



# ANNUAL REPORT 2021-22

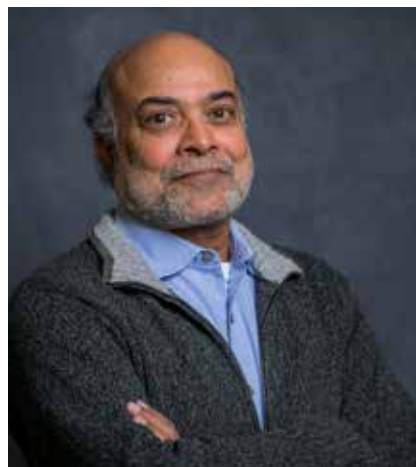
TATA-CORNELL INSTITUTE  
FOR AGRICULTURE AND NUTRITION



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# DIRECTOR'S NOTE



After two years that were disrupted by the COVID-19 pandemic, 2021-22 was a year of transition and emergence for TCI, as our researchers returned to their fieldwork in India, and we have arrived at a new normal in which

travel and meeting in person are again possible. As you will read in this report, the pandemic has impacted TCI, but it has not prevented us from continuing our important work. I am proud of our team for their perseverance during this time.

We have continued to produce a high level of quality research, self-publishing two reports and publishing 14 articles in peer-reviewed journals. You'll read about many of them in this report. They span a variety of topics, from the impact of India's pandemic lockdowns on women's nutrition to the drivers of overweight and obesity for Indian men and women in rural and urban areas.

Three TCI scholars earned degrees in 2021-22—two PhDs and one Master's degree. We also welcomed two new scholars in the fall of 2021, while another began a new doctoral program after receiving his Master's, bringing us to 15 scholars in the TCI Scholars program.

TCI's Center of Excellence, which began as part of the Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) project, expanded this past year with the launch of our Farmer Producer Organization (FPO) Hub, which serves as a repository of learning, information, and knowledge for the advancement of FPOs in India. The

centerpiece of the Hub is the Database for Indian FPOs, a first-of-its-kind platform that brings together information on thousands of FPOs to facilitate research on small-farm aggregation models.

This year also marks the beginning of an ambitious new project for TCI: Zero-Hunger, Zero-Carbon Food Systems. Agriculture is responsible for nearly 20% of India's greenhouse gas emissions, a number that will only rise as the country's population grows. With this initiative, we seek to create a roadmap for mitigating emissions tied to farming while maintaining or even improving agricultural productivity.

This project represents a significant movement in our work toward sustainability in agriculture. As the need to confront the climate crisis grows more urgent with each year, we must bolster food systems against climate change while also recognizing the role that agriculture plays in contributing to global warming. I am proud that TCI is at the forefront of research aimed at ensuring that the food systems of tomorrow are not only nutrition-sensitive, but sustainable as well.

During the 2022-23 academic year, TCI will commemorate its 10th anniversary. Since its founding, TCI has become a productive research institute performing innovative and influential work in a wide variety of fields. I am confident that, over the course of the next decade, we will continue to generate high-quality research that tackles the most pressing challenges facing food systems in the developing world.

I hope that you enjoy reading this annual report. Thank you for supporting TCI.

Prabhu Pingali  
Founding Director, TCI

# BY THE NUMBERS

As of March 2022

14

Researchers

2

Postdoctoral Associates

15

TCI Scholars

6

Faculty Fellows

21

Alumni

14

PhDs Earned

4

Master's Degrees Earned

10

Academic Disciplines

5

Reports

3

Books

36

Journal Articles

12

Book Chapters

15

Policy Briefs

2

Training Manuals

# OUR WORK

**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, the 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 and scholars are pursuing the bridging of 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 researchers meet with a group of women. (Photo by Maureen Valentine/TCI)*

## **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 identify and address barriers that limit small farmers in accessing value chains and markets, and empower them to enhance their incomes and welfare.

# COVID-19

## TCI Adapts to the Pandemic Era

As the COVID-19 pandemic extends into a third year, it continues to be the defining issue of our time, impacting virtually every aspect of life. This has been true at TCI, where research continues to examine the pandemic's impact on food systems, and scholars are returning to work in the field with plans adapted to prioritize public health and safety.

At the outset of the pandemic, TCI pivoted its research agenda to assess the effects of COVID-19 lockdowns on food and nutritional security in India. An initial report released in 2020 detailed the price fluctuations caused by the national lockdown instituted in March of that year, which caused the prices of more nutritious foods to rise while leaving staple grains largely unaffected. In 2021–22, researchers continued to assess the pandemic's impact, diving deeper into the data, and evaluating long-term trends.

