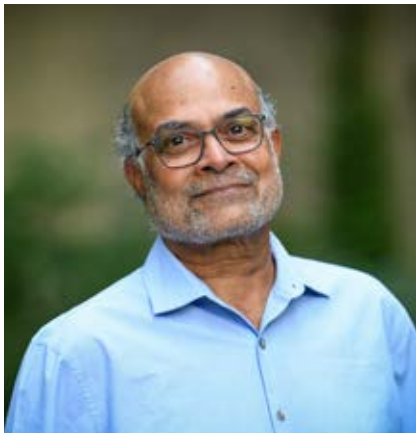
# ANNUAL REPORT 2024-25

TATA-CORNELL INSTITUTE
FOR AGRICULTURE AND NUTRITION

# TABLE OF CONTENTS

# DIRECTOR'S NOTE



The 2024–25 academic year was bittersweet for the Tata–Cornell Institute for Agriculture and Nutrition (TCI). While the Institute continued to produce rigorous, impactful research on Indian food systems, we lost our namesake, Mr. Ratan N. Tata, who passed away in Mumbai on October 9, 2024. TCI only exists because of his vision and generosity, and he will be sorely missed. The impact of his support for rural development in India, however, will be felt for many years to come.

Mr. Tata's vision for TCI was a research institute that would bring the resources and expertise of Cornell University to bear on the issues of malnutrition and rural poverty in India. Our accomplishments in this past year speak to that vision, as you will read in this report. In 2024–25, TCI researchers published five studies in peer-reviewed journals like *PLOS One* and *Food Policy*, as well as six policy briefs. Our published research touched on an array of topics, from supermarkets to open defecation.

Two of the policy briefs we published this year were special briefs related to TCI research projects. One explained how reducing the area of land used to produce rice in Chhattisgarh by 25% could lower India's rice-related methane emissions by 3%. Another explained how India's promotion of farmer producer organizations (FPOs) is hampered by a lack of data, making the case for a comprehensive FPO tracking system.

Increasingly, our research is focused on ensuring that India's food systems are not only nutrition-sensitive, but also environmentally sustainable. In Bihar, under our Zero-Hunger, Zero-Carbon Food Systems project, we are testing the effectiveness of new technologies, such as agrivoltaics, to reduce agricultural greenhouse gas emissions while improving productivity. In Chhattisgarh, we are studying pathways to diversify cropping patterns away from rice production, which is resource-intensive and creates large amounts of methane, in favor of climate-resilient crops, like pulses, oilseeds, and millets, which are better agro-climatically suited to the state. A new project, Promoting Value Chains for Climate Resilience and Nutritious Diets, will make recommendations to bolster value chains in support of climate-smart crops.

In addition to our research, TCI also educates the next generation of food systems researchers and practitioners through our TCI Scholars Program. This year, three scholars earned their doctorates, and one earned a master's degree. Ekta Joshi and Shree Saha received PhDs in Applied Economics and Management and are beginning careers at prominent international organizations. Shivranjani Baruah received her doctorate in Plant Pathology and Plant-Microbe Biology and will soon begin a new position as a postdoctoral researcher. Annie Gurmeher Kaur earned her MS in Applied Economics and Management and is now working toward a PhD. I look forward to watching each of their careers progress.

The research detailed in this report is made possible by the generous support of our funders, including grants from the Walmart Foundation, the Rockefeller Foundation, and the Novo Nordisk Foundation, as well as the founding endowment given to Cornell by the Tata Education and Development Trust.

I am tremendously proud of the work done by TCI researchers in support of Mr. Tata's vision for India's development. I hope that you enjoy reading about it in this report and thank you for supporting TCI.

Prabhu Pingali
Founding Director, TCI.

# BY THE NUMBERS

As of May 2025

**11** Researchers

**7** TCI Scholars

**4** Faculty Fellows

**35** Alumni

**22** PhDs Earned

**9** Master's Degrees Earned

**16** Academic Disciplines

**7** Reports

**4** Books

**55** Journal Articles

**14** Book Chapters

**31** Policy Briefs

**3** Fact Sheets

**2** Training Manuals

# OVERVIEW

## TCI is a long-term, multidisciplinary research initiative focused on creating and assessing innovative, food systems-based approaches to improving nutrition and livelihoods in India and other developing countries.

### Agriculture Transformation, Food Systems & Nutrition Transition

India's ongoing transformation from low-productivity agriculture to an advanced economy has profound implications for nutrition in the country. TCI research explores the impact of these changes to help India's food systems adapt and adequately provide for the shifting needs of its people.

### Climate Change & Sustainable Agriculture

As climate change continues, India's agricultural sector must grapple with its effects and adopt more resource-conscious, sustainable practices. TCI's research focuses on building resilient food systems capable of weathering climate change while meeting the nutritional needs of growing populations.

### Food & Ag Science Innovations

Building food systems that prioritize nutrition requires leveraging the latest scientific advancements in areas like soil health and fortification. TCI researchers are bridging the gaps between research and implementation through awareness-building, technology, and knowledge transfer.

### Food Safety, Water & Sanitation

Nutrient absorption is significantly impacted by interrelated factors involving food contamination, access to safe water, and hygiene. TCI research in these areas aims to inform effective interventions that ensure that families and individuals can enjoy the full nutritional benefits of the foods they eat.

*TCI Scholar Kiera Crowley and a member of her research team interview a farmer in Bihar, India. (Photo provided)*

## Gender & Nutrition

In India, 80% of economically active women are employed in the agricultural sector, with many performing unpaid household labor. TCI seeks to improve nutrition outcomes by understanding how women's empowerment at the community and household levels helps to bolster positive nutritional behaviors and improved intrahousehold access to food.

