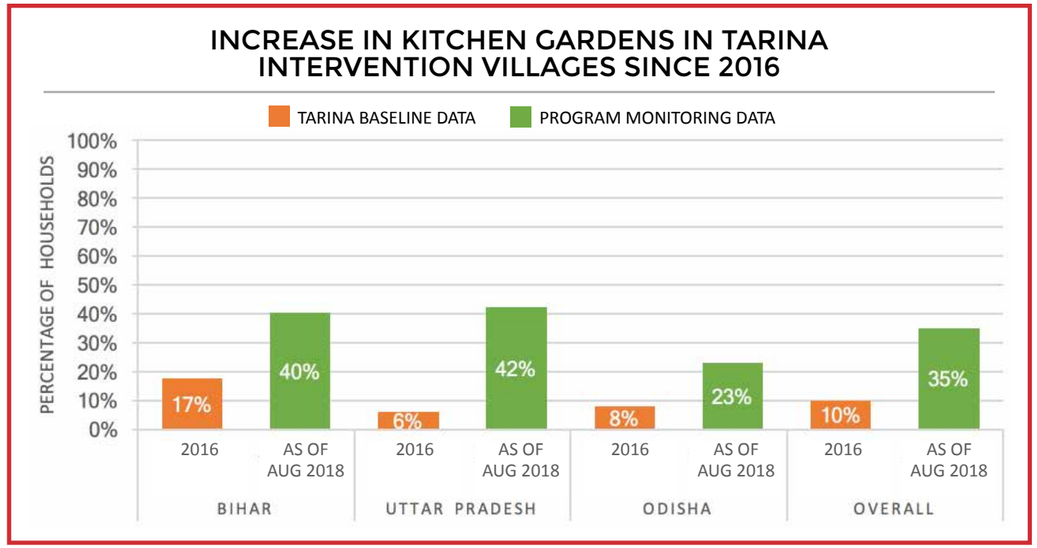


Figure 5: Since 2016 TARINA has encouraged 7,777 households to set up kitchen gardens in Bihar, Uttar Pradesh and Odisha.

been formed in nearly one-quarter of all TARINA villages.

As part of breed improvement initiatives, TARINA has initiated artificial insemination (AI) of goats. With a technical facility set up in the Pune district of Maharashtra, TARINA is now equipped to produce at least 3,000 semen straws (per month), drawn from various varieties of improved bucks.

RESEARCH UNDER TARINA

- Intensifying Goat Production Through a Sustainable Feeding System,

Led by Maureen Valentine, Tata-Cornell Scholar

Postharvest Loss Management

Postharvest loss is one of the major challenges, affecting not only the adequacy of food supply but also the quality of household diets in areas that employ predominantly traditional agriculture. TARINA is piloting and scaling up improved storage technologies, like hermetic bags, grain storage drums, and moisture meters. These technologies have been introduced for pulses, such as chickpea, green gram, and black gram; vegetables; and staples, including wheat, in all TARINA locations. Awareness is being generated through self-help groups and farmer field school platforms. Around 820 households have received the benefits of these technologies and have been able to store approximately 55 tons of crop harvest for future consumption, selling it in the market, or using it for seed in the next sowing season.

RESEARCH UNDER TARINA

- Postharvest Loss Management with a Focus on Mycotoxin Exposure: Reducing Nutritional and Socioeconomic Burdens of Unsafe Food,

Led by Anthony Wenndt, Tata-Cornell Scholar

Empowering Women in Agriculture

Reducing women's drudgery in agriculture not only encourages a larger participation of women in production systems but frees their time and energy to also focus on improved childcare and personal and household health, thereby contributing to improved nutritional outcomes. TARINA is working toward this objective by piloting and scaling up various technologies, based on the needs assessed within the community. TARINA has introduced 25 innovative, labor-saving technologies (LST), and 1,384 farmers have trained on LSTs across all three locations since the onset of the program.

Changing Individual and Community Behavior toward Better Nutrition

TARINA on-the-ground is enabling the individuals and community through Social and Behavioral Change Communication (SBCC) methods and tools toward achieving better nutrition. The two-tiered Social and Behavioral Change Communication intervention of TARINA focuses on (1) enhancing community-level capacity of technical knowledge, and awareness of a better food system and enabling environment for improved nutritional outcomes; and (2) increasing demand and improving consumption of nutritious food at the household level, using an engendered approach for empowering individuals (Figure 6).

To strengthen the gendered approach for improving the rural food system and leveraging an enabled community awareness, TARINA's SBCC tries to impact individual-level behavior through the Nutrition Gender Toolkit (NGTK). Utilizing the TARINA SBCC strategy, as of August 2018, 9,187 peers have been trained as change agents in villages of Odisha, Bihar, and Patna. Also, 6,712 women and 1,096 men have successfully participated in the behavior change intervention through the incremental module of NGTK. Three hundred sixty-nine self-help groups (SHGs) have been reenergized through various training programs.

Enhancing Capacities of Key Players around Food Systems and Nutrition

TARINA, through expertise and research products of its Center of Excellence (CoE), works toward

Figure 6: The two-tiered Social and Behavioral Change Communication (SBCC) Strategy focuses on enhancing community level capacity and increasing demand and consumption of nutritious foods.