*While COVID-19 has changed some of the ways that TCI works, the Institute has adapted to this generational challenge*

In a study published in *Economia Politica*, TCI researchers examined the lockdown's effects on different genders. They found that dietary diversity declined among women and that women were less likely to eat nutritious foods, like meat, fruit, and vegetables, during the lockdown. For example, the number of women consuming vitamin A-rich fruits and vegetables dropped by 42 percent.

In a separate effort, TCI Scholar Shree Saha examined the impact of a round of state-level lockdowns initiated to

contain the Delta variant of COVID-19 in the spring of 2021. She found that food prices continued to increase from the initial national lockdown. Through March 2021, wholesale and retail prices rose an average of 8 and 12 percent, respectively.

Due to the pandemic, TCI summer interns remained in Ithaca, New York, in 2021, instead of traveling to India for field-based research. At the TCI offices at Cornell University, interns Francesca DiGiorgio and Bhavna Sivasubramanian spent the summer digging into data related markets in India.

A graduate student working toward a Master of Public Health, DiGiorgio worked with data collected from TCI's Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) program to investigate how food prices and food availability at local markets influence women's diet diversity. She found that women's diets and household purchases were cereal-centric despite high market diversity year-round, suggesting that volatile food prices for nonstaples limit a consistent access to diverse diets.

Sivasubramanian, who is pursuing a Master of Regional Planning, used data on state-run agricultural markets, known as mandis, to create maps depicting the density of such markets at the state and district levels, in addition to their proximity to rail stations and other attributes. With market regulation left to the states in India, her maps show the extent of variation across states and districts.

Meanwhile, TCI scholars have slowly begun returning to India to conduct research in the field, a key pillar of the TCI program. Yet, in recognition of the continuing threat posed by COVID-19, scholars have changed their research plans in the name of safety.



*A man wears a face mask while working at a produce market. (Photo by Arun Sambhu Mishra on Shutterstock)*

One such scholar is Vanisha Sharma, who is studying the effect of social media networks on the uptake of agricultural technology by farmers in rural India. After initially planning to undertake in-person surveys, Sharma pivoted to surveys primarily conducted over the phone—a fitting tactic, given her research topic. Limiting in-person encounters lowers the risk of team members and survey respondents contracting COVID-19.

Another scholar, Amrutha Pampackal began her fieldwork after a seven-month delay caused by the pandemic. She is now conducting seasonal surveys to assess the nutritional security of tribal communities in the forested landscapes of Kalahandi district in Odisha. To protect both survey team members and community members, Pampackal has avoided large focus groups and conducted all survey activities outdoors.

While COVID-19 has changed some of the ways that TCI works, the Institute has adapted to this generational challenge. From monitoring the pandemic's impact on food security to innovating research methods that protect the public health, TCI has shown that its ability to conduct meaningful research continues undiminished.

# TARINA

## Appraising TARINA's Legacy

As TCI's flagship program from 2015–2020, Technical Assistance and Research in Indian Nutrition and Agriculture (TARINA) undertook a variety of activities aimed at diversifying India's food systems by promoting nutrition-sensitive agricultural interventions, influencing policy to ensure the availability and accessibility of diverse foods, and building capacity for nutrition-sensitive interventions at the local level.



TARINA research developed metrics for measuring women's empowerment in agriculture that were tailored to the Indian context. (Photo by Anna David Thottappilly/TCI)

In roughly five years, TARINA-related projects served 15,315 households in three critical states of eastern India: Bihar, Odisha, and Uttar Pradesh. As a result of such projects, the number of households producing nonstaples, like pulses and oilseeds, increased from 30% to 68%, livestock farming increased from 60% to 72%, and the adoption of homestead vegetables increased from 11% to 40%.

The on-the-ground success of these projects have translated into policy changes at the state level. For example, TARINA practices for intensifying the production of pulses have been adopted by 44 *Krishi Vigyan Kendras* (agricultural extension centers) in Bihar, while models of crop-specific women's collectivization, piloted under TARINA, have been integrated into the Uttar Pradesh State Rural Livelihood Mission. TARINA's kitchen garden model is now used in 1,594 tribal residential schools in Odisha.

Perhaps, TARINA's greatest legacy is the abundance of new evidence in support of improving nutrition outcomes that TARINA added to the literature. The TCI Center of Excellence, established under TARINA, produced more than 10 peer-reviewed articles, 21 policy documents, and 5 training manuals, in addition to several editorials in the Indian press.