## ICTs, Data Systems & Ag-Tech

Information and communication technologies (ICTs) and other technological inventions can boost agricultural productivity and improve livelihoods, while strong, comprehensive data systems help ensure that policies and strategies are built on a foundation of solid evidence. TCI explores how new technologies can enhance food systems while working to build and improve databases and platforms.

## Markets & Value Chains

Rising demand for diverse agricultural products presents an opportunity for smallholder farmers to improve their livelihoods. TCI research aims to empower small farmers by identifying and addressing barriers that limit their access to value chains and markets.

# REMEMBERING RATAN TATA

TCI was deeply saddened by the passing of Cornell alumnus Mr. Ratan N. Tata, on October 9, 2024, in Mumbai. He was 89. A preeminent businessman and dedicated philanthropist, Mr. Tata had a profound impact on both India and Cornell University. In 2008, a $25 million endowment given to Cornell by the Tata Trusts established TCI as an initiative to improve nutrition outcomes in India. His support for education and rural development in India will be felt for generations.

"Ratan Tata was a singular figure who has touched the lives of millions of Indians through his generous philanthropy," TCI Director Prabhu Pingali said. "We at TCI endeavor to honor his memory through our continued research aimed at improving nutrition and rural livelihoods in India."

Tata was chairman emeritus of Tata Sons, the holding company for the Tata Group, a multinational conglomerate with interests ranging from steel, cars, and infrastructure to financial and digital services, consumer brands and hospitality. The company expanded its global reach and grew significantly under Tata's leadership from 1991 to 2012, with revenue exceeding $100 billion upon his retirement, while being recognized for its focus on the public good. From 2012 until his death, Tata chaired the Tata Trusts, India's largest private sector philanthropic organization, and was owner of a 66% stake in the Tata Group, as well as his own venture capital firm.

*"Ratan Tata was a singular figure who has touched the lives of millions of Indians through his generous philanthropy," TCI Director Prabhu Pingali said. "We at TCI endeavor to honor his memory through our continued research aimed at improving nutrition and rural livelihoods in India."*

In addition to the gift creating TCI, the Tata Trusts also endowed the Tata Scholarship for Students from India at Cornell. In 2017, a $50 million investment from Tata Consultancy Services helped build the Tata Innovation Center on Cornell Tech's Roosevelt Island campus in New York City.

*TCI Director Prabhu Pingali with Ratan Tata in 2024. (Photo by TCI)*

"Ratan Tata has left an extraordinary legacy in India, across the world, and at Cornell, which he cared about deeply," Cornell President Michael I. Kotlikoff told the *Cornell Chronicle*. "Ratan's quiet demeanor and humility belied his international profile. His generosity and concern for others enabled research and scholarship that improved the education and health of millions of people in India and beyond, and extended Cornell's global impact."

*Ratan Tata and then-Cornell President David Skorton in 2008 after signing their historic agreement providing an endowment of $50 million to Cornell for the creation of TCI and for the education of Indian students at Cornell. (Photo by Robert Barker/ Cornell University)*

*Ratan Tata at a reception for Tata Scholars at Cornell University in 2012. (Photo by Jason Koski/Cornell University)*

*Ratan Tata meets with a group of Tata Scholars in 2012. Tata Scholars receive a full scholarship for the duration of their undergraduate studies at Cornell. (Photo by Jason Koski/Cornell University)*

# AGRICULTURE
## TRANSFORMATION, FOOD SYSTEMS & NUTRITION TRANSITION

## Charting a Future for India's PDS

As India continues its efforts to curb stubbornly high rates of hunger and malnutrition, the Public Distribution System (PDS) plays a crucial role by providing subsidized food grain to more than 800 million people. TCI research has aimed to bolster the PDS by estimating its "true cost," inclusive of hidden environmental and economic impacts, and modeling the benefits of incorporating more millets into the program as a substitute for rice. The Institute held a pair of meetings in India in the past year to share the results of its research and spark discussions about the future of the PDS.

At a meeting in Delhi in January 2025, TCI convened a group of researchers interested in food-based safety nets to discuss future pathways for the PDS. The event featured two panels, which reflected on the PDS's past successes and challenges and discussed potential changes to the program. Panelists included TCI research associate Raghav Puri, who leads the institute's project on the True Cost of Food Subsidies in India; Ashok Gulati, distinguished professor at the Indian Council for Research on International Economic Relations (ICRIER); former Union Food and Agriculture Secretary T. Nandakumar; and International Food Policy Research Institute (IFPRI) senior research fellow Avinash Kishore.


*In January 2025, TCI and ICRISAT co-hosted an event on the promotion of millets in the PDS.. (Photo by TCI)*

> *Alongside staples, like rice and wheat, millets provide important benefits for food security and nutrition, yet their inclusion in the PDS remains largely underutilized.*

Also, in January, TCI partnered with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to hold a forum on promoting millets in the PDS at ICRISAT's Hyderabad campus. Known as "smart foods," millets are globally celebrated for being nutrient-rich and climate-resilient foods. Alongside staples, like rice and wheat, millets provide important benefits for food security and nutrition, yet their inclusion in the PDS remains largely underutilized. Participants in the forum included researchers and government officials from across India.

Lessons from both meetings will be included in a forthcoming book, *Future Pathways for India's Public Distribution System*, authored by Puri and TCI Director Prabhu Pingali. The book will complete a trilogy of TCI books on Indian food systems and social programs, including *Transforming Food Systems for a Rising India* and *The Future of India's Social Safety Nets*.