RESEARCH UNDER TARINA

- Increasing Production and Consumption of Orange-Fleshed Sweet Potatoes to Address Micronutrient Deficiencies

  Led by Kathryn Merckel, Tata-Cornell Scholar

- Achieving and Sustaining Open Defecation Free Villages through Community Mobilization

  Led by Payal Seth, Tata-Cornell Scholar

- Exploring Feasible Options for Diversifying the Basket of Food included in India's Food-based Safety Net Program

  Led by TARINA research partner IFPRI

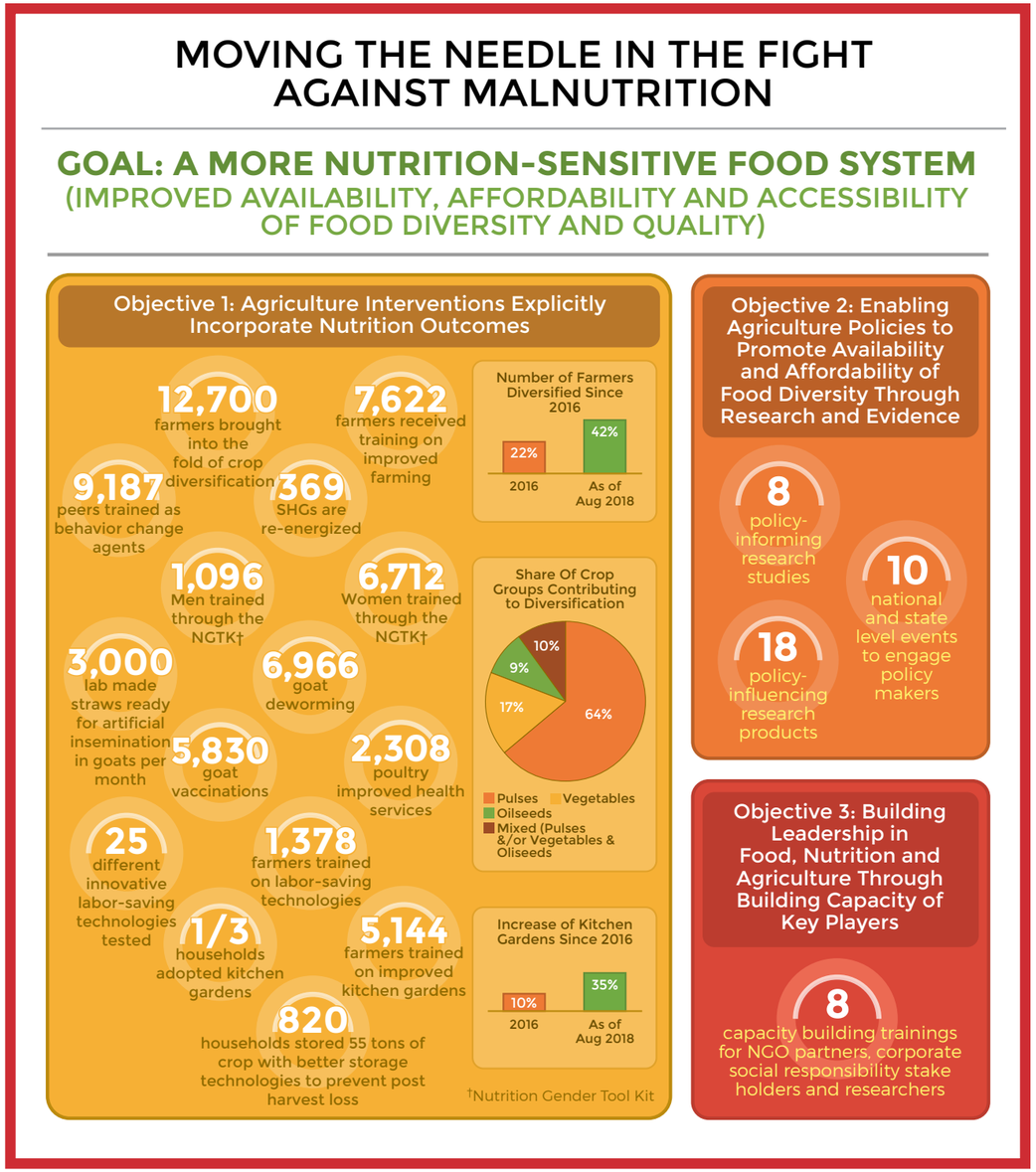
building capacities of partner organizations, grassroots-level frontline workers, and various stakeholders. Throughout the past year, various training sessions and workshops were held for Corporate Social Responsibility (CSR) managers and NGO project managers. Ranging from trainings on Monitoring and Evaluation (M&E) to evidence-based solutions for development effectiveness, emphasis has been placed on effective program implementation, better monitoring, and impact evaluation for agriculture and food systems-oriented intervention programs.

In many technical sessions, these workshops focused on the fundamentals of M&E, including the Theory of Change (ToC) and Management Information System evaluation methods, sampling methods, and data interpretation. Basics of drafting Terms of Reference (ToR) for commissioning studies, along with examples of best practices and good evaluations, were also shared. Overall, the workshops aimed to provide practical guidance on how managers can improve the implementation and effectiveness of their projects to maximize impact. TARINA will continue its efforts to prepare and strengthen M&E capacities of various stakeholders.