TARINA's research contributions can be grouped into three main areas: gender; markets; and food safety.

Researchers working in the TARINA program made remarkable contributions to the literature on gender and nutrition. In one important study published in the *Food and Nutrition Bulletin*, researchers revealed a dietary gap between women and other members of their households, finding that women consistently consume fewer food groups. Crucially, the food groups driving this gap were found to be among the most nutritious nonstaples, including animal-sourced foods and vitamin A-rich fruits and vegetables.

Much of TARINA's research into gender and nutrition has focused on women's empowerment as a pathway to improve nutrition. One of TARINA's major contributions in this area has been the creation of an adaptable metric to

measure women's empowerment in the Indian context. Using culturally specific sub-indicators, TARINA's modified Women's Empowerment in Agriculture Index (WEAI) can quantify empowerment levels in India with greater precision than the generalized index from which it was adapted. Using the modified WEAI, researchers found that more than 80% of women in TARINA intervention states were disempowered.

TARINA researchers also found a link between women's empowerment and micronutrient status, reporting in *Food Policy* that improved women's empowerment may mitigate the risk of iron deficiency.

Market access, a key factor for household access to diversified food, also relates to women's empowerment. TARINA has contributed significantly to this body of literature by uncovering the potential of market access as a pathway for improved nutrition and exploring its interactions with women empowerment.

In an article in the *Food and Nutrition Bulletin*, researchers demonstrated that market integration, along with on-farm production diversity, has a significant impact on improved dietary diversity. Another study, published in *Food Security*,

*Through the households that it engaged with directly, the programs it built that were adopted by local governments, and the research it produced, TARINA leaves behind a strong legacy of building and strengthening nutrition-sensitive food systems*

demonstrated that, while market access is tied to women's dietary diversity, women who are empowered in agriculture are better able to translate their influence into purchases that diversify their diets. This finding is important for



Mycotoxins produced by mold growing on groundnuts and other foods can cause a range of adverse health outcomes. (Photo by Bolgarchuk Roman on Shutterstock)

India's food and nutrition policies, where markets are largely missing from the discussion of women's nutrition security.

TARINA also made important contributions to academic literature and Indian policy discussions with its research into market affordability. In a study published in *Global Food Security*, researchers found that the nutritious, sustainable diet recommended by the EAT-Lancet Commission is out of reach of many rural Indians, as it costs 3–5 times more than the average diet. The study underscores the importance of agricultural diversification for lowering the cost of nutritious foods in India.

TARINA has also made important contributions toward a better understanding of food safety in India, specifically as it relates to mycotoxin contamination. Produced by mold, mycotoxins cause a range of adverse health outcomes, including cancer. In studies published in *PLOS One* and in *Food Control*, researchers found mycotoxin



TARINA researchers studied the extent to which market access affects dietary diversity. (Photo by Mayur Deshpande on Unsplash)

contamination levels warranting public health intervention and determined that the risk of contamination varies according to season—information that enables more targeted interventions. Researchers also created an index of household-level risk factors for contamination, such as improper grain storage.

*The TCI Center of Excellence, established under TARINA, produced more than 10 peer-reviewed articles, 21 policy documents, and 5 training manuals, in addition to several editorials in the Indian press*

Beyond providing a clearer picture of mycotoxin contamination in Indian food systems, TARINA also pioneered a participatory approach that includes local

farmers in the intervention design process. Engaging farmers allows practitioners to design mitigation strategies that are tailored to local needs and more likely to be effective and sustainable.

Though the TARINA program has concluded, its impact persists in India and in the broader community of food systems researchers and development practitioners. Established under TARINA, the TCI Center of Excellence continues to support nutrition-sensitive agriculture in India through evidence building, capacity development, and advocacy. Through the households that it engaged with directly, the programs it built that were adopted by local governments, and the research it produced, TARINA leaves behind a strong legacy of building and strengthening nutrition-sensitive food systems.

**Find TARINA-related research and publications at the TCI Center of Excellence at [tcj.cornell.edu/center-of-excellence](http://tcj.cornell.edu/center-of-excellence)**



## ALUMNI SPOTLIGHT



### Kathryn Merckel

As a TCI scholar pursuing a PhD in International Nutrition, Kathryn Merckel led an effectiveness trial testing the potential of orange-fleshed sweet potatoes to improve nutritional outcomes in Uttar Pradesh, India. Now, Merckel works to improve nutrition,

through interventions across the world, as the Associate Director for Nutrition and Food Systems at the international development nonprofit ACDI/VOCA, based in Washington, DC.