# STAFF SPOTLIGHT

## Raghav Puri

In recent years, TCI has shined a light on the "true cost" of India's Public Distribution System (PDS), an enormous food subsidy program that helps keep 800 million Indians food secure. Leading that research has been Raghav Puri, a research associate who studies the design, implementation, and impact of health and nutrition programs in India.

Puri developed an interest in the PDS after interviewing program beneficiaries and administrators as part of a survey in central India. "This experience not only helped me recognize the importance of food-based safety nets in ensuring food security but also provided me with an opportunity to appreciate the complexities of last-mile delivery of social programs," he says.

As a researcher, Puri brings both quantitative and qualitative research skills to his work. He learned the value of qualitative research after interviewing beneficiaries and administrators of various social programs in India for the Right to Food Campaign and the World Bank. Qualitative insights from those interviews helped to explain many of the quantitative findings that he and his colleagues found in administrative data.

"While I am trained as a quantitative social scientist, I find it helpful to corroborate my research findings with qualitative insights," Puri says.

With its focus on agriculture and nutrition in India, TCI has been an optimal place for Puri to pursue his interests and grow as a researcher after earning his PhD in Public Administration from Syracuse University.

"Over the past four years, I have led projects as co-principal investigator, conducted field research in various parts of India, presented my research at numerous forums, and contributed my insights to key reports," Puri says. "All these opportunities have largely been made possible by the resources and mentorship available at TCI."

Puri is currently co-authoring a book on future pathways for the PDS with TCI Director Prabhu Pingali.

# FOOD
## & AG SCIENCE INNOVATIONS

## Raising Capacity to Improve "Underutilized" Crops

In agricultural research and development, staple grains like rice and wheat dominate attention, while coarse grains, roots, tubers, and pulses are often overlooked. Yet, these "underutilized" crops are vital for smallholder farmers in developing countries due to their nutritional benefits and adaptability to diverse agroecological zones. Crops, such as millets, cassava, and cowpea, offer rich nutritional profiles and are particularly suited to varying environmental conditions.

Despite their significance, underutilized crops have received insufficient attention from agricultural research institutions. Limited investment in plant breeding has left these crops susceptible to low yields and increased vulnerability to pests and diseases, discouraging farmers from cultivating them. Given their importance for local consumption, most improvement activities have been undertaken by public sector breeding programs.

To address these challenges, TCI led the institutional capacity evaluation component of the Feed the Future Innovation Lab for Crop Improvement (ILCI). This initiative partners with national agricultural research institutes across Africa, Latin America, and the Caribbean to collaboratively develop tools, technologies, and methodologies aimed at enhancing vital crops and strengthening institutional capacities. TCI was responsible for systematically assessing and tracking the development of partner institutions' progress.

In this role, TCI researchers conducted surveys and field visits to measure institutional growth, understand capacity-building processes, and identify ongoing challenges. Survey outcomes demonstrated that, since the project's inception, partner programs broadened stakeholder engagement, adopted genomic technologies, enhanced digital data collection practices, and implemented breeding management software, resulting in more efficient, accurate, and transparent breeding operations. Field visits highlighted persistent challenges that have hindered research capabilities, such as funding constraints and infrastructural limitations.

TCI's findings indicate that the ILCI effectively supported public research institutions in overcoming critical barriers to breeding improved varieties of underutilized crops. Key successes include aligning breeding initiatives with local community needs, fostering inclusive stakeholder participation, and strengthening regional cooperation. To maintain these advances, ongoing investment in capacity-building initiatives and robust partnerships remains essential. TCI synthesized these insights into comprehensive reports for each partnering breeding program, detailing specific capacity improvements and identifying remaining gaps based on comparative survey data. Enhanced with narratives from focus group discussions, these reports contextualize each country's unique crop improvement environment, serving as strategic resources for future investments and providing a clear picture of how interventions have contributed to capacity development and where further improvements are necessary.

## Fast-Tracking Disease-Resistant Crops

Every year, 20–40% of crops across the world are lost to disease and pests. In India and other developing countries, these losses can threaten food and nutritional security. The best solution for overcoming this challenge is to breed disease-resistant crop varieties, but that process is challenging, especially in developing countries. Large-scale screening for disease resistance depends on manual phenotyping techniques, which are time consuming and difficult to standardize.

To help hasten the crop improvement process, TCI supported a proof-of-concept study, led by TCI alumna Shivranjani Baruah, to assess the use of spectral imaging as a high-output method to detect and quantify bacterial blight in rice crops. Baruah's process uses canopy-mounted multispectral sensors, along with drone-based multispectral and hyperspectral sensors, to identify disease-dependent changes in plant physiology that cannot be seen by the human eye.

*Shivranjani Baruah used drone-based sensors to identify evidence of disease in rice crops that can't be seen with the human eye. (Photo courtesy of ICRISAT)*

At the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad, India, Baruah conducted three trials using ICRISAT's LeasyScan 3D imaging platform. She also tested how the process could be scaled up to operate under natural field conditions.

With TCI support, Baruah established the first successful disease phenotyping pipeline in the LeasyScan facility. The process predicted disease severity with 76% accuracy, using just four spectral bands. Previous studies predicted bacterial blight severity with 82% accuracy but were dependent on 26 spectral bands.

*With TCI support, Baruah established the first successful disease phenotyping pipeline in the LeasyScan facility. The process predicted disease severity with 76% accuracy, using just four spectral bands.*

Baruah's research is an important step toward a high-output phenotyping method, which can make it easier and faster to develop disease-resistant crop varieties in the developing world, and help to reduce losses and increase the availability of food where it is needed most.