Engaging Policymakers for Increased Political Commitment to Nutrition-Sensitive Agriculture in India

TARINA has been shifting gears in engaging with the state and central government, policymakers, sector leaders, and leading research institutions to increase awareness and political commitment for linking agriculture and nutrition in India. In collaboration with other partners, TARINA has held several national- and state-level fora to disseminate evidence and facilitate dialogue on strategic policy issues related to sustainable, nutrition-sensitive agriculture.

- TARINA, along with the National Institute of Public Finance and Policy (NIPFP), co-hosted a national-level roundtable in February 2018 on "Budgeting for a Diversified Food System for Improved Nutritional Outcomes: Perspectives and Opportunities." The focus of the dialogue and deliberation was to shine more light on the pattern of government expenditure on agriculture and to assess how sensitive the spending is toward a diversified food system, which is essential to mitigating malnutrition.
- TARINA, in partnership with the Asian Development Research Institute (ADRI), held an advocacy dialogue on "Towards Developing a Diversified Food System in Bihar for Improving Nutritional Outcomes" in March 2018. Leading government officials, who are actively involved in policy-level decisions related to agriculture in Bihar, attended this policy dialogue.
- TARINA, in partnership with the International Food Policy Research Institute (IFPRI), organized a policy workshop on "Small Farm Aggregation Models in India" in August 2018. The objective of the dialogue was to assess the challenges faced by the Farmer Producer Companies/ Farmer Producer Organizations (FPCs/FPOs) in governance, management, market linkage, vertical coordination, and larger private sector participation in linking small farmers to markets.



PUBLICATIONS

WOMEN'S EMPOWERMENT IN INDIAN AGRICULTURE: DOES MARKET ORIENTATION OF FARMING SYSTEMS MATTER?

PUBLICATION

Gupta, Soumya, Prabhu Pingali, and Per Pinstrup-Andersen. 2018. "Women's Empowerment in Indian Agriculture: Does Market Orientation of Farming Systems Matter?" Food Security 9 (6): 1447–63.

BACKGROUND

Women's abilities to access productive resources and make decisions about their use is expected to vary, depending on the nature of farming systems of which their households are a part. In this paper, we adapt and apply the multidimensional Women's Empowerment in Agriculture Index (WEAI) to three distinct farming systems in India, which together reflect a spectrum of degrees of market orientation. We then test the relationship between women's empowerment in agriculture and household market integration, as well as the relationship between empowerment levels and women's decision-making in nonagricultural domains. This is the first empirical use of the WEAI across multiple farming systems in an Indian context.

METHODS

Primary data for this study was collected from a total of 960 households in the Chandrapur district of Maharashtra, India, in 2014. A representative man and representative woman from each household were identified as respondents for a household survey that collected extensive information on agriculture and land use, dietary intake, household-level socioeconomic and demographic information as well as anthropometry. The WEAI focused on the extent to which men and women are able to access resources and make decisions in five domains of agriculture—production (input and autonomy), resources (assets, decision-making, and credit), control over income, leadership (group membership and public speaking), and time use (workload and leisure). For the purpose of determining household market integration, households were classified into one of three groups—landless, food-cropping, or cash-cropping—depending upon the marketable surplus produced in 2013–14.

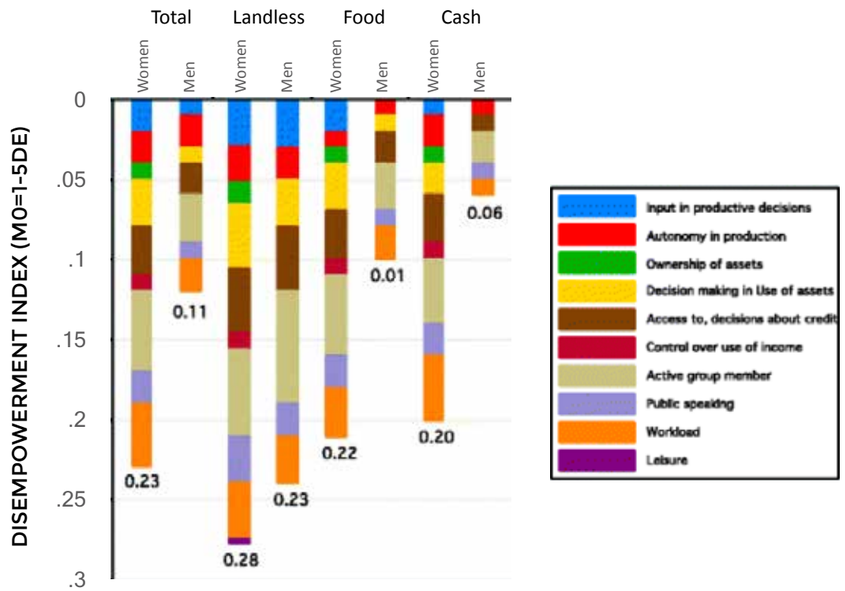
FINDINGS

Aggregate empowerment levels in agriculture improve as market orientation of households increases, that is, proceeding from landless households to food-cropping and cash-cropping households. Women's empowerment in agriculture is significantly higher among cash-cropping and food-cropping households, relative to the landless households.
The multidimensional nature of the WEAI enables us to identify a "joint distribution of deprivations," that is, deprivations that an individual faces simultaneously. Results from our study conclude that the domains of group membership, credit, and workload make up the joint distribution of deprivations for women. Women's empowerment in agriculture has spillover effects in nonagricultural domains, too. We find that the odds of a woman having autonomy in decision-making related to minor household expenditures, family planning, seeking healthcare, child feeding, and visiting their maternal homes are higher when the woman is also empowered in agriculture.