At ACDI/VOCA, Merckel works with teams in the field to integrate nutrition into the organization's projects using context-specific approaches. She supports interventions throughout the world, including in West and East Africa, Bangladesh, and India. One such intervention aims to improve the market readiness of farmer producer organizations in Andhra Pradesh, India. A project called IGNITE, which Merckel likened to TCI's TARINA project, seeks to build the capacity of African agricultural institutions to integrate nutrition and gender into their programs and businesses.

Merckel said that her time at TCI has been crucial to her success at ACDI/VOCA. The experience of designing and implementing her research project in Uttar Pradesh—from identifying study locations, connecting with local organizations, hiring and managing project staff, writing and deploying surveys, and managing, analyzing, and reporting on complex data—prepared her well for providing support and guidance throughout the process of proposing, implementing, and evaluating projects that create positive impacts across national and regional food and market systems.

Also, the interdisciplinary nature of the TCI research group exposed her to a broad diversity of expertise and viewpoints.

"On any given day, I work with agriculturalists, economists, gender, and youth inclusion experts, and more," Merckel said. "The cross-cutting and diverse knowledge of these many subjects has allowed me to work effectively and productively within these many fields and communicate how each can be leveraged to improve nutrition and food security."

# AGRICULTURE

## TRANSFORMATION, FOOD SYSTEMS & NUTRITION TRANSITION

### Achieving Zero Hunger in Bihar

TCI's 2020 report on *Food, Agriculture, and Nutrition in India* (FAN 2020), with its detailed assessment of the prospects for enhancing productivity and increasing farm income across the country, prompted important conversations on India's efforts to reach zero hunger. One of the lessons from FAN 2020 was the value of conducting the same exercise at a more local level. To that end, TCI is producing a series of state-level reports, starting with Bihar.



A vendor sells a variety of vegetables at a market in Bihar. (Photo by Kiera Crowley/TCI)

Published in early 2022, *Food, Agriculture, and Nutrition in Bihar: Getting to Zero Hunger* (FAN-Bihar) provides a detailed reassessment of the food system approach for achieving zero hunger in Bihar by 2030. The report focuses on key elements of the food system to address high malnutrition rates in the state, including crop diversification, food production and availability, improved market linkages, gender empowerment, and improved nutrition behaviors.

In the report, TCI advocates for increasing farmer incomes and agricultural productivity through effective yield

stabilization and improved market linkages, in addition to diversifying cropping systems toward more nonstaple crops. The report also notes the important role that social safety nets can play to increase the availability of diverse foods. Given the multisectoral nature of the malnutrition issue, the report calls for a convergence of programs and policies across ministries and departments from the state level down to the village.

**Download *Food, Agriculture, and Nutrition in Bihar: Getting to Zero Hunger* at [tci.cornell.edu/publications](http://tci.cornell.edu/publications)**

### Revealing the True Cost of Healthy Diets

The EAT-Lancet diet purports to represent the least expensive, healthy nutritional diet possible in sustainable food systems, but TCI research shows that it remains out of reach for most Indians.

In a study published in *Global Food Security*, TCI researchers demonstrated that while Indians eat a diet that costs roughly US\$1 per person per day, the EAT-Lancet diet costs US\$3–US\$5. To satisfy the EAT-Lancet recommendations, an individual would have to spend US\$1 more each day on each of three food groups: meat, fish, and poultry; dairy products; and fruit.

The researchers find that seasonality contributes to price volatility for fruit, green leafy vegetables, and other vegetables. This drives the cost of the EAT-Lancet diet as high as US\$6 per day at certain times of the year, though the cost is generally lower.

To meet the EAT-Lancet Commission's goal of feeding 10 billion people sustainable, healthy diets by 2050, consumption of all food groups, except starchy vegetables, will need to be increased in South Asia. To make the EAT-Lancet diet more affordable in India, TCI researchers

recommend crop diversification in addition to investments in rural infrastructure and well-functioning markets.

“Ground Truthing the Cost of Achieving the EAT Lancet Recommended Diets: Evidence from Rural India,” Soumya Gupta, Vidya Vemireddy, Dhiraj K. Singh, and Prabhu Pingali, *Global Food Security*, Volume 28, March 2021.