## Boosting Goat Productivity with Advanced Breeding

For India's smallholder farmers, raising goats can be a profitable venture, especially as a source of income during crop failures. Breeding goats, using artificial insemination, can greatly improve the animals' productivity, but its adoption is limited due to low awareness, poor access to services, and governance challenges within agricultural extension systems.

Together with BAIF Development Research Foundation, TCI led a study assessing the benefits of artificial insemination for goat breeding and factors affecting farmers' decisions to adopt the practice. As part of the study, TCI and BAIF provided artificial insemination and other healthcare services to goat-rearing households across Rajasthan, Bihar, Maharashtra, and Odisha.

At the conclusion of the study, farmers exhibited increased awareness of artificial insemination, and a significant proportion expressed a willingness to pay for such services. Households that received the intervention reported benefits, including improved weight gain, healthier kids, higher kidding rates, and greater convenience in managed breeding cycles. Farmers also showed an increased willingness to pay for complementary health services, such as vaccination and deworming, indicating a growing trust in veterinary services.

*At the conclusion of the study, farmers exhibited increased awareness of artificial insemination, and a significant proportion expressed a willingness to pay for such services.*

The study underscores the importance of supportive systems of governance, training, and service to enable sustained adoption of innovative technologies by smallholder farmers. It can help pave the way for more effective and sustainable goat breeding practices, positively impacting the livelihoods of small and marginal farmers.

## Promoting Better Breeding for Improved Livestock Productivity

With the world's population growing and dietary preferences changing, rising demand for animal-based food products, such as milk, presents an opportunity for farmers in the developing world. Artificial insemination of livestock can help these farmers improve their productivity and increase their incomes, but usage of the technology has been limited thus far.

*Compared to natural breeding, artificial insemination can improve goats' productivity. (Photo by Maureen Valentine/TCI)*

A TCI analysis published in *Economic & Political Weekly* sheds some light on the considerations that influence farmers' decisions on whether to use artificial insemination for their livestock. The article presents a systematic analysis of previously published research on artificial insemination, highlighting factors that most heavily affect the technology's adoption. TCI researchers examined 18 studies that spanned 10 different developing countries. They grouped the factors into five categories: sociodemographics, livestock and farm-related attributes, artificial insemination-related details, institutional support, and psychological drivers.

The most influential factors that the researchers found were those affecting farmers' awareness of artificial insemination, the existence of infrastructure supporting the use of the technology, and overall costs.

The analysis provides policymakers with multiple avenues for encouraging the adoption of artificial insemination, which can improve farmers' incomes while making

livestock production in developing countries like India more sustainable.

Seth, P., Chandran, B. Mittra, B., and Pingali, P. 2025. "Understanding the Determinants of Farmers' Adoption of Artificial Insemination in Livestock." *Economic & Political Weekly* 60 (7), February. https://doi.org/10.71279/epw.v60i6.42332.

## Making Soils Healthy in Bihar

Healthy soils are crucial to sustainable agricultural production. In Bihar, conventional cultivation practices have degraded soil quality, limiting the effectiveness of fertilizers and hurting productivity.

One of TCI's longest-running projects, Optimizing Soil Health established a partnership with the Dr. Rajendra Prasad Central Agricultural University (RPCAU) in Bihar to raise awareness of soil health, educate young soil scientists, and undertake critical studies of soil health and agricultural production.

TCI formalized a relationship with RPCAU in 2017, to build a cutting-edge soil health lab on its campus in Pusa. Under the guidance of Ranjan Laik, a professor in the University's Department of Soil Science, the lab empowers scientists to analyze and assess the biological, chemical, and physical properties of soil samples.

In the 7 years since the lab opened, its researchers have produced a substantial amount of research, with 11 studies published in peer-reviewed journals. One such study found deficiencies in soil health in cropping systems across Bihar's agroclimatic zones and identified the main factors causing gaps between cultivated and uncultivated soils.

The lab has also made progress in developing a reliable method for assessing soil health in Bihar, identifying different variables and indicators that most affect soil health in the state's varied agro-ecological contexts. Researchers also developed a method of predicting soil quality parameters using spectroscopy.

*The soil health lab established by TCI at the Dr. Rajendra Prasad Central Agricultural University in Bihar has equipment for testing the chemical, biological, and physical qualities of soil. (Photo provided)*

Another study assessed the impact of "conservation agriculture"—practices that include minimum tillage, residue management, and crop diversification—and found that it resulted in significant yield increases, compared to current practices in the Eastern Indo-Gangetic Plain. A different study found that the application of zinc, along with the incorporation of crop residue, significantly improved soil's biological properties and organic carbon levels.

Dozens of students have been trained at the lab. During an initial opening workshop in July 2018, 20 MSc and 10 PhD students learned to use the new equipment and received instruction on the comprehensive assessment of soil health framework developed at Cornell. Four PhD and 3 MSc students have used the lab to conduct soil health research since then, and 2 students are currently doing such research. About 10 others have also used the lab to analyze soil samples.

# MARKETS & VALUE CHAINS

## Leveraging Supermarkets for Small Farmer Incomes

Supermarkets have spread rapidly in India over the past 20 years, leading some experts to predict that they and their rural procurement centers would benefit farmers through reduced transaction costs and improved market access. Others, however, feared that smallholders would be squeezed out by supermarkets' high standards for quality, consistency, and volume.