SIGNIFICANCE

The strong relationship between market orientation and empowerment levels in our paper suggests that linking women to markets can be a pathway to enhancing their empowerment in agricultural domains. Investing in infrastructure to set up well-functioning markets, as well as in infrastructure that allows women to access those markets by way of roads and means of transportation, can be a first step in this direction. This action can be followed by providing women with information related to market prices, producer companies, and so on, depending on the context. Ensuring their ability to make decisions related to the cultivation of crops and their participation in the sale of those crops, with the receipt of the associated income, can be some areas for which relevant policies can be designed, applied, and evaluated. Exploring and accounting for social norms/practices that could possibly limit women's mobility should be an important component of such policies.

CONTRIBUTION OF DIFFERENT SUB-INDICATORS TO DISEMPOWERMENT



The drivers of women's disempowerment in agriculture are group membership, decision-making related to the use of assets, credit, and workload.

FOOD SECURITY AND NUTRITION IN RURAL INDIA: UNDERSTANDING STATE LEVEL HETEROGENEITY

PUBLICATION

Rahman, Andaleeb, Prabhu Pingali, and Bhaskar Mittra. 2019. "Food Security and Nutrition in Rural India: Understanding State Level Heterogeneity." World Food Policy 4 (2) /5 (1), forthcoming.

BACKGROUND

Nutritional outcomes in India have improved marginally, yet the policy framework fails to recognize the role of food and agricultural policies in improving nutrition. The Green Revolution-inspired food and agricultural policy of India has outlived its usefulness, yet it continues to cast its shadow. Despite the policy stasis, some of the Indian states have managed to work around these policies and have reformed their food systems for better nutritional outcomes. Better governance and commitment to welfare has been the key paradigm on which these reforms have come about. This paper analyzes and connects current nutritional outcomes to the governance structure and policy priorities across Indian states. This analysis is useful in explaining wide disparities in nutritional outcomes across Indian states.

There are multiple pathways to improved nutritional outcomes. This paper builds upon the UNICEF (1990) conceptual framework and one described in Pingali and Ricketts (2014) to highlight the four intersecting pathways: income, food supply, intrahousehold distribution of food, and environmental health. In our paper, we argue that all of these factors vary significantly across Indian states. We rank the states based upon these variables and show that the subnational variation in undernutrition could be explained by the set of institutions, political regimes, and nature of governance of the individual states. We highlight the role of food assistance programs, incidence of poverty, practice of open defecation, and other immediate factors, as well as political will and other institutional factors that vary widely across states. Highlighting these subnational variations and examining them through the lens of comparative analysis helps in understanding the various causal links from changes in economic conditions, political priorities, and other indicators for social development to overall nutritional status.

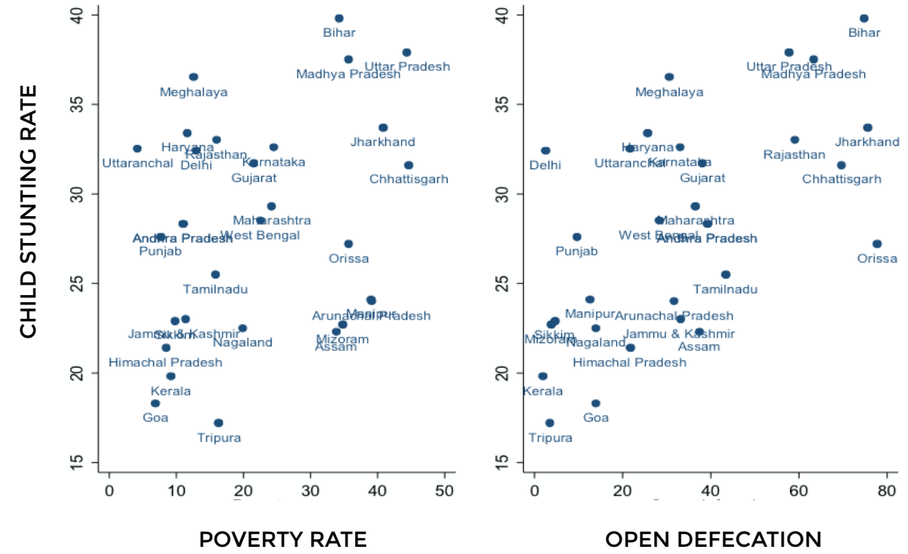
FINDINGS

- It is critical to look beyond national-level policies and governance to tackle malnutrition.
- States with better agricultural systems and improved provisions for health and hygiene have done well in reducing malnutrition.
- Specific focus on agricultural productivity and growth in the eastern states of India is essential for further productivity gains.
- Public policy reforms and overall governance remains key in addressing the issue of nutrition.