### Causes of Obesity Depend on Gender, Age, and Geography

As India transitions into a more developed economy, obesity has emerged as a new front compounding the struggle to improve nutrition in the country. New research from TCI sheds light on the patterns of obesity within India, underscoring the need for policies and programs that consider the factors driving obesity rates within different groups and communities.

In a study published in the journal *Economics & Human*



TCI research shows that access to certain types of technology, such as automobiles, is one of the drivers of obesity in Indian men. (Photo by Aditya Rathod on Unsplash)

*Biology*, TCI researchers demonstrated that obesity is tied to variables, such as gender, age, and the level of economic development where individuals reside.

Using data from India's National Family Health Surveys, the researchers revealed that biological differences, as well as intrahousehold differences in behavior and access to technology, explain how obesity has emerged differently across genders in India. Changes to the overall health environment brought about by economic development were also found to play a role, with urbanization and increasing sedentary lifestyles associated with rising obesity rates.

Based on their findings, the researchers recommend that efforts to stem obesity in India use targeted approaches that account for group- and community-based differences. However, they caution that, in the long term, India's struggle with obesity and with undernutrition will require broad food and agricultural policy shifts to increase the availability and affordability of healthy foods.

“Transitioning to an Obese India: Demographic and Structural Determinants of the Rapid Rise in Overweight Incidence,” Anaka Aiyar, Sunaina Dhingra, and Prabhu Pingali, *Economics & Human Biology*, Volume 43, December 2021.

### Local Factors Are Key to Reducing Stunting

Across the developing world, stunted growth causes serious consequences for children, including poor educational performance and increased risk of chronic diseases as adults. India has mostly used nationally focused, nutrition-oriented policies to curb stunting, but the condition remains prevalent in many parts of the country.

New TCI research shows that Indian policymakers can create targeted programs that more effectively



reduce stunting by adopting comprehensive, regionally focused approaches that account for local differences in environmental factors like climate.

In a two-part study published in *Current Science*, researchers identified possible contributors to stunting in Karnataka, India, and used the example of relative rainfall to demonstrate how complex interactions between risk factors can increase or decrease the likelihood of stunting at the local level.



Stunted growth puts children at risk of chronic diseases as adults and can limit educational attainment. (Photo by Charu Chaturvedi/Unsplash)

The researchers found evidence that differences in rainfall influence the relative risk of stunting across Karnataka. Stunting is more prevalent overall in districts with low rainfall, but interactions between risk factors reveal more subtle differences. For example, the children of younger mothers face a higher risk of stunting in districts with high rainfall but not in those with low rainfall.

Although the research focused on the impact of climate, other environmental factors, including cultural background

and genetics, should also be explored to improve the efficacy of anti-stunting programs.

“Multiple Risk Factors Contribute to Childhood Stunting in Karnataka, India,” Srilakshmi M. Raj, Ruwanthi Ekanayake, Meenakshi Bhat, Jayarama Kadandale, and Prabhu Pingali, *Current Science*, Vol. 121, No. 3, August 10, 2021.

“Risk Factors in Childhood Stunting in Karnataka, India, Vary by Geography,” Srilakshmi M. Raj, Ruwanthi Ekanayake, Kiera Crowley, Meenakshi Bhat, Jayarama Kadandale, and Prabhu Pingali, *Current Science*, Vol. 121, No. 4, August 25, 2021.

## Publications

In 2021–22,\* TCI researchers published 14 journal articles and 1 book chapter, in addition to 2 self-published reports.

To view all TCI publications, visit [tci.cornell.edu/publications](https://tci.cornell.edu/publications)

\*As of March 2022

## SCHOLAR SPOTLIGHT



### Anna David Thottappilly

A PhD candidate in Applied Economics and Management, TCI Scholar Anna David Thottappilly's interest in development economics was spurred by seeing the impact of inequality around her.

Confronted with the stark income disparity in New Delhi, she asked herself, “Isn’t there anything that can be done to make this situation better?”

At TCI, Thottappilly’s research focuses on the nutritional impact of local markets in underdeveloped rural areas of India. She was introduced to the topic while conducting exploratory fieldwork early in her studies. She wanted to know if markets affected smallholder farmers’ choices of what crops to grow and to consume.

Fieldwork was a big part of Thottappilly’s decision to join TCI. With her passion for addressing inequality, she wanted to see firsthand how Indians lived outside of her home state of Kerala. “It was very difficult,” she said of her experience. “The kind of underdevelopment I saw was far beyond what I even thought it could be.”