A study published in the journal *Economic & Political Weekly* showed that selling to supermarkets does increase the incomes of farmers. Using data from field surveys of farm households conducted across four states, researchers from TCI and other institutions found that farmers selling to supermarkets had an expected net income 14 percent greater than farmers selling to traditional markets.

> *Specialized vegetable farms and those equipped with irrigation were more likely to sell to supermarkets.*

Although the study showed that selling to supermarkets benefits farmers, it also revealed that smaller, asset-poor farms are less likely to sell to supermarkets than their better-positioned peers. Specialized vegetable farms and


*TCI research shows that farmers who sell to supermarkets have higher incomes than those who sell to traditional markets. (Photo by Alisha Vasudev/Shutterstock)*

those equipped with irrigation were more likely to sell to supermarkets.

By estimating the monetary benefit of modern markets and revealing the factors that determine which farmers stand to profit, this research provides policymakers with key insights for helping more smallholders take advantage of the continued expansion of supermarkets.

> Nuthalapati, C. S., A. K. Mishra, P. Pingali, and T. Reardon. 2024. "Determinants and Income Effects of Small Farmers Selling to Supermarkets versus Traditional Market Channels in Four Regions of India." *Economic & Political Weekly* 59(44–5), November.

## Cutting Food Loss and Waste

As the world works to achieve goals related to food security, climate change, and sustainable food systems, food loss and waste in food value chains must be addressed. Although it is a global imperative, reducing and preventing food loss and waste requires an understanding of the problem within different contexts, including the status of structural transformation of economies and food systems within the areas of study.

*Wasted Potential: Tackling Food Loss and Waste Across Transforming Food Systems*, a forthcoming book from TCI alumna Jocelyn Boiteau and Director Prabhu Pingali, examines how reforms of food systems can support food loss and waste reduction efforts to promote sustainable, safe, and nutritious diets in countries at different points of structural transformation. Using a food systems lens, they focus on low- and middle-income countries to explore entry points for investments and intervention priorities to reduce food loss and waste.

The book presents, for the first time, a comprehensive framework of food loss and waste pathways to describe the links between food quality loss and physical food loss and waste that directly impact diets and food diverted for nonfood uses. Food loss and waste is complex and has many dimensions, requiring a variety of approaches to estimate the extent of losses and identify the layered causes across food products, value chain stages, and geographies.

*The book presents, for the first time, a comprehensive framework of food loss and waste pathways to describe the links between food quality loss and physical food loss and waste that directly impact diets and food diverted for nonfood uses.*

Based on their review of the evidence, Boiteau and Pingali identify promising and inclusive policy agendas that align food loss and waste prevention with sustainable food systems goals. This book will appeal to both professionals interested in food loss and waste prevention and to academic researchers studying the issue.

## Promoting Food Value Chains

As India strives to produce more foods that are both nutritious and better suited to its changing climate, it will need to diversify its agricultural system away from rice and wheat, in favor of crops, like vegetables, pulses, and coarse grains. Achieving this diversification will require robust, extensive value chains to support production and bring new foods to consumers' plates. Food value chains play a vital role in food systems by helping to connect farmers with markets, providing critical infrastructure, and ensuring economic incentives.

A new TCI project supported by the Novo Nordisk Foundation, Promoting Value Chains for Climate Resilience and Nutritious Diets, will map and analyze the value chains

*By connecting farmers with markets, providing critical infrastructure, and ensuring economic incentives, value chains play a vital role in shaping food systems. (Photo by Mathew Abraham/TCI)*

for millets, tomatoes, pulses, and soybeans—crops that are representative of key food groups, including coarse grains, horticultural produce, pulses, and oilseeds. Through their analysis, TCI researchers will identify challenges and inefficiencies along the value chains and recommend options for addressing them.

*Through their analysis, TCI researchers will identify challenges and inefficiencies along the value chains and recommend options for addressing them.*

Researchers will also consult with key stakeholders in the relevant value chains, including policymakers, scientists, and civil society organizations. These consultations will reveal key areas of focus and confirm the validity of proposed interventions.

This project will produce valuable evidence and insights that policymakers can use to develop strong value chains for diverse crops, helping India to transition to a more sustainable, climate-friendly food system, while making nutritious foods more accessible and affordable.

# SCHOLAR SPOTLIGHT

## Sumedha Minocha

After working as an analyst, using critical thinking and creativity to answer research questions, TCI Scholar Sumedha Minocha decided that she was ready for the next step—learning rigorous research methods and designing studies to answer her own research questions. So, she joined TCI as a PhD student in Applied Economics and Management.

Minocha's research is focused on welfare policies for pregnant women in India. In particular, she studies differences in the implementation of food transfers through the Integrated Child Development Services. As part of her studies, she surveyed 900 women in Maharashtra to learn how providing ready-to-cook rations or cooked meals impacts women's and children's nutrition and intrahousehold food allocation.

As a mother herself, Minocha is driven to improve women's and children's nutrition and health through her research. "This topic is very personal and relatable, so its motivating that I can learn from it and implement in my own life," she says.

At TCI, Minocha has thrived in a community of scholars who learn from each other, gaining confidence as a researcher.

"Sometimes graduate school can be an overwhelming place, but being a TCI scholar has fostered a sense of community," Minocha says. "It has given me a platform to learn from others, share ideas, and engage in discussions that are focused on a common topic that we all love."

Minocha also lauds TCI for providing her with support to collect her own data in the field, exposing her to the on-the-ground realities of the communities she is studying. "It was an immersive experience and shaped me in becoming a confident and independent researcher," she says.