SIGNIFICANCE

This paper highlights the importance of nutrition as a central focus of food policy reforms in India. A nutrition-sensitive food system, however, may face serious threats from the political economy around these policies, often contradicting the interests of producers and consumers. Food policy reforms at the state level provide insights. These findings hold significance from the perspective of spatial disparities among states in India, especially around nutritional outcomes. We highlight improvements in overall governance and service delivery as a key to reducing undernutrition.

CORRELATES OF CHILD STUNTING BY STATES: POVERTY LEVELS AND THE PREVALENCE OF OPEN DEFECATION



Source: NFHS 2015-16 and RSOC 2013

States with higher levels of poverty and open defecation are also the ones with greater rates of child malnutrition.

THE ROLE OF AGRICULTURE IN WOMEN'S NUTRITION: EMPIRICAL EVIDENCE FROM INDIA

PUBLICATION

Rao, Tanvi, and Prabhu Pingali. 2018. "The Role of Agriculture in Women's Nutrition: Empirical Evidence from India." PloS One 13 (8): e0201115.

BACKGROUND

It is estimated that 42.2% of women in India prior to becoming pregnant are underweight. This statistic compares poorly to sub-Saharan Africa, where 16.5% of pre-pregnant women are underweight despite being much poorer on average. Not only is malnutrition among Indian women high, it is also persistent. Between 2005 and 2014, the level of malnutrition among adolescent girls aged 15–19 years has remained stubbornly high, with close to 45% of girls in the age group being reported as "too thin" in 2014.

Empirical evidence on the relationship between agricultural income and nutritional status of cultivators in the Indian context has been impeded thus far due to the lack of suitable data. Normally, information on agricultural production and anthropometric data on cultivators do not coexist in large surveys. The data set we use—ICRISAT's Village Dynamics in South Asia (VDSA) data—is a notable exception.

METHODS

We investigate the association between household agricultural income and women's body mass index (BMI). To test the association under question, we use five years of household- and individual-level panel data from 18 villages across 5 Indian states. The total number of women in our sample varies from 791 to 992 women, from year to year. We use within-household variation, in lagged agricultural incomes and BMI over time, to estimate:
(1) the extent to which short-term changes in agricultural income are associated with short-term changes in BMI; and
(2) the association between agricultural income growth and BMI growth over a longer term.

FINDINGS

Over the longer term, for households that farm regularly, we find 10 percentage point agricultural income growth to be associated with a 0.10 percentage point growth in BMI. Effects of agricultural income are driven by younger women, in the age group of 15–25 years, who face a particularly strong nutritional disadvantage in India.

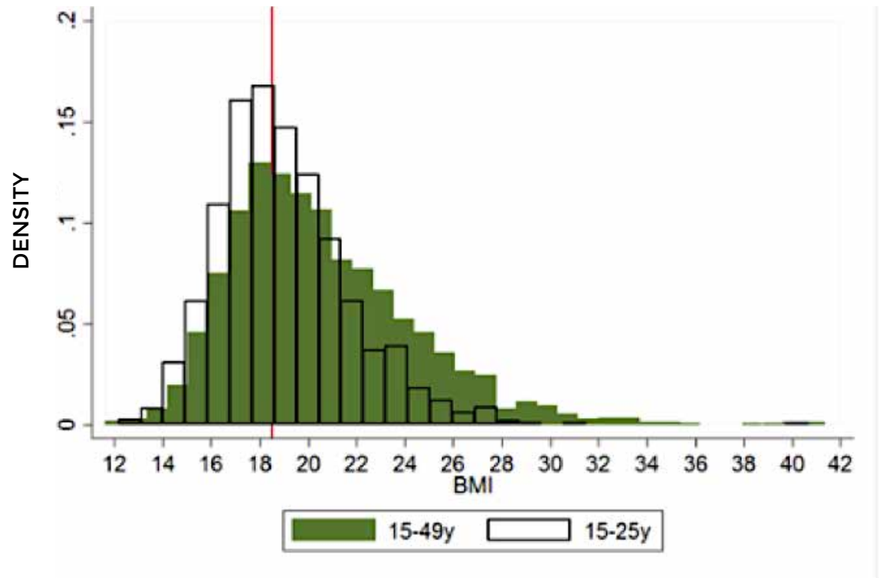
Next, we explore the pathways through which household agricultural income and BMI are linked. We show that both the own-production and market purchase of food are associated with nutritional improvements. Although women's BMI is associated with an increase in the consumption of own-produced cereals, the market plays an important role in facilitating access to more nutritious foods like pulses.

SIGNIFICANCE

It was not clear a priori whether the association between household agricultural income and women's BMI would be positive or negative. Agricultural production could benefit nutrition by way of being a source of food and income. On the other hand, heavy agricultural workloads and exposure to toxins and disease through agricultural activities can deleteriously affect women's health and nutrition. Therefore, while the positive association between agricultural income growth and BMI growth is economically modest, it is important in view of the fact that we do not find a corresponding effect for growth in nonagricultural income.

Secondly, the relationship between agricultural income and BMI is driven by young women. Although we do not investigate mechanisms behind this finding, the result is consistent with multiple findings in the development literature that indicate that "low status" family members eat better in better times and vice versa. This could be explained by families following a "pure investment strategy" of allocating intrahousehold resources to cushion better endowed or more productive household members at the cost of more vulnerable household members during scarce times, or by preference biases. Lastly, our "pathway" results suggest that income effects on account of agricultural earnings might be important for nutrition in the Indian context.