Thottappilly says that the interdisciplinary nature of TCI’s work has helped her grow as a social scientist, because she must think outside of her own area of study when presenting her research to a group that includes not just economists but scholars from areas of study as varied as food science and sociology.

Combined with her field experience, Thottappilly says that presenting research to a diverse cohort helps drive home the real world stakes of her work.

“I’m not doing economics to come up with fancy theories or economic models, but to implement something that really matters,” she said. “That makes me feel really motivated to work.”

# FOOD & AG-SCIENCE INNOVATIONS

## Improving Soil Health through Sustainable Management

Soils are dynamic and complex living systems that can be influenced by a range of factors, like land management practices, crop diversity, or climatic changes. Understanding the relationship between land management, soil health, and crop yield are crucial to increasing farm production and developing sustainable land management systems, especially in India, where overall soil quality is on the decline.

In Bihar, where extreme poverty and an immense vulnerability to climate change have hampered the ability of the state to realize the yield potential in its rice-wheat cropping systems, TCI is working to improve soil health through a better understanding of the impact of land management. Rice-wheat systems, in particular, can harm soil quality, with continuous intensive cropping, often leading to loss of organic matter, nutrient imbalances, groundwater depletion, and decreased pest resistance.

*Using the comprehensive assessment of soil health (CASH) approach developed at Cornell University to assess the physical, chemical, and biological properties of soil, Krishnan found that reducing tillage and crop residue additions have a positive effect on soil health.*

TCI Scholar Kavya Krishnan has analyzed soils from seven long-term agricultural trials in Bihar to determine the effect of crop diversity, tillage practices, crop residue incorporation, and organic amendments on soil health in rice-wheat systems. Using the comprehensive assessment

of soil health (CASH) approach developed at Cornell University to assess the physical, chemical, and biological properties of soil, Krishnan found that reducing tillage and crop residue additions have a positive effect on soil health. However, the effect of crop diversification is not yet clear.



*Maintaining healthy soils can improve agricultural productivity. (Photo by Pradeep Gaur on Shutterstock)*

In partnership with Cereal Systems of South Asia, Krishnan is also analyzing soil samples collected from 400 farmer fields, spanning 14 districts in Bihar, along with information on yields and management practices collected via survey. These samples will provide a better understanding of the links between yield, management practices, and soil health, and how they vary across the state.

Through the efforts of Krishnan, TCI is gaining insight into the relationship between land management and soil health, which can help improve agricultural productivity and bolster food security in states like Bihar.

## Building Better Puffed Snacks for Weaning Babies

Weaning is an important time in a baby's development, as a child learns to eat solid food and the child's nutritional needs—for protein, in particular—increase. Puffed cereal snacks that quickly dissolve in a baby's mouth are a popular weaning option for many parents, but they have a crucial disadvantage: the current crop of commercially produced, starch-based puffs contain no protein. TCI alumna Bindvi Arora has developed protein-packed puffed snacks that provide parents with a more nutritious option for their weaning children.

*The protein-rich puffs developed by Arora have the potential to improve the nutritional intake of children at risk of undernutrition during the weaning process.*

While traditional puffed snacks are produced using steam-based extrusion, the high temperatures involved can damage sensitive nutrients like protein. Arora used a hybrid extrusion process called supercritical fluid extrusion to make puffs out of milk protein concentrate. The process uses lower temperatures that do not harm proteins.

By fine-tuning the process, Arora created puffs that are more than 65% protein and dissolve in the mouth in under 30 seconds with little chewing. In a sensory panel convened by Arora, the in-mouth dissolving properties of her milk protein-based puffs were found to be comparable to starch-based puffs.

The protein-rich puffs developed by Arora have the potential to improve the nutritional intake of children at

risk of undernutrition during the weaning process. They may additionally be of utility for elderly populations and people with dysphagic conditions.

## TCI Alumna Wins Soil Science Award

TCI alumna Fatma Rekik was given the 2021 Truog Soil Science Outstanding Dissertation Award by the Soil Science Society of America. The award recognizes a recent PhD recipient who has made outstanding contributions to soil science, as evidenced by their thesis or dissertation.



*TCI alumna Fatma Rekik was recognized by the Soil Science Society of America for her doctoral dissertation. (Photo courtesy of Fatma Rekik)*

Rekik is currently a post-doctoral fellow at the International Center for Biosaline Agriculture in Dubai, United Arab Emirates. As a TCI scholar, she studied the soil health-human health interlinkages from a nutritional standpoint in Jharkhand, India.