# GENDER & NUTRITION

## Understanding Women's Empowerment and Nutrition in an Urbanizing India

India today is a rapidly changing place. Roughly one-third of Indians live in urban areas, and the World Bank estimates that 40% will live in cities by 2036. Urbanization brings changes that can improve nutrition outcomes, such as better access to markets, but this transformation can also complicate India's efforts to combat malnutrition, including women's empowerment programs.

In a study published in the journal *Food Policy*, TCI researchers used "couples" data from India's National Family Health Survey and satellite data on nighttime lights to assess how women's empowerment impacts nutrition outcomes at different levels of urbanization.

The researchers found a significant link between overall urbanization and dietary diversity. As urbanization levels doubled, the dietary diversity scores of both women and men increased by 7–8%. Women's empowerment was found to rise along with urbanization, and empowerment was associated with greater dietary diversity for women, though not for men. For every unit increase in the Women's Empowerment in Nutrition Index, women's dietary diversity improved by 0.19 food groups.

The researchers also discovered that urbanization becomes more important than empowerment at higher income levels, possibly because women's empowerment is already high in cities, or because the role of empowerment is subsumed by the benefits of urbanization, like higher incomes.

However, urbanization was not found to be a significant driver of diet quality among lower-income households, whereas empowerment had a noteworthy impact. This shows that some components of empowerment, such as women's ability to make household purchasing decisions,

*Women's empowerment is an important pathway for improving nutrition outcomes, but its impact changes depending on other factors, such as household income. (Photo by TCI)*

can likely overcome the economic constraints that develop from low levels of urbanization.

This study underlines the nutritional benefits that urbanization brings to India while providing policymakers with evidence to develop a more nuanced approach to women's empowerment in a changing country.

> Gupta S., Seth P., Vemireddy V., and Pingali P. 2024. "Women's empowerment and intra-household diet diversity across the urban continuum: Evidence from India's DHS." *Food Policy* Vol. 128, 102680, October..

## Empowering Rural Women Through Producer Organizations

Women play multiple roles in agriculture—as farmers, laborers, entrepreneurs, and unpaid workers—while simultaneously managing household responsibilities, such as childcare and food preparation. Despite their significant contributions, women face deeply rooted, gender-based challenges, including limited access to land, credit, technology, and markets, all of which hinder their productivity and participation in high-value, market-oriented agricultural activities. As a result, farms managed by women often yield less than those managed by men, due to structural constraints rather than lack of ability.

Research shows that equalizing women's access to agricultural inputs and services can lead to substantial gains in productivity, food security, and household welfare. Women's access to resources has been linked to improved outcomes in children's health, nutrition, and education. Over the past few decades, self-help groups (SHGs) have emerged as important grassroots platforms for women's financial inclusion, social empowerment, and livelihood enhancement. These groups foster collective action, improve access to resources, and build women's decision-making capacity. However, SHGs often face limitations in meeting the evolving aspirations for rural women—particularly, in scaling up of economic activities and accessing formal markets. To address this, SHGs have increasingly been transformed into formal farmer producer organizations (FPOs). This institutional shift enables economies of scale, reduces transaction costs, and strengthens women's collective access to inputs, extension services, and markets—enhancing their economic agency and leadership.

As part of TCI's ongoing project, FPO-Led Small Farm Market Access Models, researchers investigated how women's SHGs evolve into FPOs. The study focuses on six Indian states—Tamil Nadu, Uttarakhand, Bihar, Assam, Maharashtra, and Chhattisgarh—using a case study approach. Data was gathered through key informant interviews, focus group discussions, and document analysis to understand the institutional, socioeconomic, and organizational factors shaping the SHG-to-FPO transition.

Preliminary findings highlight the pivotal role of civil society organizations in facilitating the transformation. SHGs serve as the foundation for FPOs, which provide critical services such as access to quality inputs, collective marketing, value addition, and training. These services improved members' incomes, reduced dependence on intermediaries, and enhanced market access. Most notably, the transition contributed to women's empowerment by fostering greater confidence, leadership, and participation in decision-making at both the household and community levels.

By demonstrating how SHGs and FPOs empower women, this research shows strong potential for promoting inclusive rural development through women-led agricultural enterprises.

# FOOD SAFETY
## WATER & SANITATION

## Ending Open Defecation

By spreading harmful pathogens, open defecation poses a multitude of risks, from short-term dangers like diarrhea to long-term hazards like malnutrition. These risks are especially serious for children. Despite the threat, 17% of rural Indians continue to practice open defection, even though the government has made significant progress in providing access to toilets.

A TCI study published in *PLOS One* shows that important progress toward ending open defecation is possible through the combination of subsidized toilet construction and behavior change communications—educational programs that raise awareness of the risks incurred with open defecation.

Led by alumna Payal Seth, TCI conducted a trial in 15 villages across Uttar Pradesh. The villages were divided into three groups. TCI offered subsidized toilets to one group, while another was offered subsidized toilets and provided educational programming on sanitation and the dangers of open defecation. A control group received neither.

*As part of Payal Seth's study, TCI partnered with Grameen Development Services to build subsidized toilets for some of the participant households. (Photo by Payal Seth/TCI)*

At the conclusion of the trial, open defecation decreased modestly in the villages that were only offered subsidized toilets, from 95% to 52%. In the villages that received both toilets and behavior change programming, open defecation was virtually eradicated, falling from 98% to 4%.

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The villages that received behavior change programming also saw significant improvements in child health, but the villages that received toilets but no behavior change programming did not report such significant improvements. Overall, by the end of the study, the number of underweight children in the villages that received behavior change programming fell by 20%, coinciding with a 28% decrease in reported diarrhea cases.