DISTRIBUTION OF BMI ACROSS WOMEN BY AGE



CONTRIBUTION OF EACH SUB-INDICATOR TO DISEMPOWERMENT

Younger women in India (15–25 years) face a significantly larger incidence of underweight (BMI <18.5). Our analysis shows that they stand to benefit more (nutritionally) from an increase in agricultural income.

PUBLICATIONS

UNRAVELING INDIA'S MALNUTRITION DILEMMA: A PATH TOWARD NUTRITION-SENSITIVE AGRICULTURE

PUBLICATION

Pingali, Prabhu, and Mathew Abraham. 2019. "Unravelling India's Malnutrition Dilemma: A Path toward Nutrition-Sensitive Agriculture." In Agriculture for Improved Nutrition: Seizing the Momentum, edited by S. Fan, S. Yosef and R. Pandya-Lorch CABI International, forthcoming.

BACKGROUND

Following the Green Revolution, India successfully increased agricultural productivity and overall food production, achieving a surplus in cereals for the first time ever and cementing a national focus on calorie availability. In subsequent decades, as the economy continued to grow, the country experienced a significant decline in poverty levels. Despite this momentous achievement, the rate of malnutrition in India remains stubbornly high. Between 1990 and 2009, India had the highest proportion of underweight children as compared to sub-Saharan Africa and to other South Asian countries, such as Bangladesh, Bhutan, Pakistan, Nepal, and Sri Lanka, despite its relatively higher per capita gross national income (GNI) growth.

Across the 29 Indian states, there is much variation in malnutrition rates: in 2015, the prevalence of stunting ranged from 19.7% in Kerala to 50.4% in Uttar Pradesh. There are significant regional variations in the prevalence of malnutrition associated with socioeconomic inequalities but also with differences in governance, agricultural growth, and the public provisioning of basic services. Poorer regions have higher rates of undernutrition, but even within states, variations are determined by levels of urbanization and by agroecological differences. States with higher per capita income, such as Andhra, Goa, Kerala, and Tamil Nadu, have lower child malnutrition rates, but higher prevalence of overweight/obesity among adults. Alarmingly, the prevalence of adult overweight or obesity in some of these states has almost doubled between 2005–06 and 2015–16.

Mechanisms to combat malnutrition in India over the years have taken the form of policy legislation and mission mode projects (projects with a set timeline) under various ministries of the government. These include the National Nutrition Policy (1993), National Plan of Action (1995), National Health Policy (2002), National Nutrition Mission (2003), and National Health Mission (2013). The most notable of the food-based assistance programs has been the Integrated Child Development Services (ICDS) and the Mid-Day Meal Scheme (MDMS). ICDS aims to provide nutrition services and education to children under 6 years of age and to pregnant and lactating mothers, while the MDMS addresses hunger among children aged 6–14 by providing cooked meals in all primary schools. The nutritional impacts of these schemes are not clearly established.

APPROACH

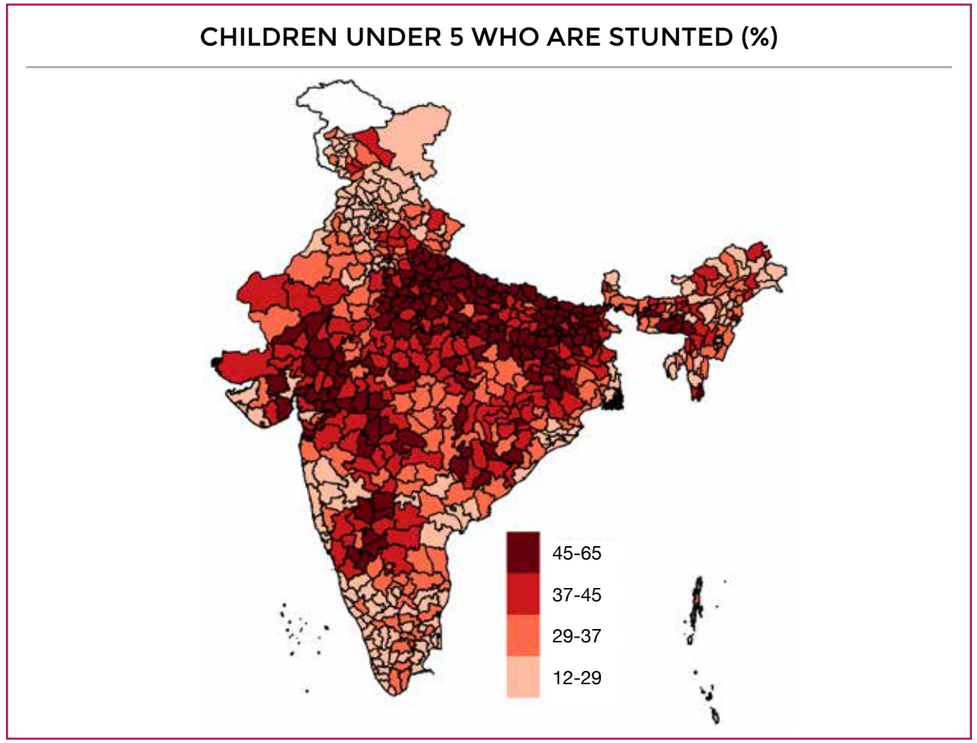
In this chapter, we argue for a multidimensional, nutrition-sensitive approach to leveraging agriculture to tackle malnutrition. This approach requires policies and schemes, such as the Public Distribution System (PDS), Integrated Child Development Services (ICDS), and Mid-Day Meal Scheme (MDMS) to integrate nutrition into all agricultural activities from production to consumption, while also addressing the intrahousehold distribution of food, especially for women and girls, and individual absorption of nutrients.