# MARKETS & VALUE CHAINS

## Empowering Smallholder Farmers

Growing demand for nutritious foods should be a boon for farmers, but due to their farm sizes, India's 125 million smallholder farmers often struggle to take advantage of such opportunities. To empower these farmers, in 2021, TCI launched its Farmer Producer Organization (FPO) Hub—a repository of learning, information, and knowledge for the advancement of Indian FPOs—within its Center of Excellence in New Delhi.

Small farms are disadvantaged in accessing of markets, credit, and agricultural inputs such as seeds. By joining together in FPOs, farmers work to jointly reduce costs and improve market access, helping to drive higher agricultural productivity, enhanced food security, and livelihood development.

Though interest in promoting FPOs is high among philanthropic actors, corporations, and the government, there are still significant barriers to entry for many, including limited financing opportunities and the time required to become self-sufficient.

*Utilizing an analytical, data-based approach, the FPO Hub will aid in the understanding, development, and promotion of effective farm-aggregation models.*

Utilizing an analytical, data-based approach, the FPO Hub will aid in the understanding, development, and promotion of effective farm-aggregation models and serve as a dissemination platform through which stakeholders can access information, technical help, and guidance. A critical part of the Hub is TCI's Database for Indian FPOs, a new



*Farmer producer organizations help smallholder farmers to reduce costs and improve market access. (Photo by Talukdar David on Shutterstock)*

platform that brings together information on thousands of FPOs to facilitate research on small-farm aggregation models.

The Hub is supported by a US\$1 million grant from the Walmart Foundation.

To celebrate the launch of the FPO Hub, TCI hosted a virtual panel attended by more than 130 researchers and representatives from government, donor organizations, the private sector, and civil society organizations.

By advancing research into small-farm aggregation models, TCI's FPO Hub is not only helping to improve the livelihoods of smallholder farmers, but also to strengthen value chains and increase the supply of diverse, nutritious foods in India.

**Learn more about the Database for Indian FPOs on page 26.**

## Reducing Loss and Waste along Fruit and Vegetable Supply Chains

Shifting diets toward healthier, more environmentally sustainable patterns requires increased fruit and vegetable consumption. In many regions, including in India, fruit and vegetable availability is insufficient to meet dietary recommendations. Reducing food loss and waste of these micronutrient-rich, yet perishable, products can help narrow this gap.

TCI alumna and postdoctoral associate Jocelyn Boiteau is helping to reach this goal by exploring reduction strategies and addressing evidence gaps in food loss measurement along perishable vegetable supply chains.

*Most quantitative food loss occurred before tomatoes left the farmgate, where farmers reported losing an average of 7.5% of total harvest.*

Using survey data collected from tomato farming households, tomato traders, vegetable traders, and vegetable retailers, Boiteau examined the extent and determinants of food loss along fresh tomato supply chains in South India. She found that average preharvest quality loss was 13.9% of harvested tomatoes. Aggregate postharvest food loss from farm to retail totaled 13.4% of total tomato quantity.

Most quantitative food loss occurred before tomatoes left the farmgate, where farmers reported losing an average of 7.5% of total harvest. In contrast, tomato traders and

vegetable traders each reported losing less than 1% of their traded lots.

For farmers, harvesting during peak season, from April to July, was associated with less postharvest food loss at the farm and market, compared with harvesting during the off-peak season.



*A pig eats discarded tomatoes at the Madanapalle tomato market in Adhra Pradesh, India. (Photo by Jocelyn Boiteau/TCI)*

Regarding quality, Boiteau found that farmers prioritize color and ripeness at harvest, typically harvesting tomatoes at the super red ripe stage. Farmers prioritize tomato size while grading. Tomatoes often lose quality before farmers decide to remove them completely from the food supply chain. Typically, when farmers give tomatoes for animal feed, they are not financially compensated.