The research shows that information can be a key tool in the fight to end open defecation in India and highlights the important role that sanitation plays in nutritional well-being and child development.

Seth, P., and Pingali, P. 2025. "Addressing Information and Credit Barriers to Making India Open Defecation Free and Improving Child Health: Evidence from a Cluster Randomized Trial in Rural India." *PLOS One*, February. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0318198.

# ALUMNI SPOTLIGHT

## Anaka Aiyar

Anaka Aiyar spent more than five years working on field-based projects in India before pursuing her PhD. After honing her skills as a postdoctoral associate at TCI, she is now an assistant professor at the University of Vermont, Burlington, where she continues her studies the impact of health policies on health and nutrition outcomes for people living in developing countries.

During her fieldwork in India, Aiyar observed that health was one of the most important assets of the underprivileged and played a defining role in determining long-term economic outcomes for families. To provide practitioners, policymakers, and academics with new insights into what drives access to health care, and consequently, health outcomes, Aiyar focused her research on health care and nutrition policy, in particular, the impact of structural barriers to health care access on the development of health capital.

As a postdoctoral associate at TCI, Aiyar contributed to a wide array of research, co-authoring a book, *Transforming Food Systems for a Rising India*, and a study on the relationship between urbanization and India's rising obesity burden. After the start of the COVID-19 pandemic, Aiyar and TCI Director Prabhu Pingali authored an opinion piece in the journal *Food Security*, arguing that a proactive approach that integrates one-health knowledge on zoonotic diseases with food safety measures is key to preventing future pandemics.

Aiyar's time at TCI has proven to be formative. She uses examples from her work at TCI while teaching courses on health economics and statistics, and she drew on the experiences of both her own research and other TCI researchers for a graduate-level course on econometrics.

"The mentorship from TCI Director Prabhu Pingali and other staff during my postdoctoral days was very valuable," Aiyar said. "TCI gave me the platform to meet scholars and research practitioners from different fields and get exposure to interdisciplinary research methods. It broadened my view on nutrition and ag research and gave me a holistic experience to develop as a researcher."

# ICTS, DATA
## SYSTEMS & AG TECH

## Data is Crucial to FPO Success

India is betting big on farmer producer organizations (FPOs) to boost its agricultural sector and improve the livelihoods of smallholder farmers, but the lack of a centralized tracking system hampers efforts to promote effective FPO models.

In a policy brief, TCI demonstrated that the lack of a centralized source of information on FPOs makes it difficult even to discern the number of FPOs currently active in India. Identifying which agencies promote or support FPOs is even more difficult, as is determining other essential characteristics, such as crops grown.

TCI researchers used data from the Ministry of Corporate Affairs to estimate the total number of FPOs to be 44,460. However, due to a discrepancy in the data with regard to the number of currently functioning FPOs, the status of many is unknown. Ministry data classifies 26,938 FPOs as active and compliant with all necessary regulatory filings and requirements, but as of 2023, only 15,455 of those FPOs had submitted their financials, which they are legally required to do on an annual basis.

Other information about FPOs is even more difficult to find, such as their gender composition and the services they provide.

Most FPOs in India are set up by government-funded organizations called implementing agencies. TCI researchers determined most of the FPOs, which are promoted by the largest implementing agencies—the National Bank for Agriculture and Rural Development and the Small Farmers Agri-Business Consortium—but information related to the roles of private philanthropic foundations in FPO implementation is virtually impossible to obtain. Similarly, data on the civil society groups, consultancies, and others that work with implementing agencies to support FPOs is frequently uncollected, leaving stakeholders in the dark about what promotion strategies do or do not work.

TCI's research in this area, facilitated by its creation of the FPO Platform for India, underscores that a centralized system with comprehensive FPO data can help researchers and other stakeholders assess the performance of India's FPOs and craft effective policies to improve FPO promotion.

## Assessing—and Supporting—India's FPO Ecosystem

In India's endeavors to promote FPOs as drivers of agricultural productivity, access to timely, reliable data is key to making effective policy decisions. TCI supports those efforts through the creation and maintenance of the FPO Platform for India, the most extensive source of comprehensive data related to India's FPO ecosystem.

*Through FPOConnect, FPOs can claim their pages and produce personalized business profiles.*

New updates to the platform in 2025 included the expansion of data on more than 45,000 FPOs, giving stakeholders access to a wealth of useful information, such as crops produced, services provided, supporting organizations, and financial information.

TCI also added a new networking tool to the platform—FPOConnect. Through FPOConnect, FPOs can claim their pages and produce personalized business profiles. The profiles are accessible through search engines, providing FPOs with a valuable online presence. Businesses, FPO promoters, service providers, and others can also join FPOConnect to follow and message FPOs directly.

With the addition of FPOConnect, the FPO Platform for India is not just a much-needed database enabling research and good policymaking, but is itself an important piece of infrastructure facilitating market opportunities and supporting FPO promotion.

## Enabling Data-Driven Policymaking

As India moves to overcome a myriad of food systems challenges—from malnutrition to climate change—timely, accurate data is paramount to informed policymaking. Perhaps, no single resource of food systems data is more important than the District-Level Database for Indian Agriculture and Allied Sectors, an online data platform created by TCI and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The database brings together data for 571 districts in 20 states from 1966–2020. Crucially, the data has been "apportioned" to control for the creation of new districts and changes to district boundaries, empowering researchers to look at the diversity in growth patterns across India from a historical perspective. In all, the database includes 74 data sets, 1,030 variables, and more than 11 million datapoints. This wide range of data can easily be downloaded and compiled via the open-access, web-based dashboard.