FINDINGS

- Countries that proactively support pro-agricultural growth policies tend to see better child development indicators, compared with countries that do not. Alone, agricultural policy is insufficient, and needs to be supported by a strong nutrition policy.
- As agricultural policies have been primarily focused on promoting cereal-based production. Institutions such as the Public Distribution System (PDS), accompanied by Minimum Support Price (MSP), has ensured price incentives for production.
- The support for staple crops relative to other crops has crowded out traditional micronutrient-rich food crops, such as coarse grains and pulses, resulting in the decline in the per capita availability of pulses from 65.5 g per day in the 1960s to about 44 g in 2015.

SIGNIFICANCE

Diversifying the country's agriculture sector away from grains is essential for improving the availability of micronutrient-rich foods. Interventions for empowering and saving time for women are crucial, as are interventions to ensure access to clean water, sanitation, and good hygiene practices. India has the largest number of malnourished children in the world, but the status quo can be changed. A nutrition-sensitive agricultural approach that addresses issues of intrahousehold distribution of food and nutrient absorption will be the way forward for India.



In India, there are significant regional disparities in the prevalence of malnutrition.

DIVERSITY IN DEVELOPMENT: INTER-STATE DIFFERENCES IN THE INDIAN GROWTH STORY

PUBLICATION

Pingali, Prabhu, and Anaka Aiyar. 2019. "Diversity in Development—Inter-State Differences in the India Growth Story." World Food Policy 4 (2)/5 (1), forthcoming.

BACKGROUND

In India, economic growth happens side-by-side with increasing regional inequality; persistent undernutrition coexists with increasing overnutrition rates; and smallholder farmers exist alongside large farms. Embedded in these observations is the idea that a comparative advantage in resource allocations in conjunction with nationally implemented development policies have influenced states' abilities to structurally transform. This has led to a situation in which, on the one hand, poorer states like Bihar have missed out on opportunities for growth presented during the Green Revolution and have become more comparable in their development outcomes to some countries in sub-Saharan Africa. On the other hand, the economic development of states such as Goa and Delhi have placed them on a trajectory in which their development outcomes are comparable to high-performing countries in Latin America.

METHODS

In this paper, we have proposed a new way to classify states to account for the heterogeneity in development outcomes using the principles of structural transformation (ST). By using the share of agriculture in GDP as a proxy for where a state is in the process of ST, along with GDP per capita, a proxy for productivity, we identify that there are four ST typologies of states within the country: Low Productive, Resource-led Growth, Agriculture-led Growth, and Rapidly Transforming. Using this typology, we are able identify unique development challenges within each group that explains India's development conundrums.

FINDINGS

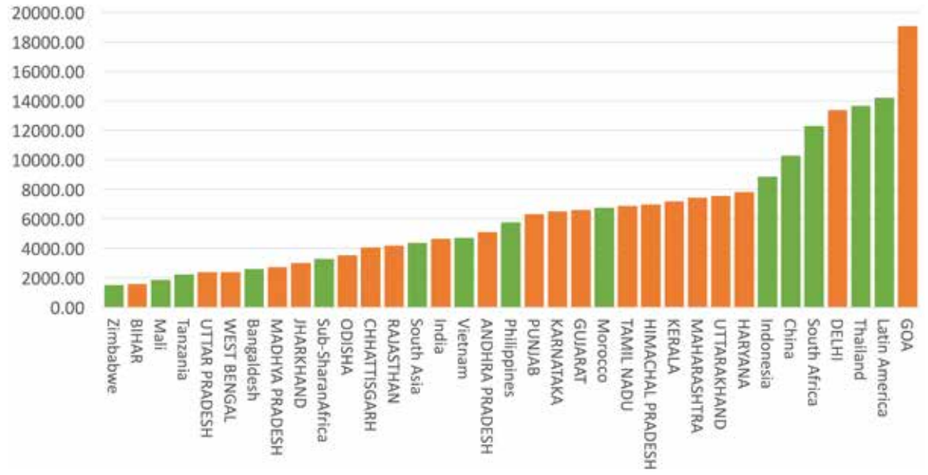
- *Low Productive*: In these states, subsistence agriculture systems dominate agricultural production, and a large share of the population depends on the agriculture sector for employment. The low productivity of the agriculture sector explains high rural poverty rates. Ensuring food security and calorie security remain the key goals for achieving better nutrition. States such as Bihar, Madhya Pradesh, Uttar Pradesh, and West Bengal are included in this category.
- *Resource-led Growth*: For these states, growth has been primarily driven by investments in the mining of natural resources. These states have lower productivity in both agriculture and nonagriculture sectors and, hence, high urban and rural poverty. For resource-led ST states, tackling hidden hunger (micronutrient deficiencies) is an important nutrition policy challenge. The experiences of Jharkhand, Chhattisgarh, and Orissa reflect the issues described in this typology.
- *Agriculture-led Growth*: In these states, agriculture's contribution to the state's economy, both in terms of value added and employment is high. High agricultural growth also contributes to lower rural poverty rates. For agriculture-led ST states, tackling hidden hunger and overnutrition should be major nutrition policy concerns. The development experience of Punjab and Andhra Pradesh are representative of this typology.
- *Rapidly Transforming*: Economic growth in these states is driven by the nonagriculture sectors. These states have higher rates of urbanization and lower poverty across both rural and urban areas. Reducing child wasting and incidence of overnutrition are important nutrition policy goals. Gujarat, Karnataka, Kerala, Maharashtra, and Tamil Nadu are examples of states within this typology.

SIGNIFICANCE

A major advantage of our model is that we are able to highlight the unique development challenges of states, as well as to identify the best possible solutions for enabling greater structural transformation. For example, overall, we find that agriculture-led growth has been an important catalyst for development and continues to be necessary for rural development, poverty reduction, and reduction in undernutrition.

Across states, the challenges for kick-starting the agricultural sector are region specific. For example, in low productive ST states, improving agriculture productivity through investments in non-staple crops is the way forward. In agriculture-led ST states, the challenge is an environmentally sustainable increase in the productivity of staples. In resource-led ST states, investing in managed livestock production will be an important component of a second green revolution. Rapidly transforming states would do well to invest in cold chains and the retail sector to ensure urban populations have access to healthy foods.

INTERNATIONAL COMPARISON IN GDP PER CAPITA (PPP, CONSTANT INTERNATIONAL $)



Data source: World Bank Databank, National Accounts Statistics. Based on authors own calculations.

Here, in this figure, we see that some states in India have GDP per capita incomes similar to some sub-Saharan African countries while other states look similar to southeast Asia or Latin America.

FOOD, AGRICULTURE, AND NUTRITION POLICY: LOOKING AHEAD TO 2050

PUBLICATION

Pingali, Prabhu, and Anaka Aiyar. 2018. "Food, Agriculture, and Nutrition Policy: Looking Ahead to 2050." In Agriculture and Food Systems to 2050, edited by Rachid Serraj and Prabhu Pingali. Hackensack, NJ: World Scientific Publishing.

BACKGROUND

Global innovation in food-related technology and efforts to increase food and nutrition access have been extremely successful in facilitating economic growth and development across the world. These innovations have helped reduce poverty, chronic hunger, and malnutrition. However, in many countries that missed the Green Revolution, structural transformation has remained stunted. We also see that economic progress has come alongside increasing environmental degradation, growing regional inequality, and increases in hidden hunger and obesity. Thus, in the past, despite many successes, food, agriculture, and nutrition (FAN) policies have either stopped short or created new roadblocks to achieving global nutrition security.

Looking ahead to 2050, pressures of population growth, increased urbanization, diet diversification, and climate change have brought back food security concerns to the policy table. Any policy decisions implemented moving forward will have to account for both the drawbacks of past policies and the challenges for the future. Identifying policies that create more sustainable food systems for the planet is an important next step in the global discourse on nutrition security.

APPROACH

In this book chapter, we discuss strategies required to move current food systems toward the development of equitable, climate-sensitive, and nutritionally balanced food systems of the future. In order to achieve this, we discuss policies that integrate priorities for increased food production with improved nutrition outcomes and greater economic development in the face of climate change. Toward this goal, we discuss the following:

- Policies for improving sustainability of agricultural production and environmental preservation for food security
- Strategies to conserve water for agriculture production and improve health outcomes
- Strategies for enabling on-farm diversification practices to increase rural prosperity and economic growth
- Policies to tackle the triple burden of malnutrition by focusing on interventions that increase macro- and micronutrients rather than just by increasing calories
- Supply chain interventions for linking urban food systems to rural income growth
- Strategies for creating new capabilities for increasing intrahousehold access to diverse diets
- Strategies for enabling investments into climate-sensitive businesses to stimulate nonfarm economic activity and employment
- Raising funds for R&D to combat climate change through implementation of carbon markets and other such climate mitigation strategies
- Enabling climate-friendly urban growth in response to urbanization
- Bolstering health interventions to prepare for noncommunicable disease risks

FINDINGS

This integrated approach to food, agriculture, and nutrition policy is one that should help diversify current agricultural food systems and will be important in ensuring nutrition security as incomes rise and diets continue to diversify. By creating climate-sustainable businesses, agriculture, and supply chain practices, we argue that structural transformation can be reinvigorated in countries that were left behind in the previous process. Investing in human development initiatives and in health systems and infrastructure, such as hospitals, water, and sanitation, can help reduce inequalities in access to nutrition. In addition, enabling conditions for urban development that is climate friendly, instituting water conservation practices, and integrating individuals and firms into carbon markets will be important strategies for future economic growth. In this vision of the food system, good health and access to nutritionally balanced foods will be an important outcome of development.

LIST OF SELECTED PUBLICATIONS FROM THE FIRST FIVE YEARS OF THE TATA-CORNELL INSTITUTE

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