The database has proven to be exceptionally useful for TCI researchers. Its data has been used for many of the Institute's publications, including its series of reports on food, agriculture, and nutrition in India, which featured a map of India's cropping systems created using the database.

With the wide-ranging, detailed information it provides, the District-Level Database is a powerful tool for stakeholders, from academic researchers to policymakers, to set priorities for food systems research and investment across India.

## Encouraging Farmers to Use Digital Tech

Digital farm management technologies have the potential to improve the agricultural productivity of India's farmers, helping to increase incomes and make a diverse range of foods more affordable in the country. However, many farmers are not taking advantage of existing tools.

To better understand the barriers to technology usage, TCI alumna Shree Saha conducted research into how the perceived complexity of a given technology affects its adoption, even when cost, availability, and human capital are not issues. Saha conducted a randomized control trial with 611 shrimp farmers in the coastal districts of Odisha, providing them with hands-on training for using Aquaconnect, a digital tool that computes feed rates for shrimp.

Preliminary results from Saha's study showed that individualized training significantly reduced overall perceptions of complexity, with farmers who received training using Aquaconnect at much higher rates than those who did not receive the individualized training. She also found a reduction in farmers' ability to use the app over time, suggesting that sustained training programs are important to encourage its long-term usage.

Saha's research shows that technology adoption is dependent on more than cost and availability, underscoring the importance of perceived complexity. Her findings can help policymakers create more effective interventions to promote technology adoption by farmers, with the goal of helping to improve productivity, increase incomes, and make food more affordable.

# CLIMATE
## CHANGE & SUSTAINABLE AGRICULTURE

## Crop Diversification for Climate Resilience

In India's "rice bowl" of Chhattisgarh, rice production reigns supreme. The primacy of rice, however, brings several problems—grain-heavy diets that cause malnutrition, unsustainable groundwater usage, and high greenhouse gas emissions. With climate change bearing down on India, Chhattisgarh must take steps to reduce its emissions and make its agricultural sector resilient to rising temperatures and more frequent extreme weather.

TCI's project on the Transformation of Agricultural Systems for Climate Resilience aims to show pathways for crop diversification in favor of climate-smart options in Chhattisgarh. The pathways being assessed through field trials include education on climate-smart farming practices, improved market access, and community-based irrigation infrastructure.

As part of the project, TCI researchers modeled the potential reductions in greenhouse gas emissions based on Chhattisgarh reducing the area of land it uses for rice production. They found that a 10% reduction would decrease rice-related emissions from 340 gigagrams (Gg) to 306 Gg. A 25% reduction would further reduce emissions to 255 Gg.

As the third highest producer of rice in India, Chhattisgarh is responsible for 9% of the country's rice-related emissions. Under the 10% reduction scenario modeled by TCI, India's total rice-related methane emissions would fall by 1%. Under the 25% scenario, total emissions would decline by 3%.

Instead of rice, TCI presents pulses, millets and oilseeds as climate-smart options to cultivate in Chhattisgarh. The hardy, resilient crops are compatible with the state's agroclimatic conditions, requiring less irrigation and synthetic fertilizers than rice. They also have comparably better nutritional profiles.

TCI's research in this area shows that crop diversification can be an effective strategy not only for mitigating greenhouse gas emissions, but also for adapting to climate change and improving the availability of nutritious foods.

## Building Zero-Hunger, Zero-Carbon Food Systems

To meet its goal of achieving net-zero greenhouse gas emissions by 2070, India needs to reduce agricultural emissions while maintaining or even accelerating productivity to feed its growing population. TCI's Zero-Hunger, Zero-Carbon Food Systems project is working toward this end by assessing pathways for the state of Bihar to reduce its agricultural emissions without sacrificing productivity.

In the first phase of the project, TCI researchers used policy dialogues, field visits, and quantitative modeling to design district-level targeted interventions in the rice and livestock sectors, two primary sources of agricultural emissions.

In the second phase of the project, researchers are now testing the viability of their proposed solutions in "real-world" scenarios. In addition to testing interventions in rice production and livestock management, TCI is testing the viability of agrivoltaics.

For the project's rice component, TCI is working with Digital Green to develop efficient and scalable solutions for delivering targeted advisory services to farmers by collecting data regarding their production practices. In addition to in-person data collection, researchers are testing data collection using chatbots. The researchers also are working to more accurately measure rice-related

*In Bihar's Gaya ji district, TCI built a 20-kW agrivoltaics installation for a group of six farmers. (Photo by TCI)*

emissions by combining field-based measurements with satellite data.

For the livestock component, TCI is partnering with BAIF Development Research Foundation to study the main drivers behind farmers' decision-making regarding the use of sex-sorted semen and methane-reducing feed supplements, in addition to investigating the price point at which farmers are willing to buy such products. Finally, researchers are assessing the effectiveness of an awareness campaign that aims to increase farmers' knowledge about the products.

TCI is also testing the viability of community-based agrivoltaics, which combines agricultural production and solar power generation on the same land. Through a partnership with PRAN (Preservation and Proliferation of Rural Resources and Nature), TCI built a 20-kW agrivoltaics installation that provides a group of 6 farmers with sufficient power to micro-irrigate approximately 8 acres of their crops, thereby enabling them to achieve 3 harvests per year and operate a wheat mill with surplus power. Researchers are monitoring various aspects of the installation, including its economic impact and effect on agricultural production.

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