During focus group discussions with farmers, conversations centered on farming as a livelihood. Farmers' motivations for reducing food loss are grounded in their

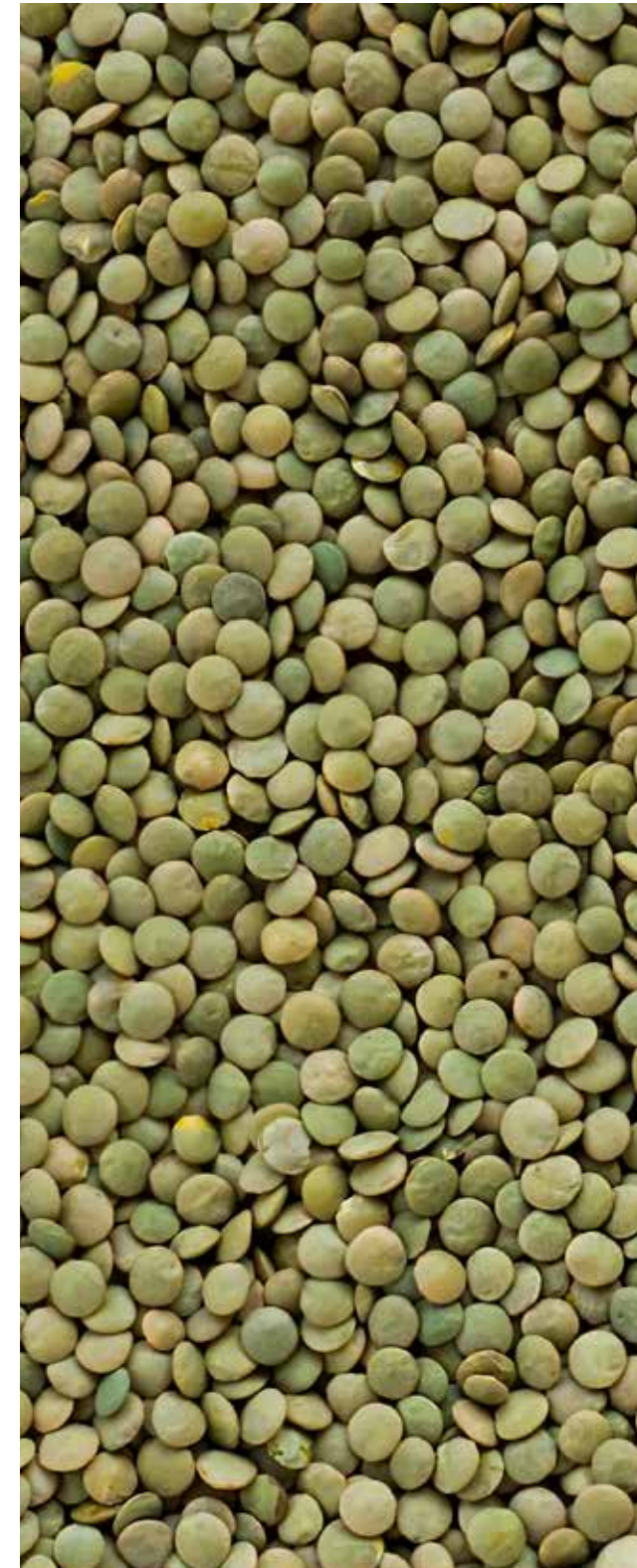


Tomatoes are packed in plastic crates at the Madanapalle tomato market. (Photo by Jocelyn Boiteau)

desire to increase their profits and ability to invest these profits.

These findings make it clear that food loss, waste indicators, and reduction strategies must reflect the context and objectives across supply chains and stakeholders. Food quality loss indicators must also be refined to increase their utility for loss reduction.

Boiteau is expanding her research to examine how food loss and waste prevention can support sustainable, safe, and nutritious diets in countries and regions with varying levels of development. With a particular focus on low- and middle-income countries, TCI is exploring entry points for food loss and waste investment and intervention priorities, as food systems transition from traditional to modern systems, as well as identifying pathways that deliver healthy diets.



## STAFF SPOTLIGHT



### Mathew Abraham

At TCI, Assistant Director Mathew Abraham is something of a jack of all trades, with job duties that range from performing research to managing grants to mentoring students.

Abraham grew up on a small rubber farm in Kerala, India, and before pursuing his doctorate, he worked in policy research and as a documentary filmmaker, reporting on livelihood issues. Those experiences stoked his passion for food security and improving smallholder farmer livelihoods through collective action. After earning his PhD at the Copenhagen Business School in 2015, Abraham joined TCI as a postdoctoral researcher. There, he found himself surrounded by what he calls “a team of like-minded, highly motivated individuals who’ve also dedicated their lives to understanding food security.”

Abraham has served as Assistant Director since 2018. In that position, Abraham has three main roles. First, he does research and serves as co-principal investigator on several projects. His research focuses on evaluation methodologies, agricultural value chains and markets, food security in developing countries, and technology and institutional innovation for agricultural development. Among the projects he leads is TCI’s project on farmer producer organization (FPO)-led small farm market access models, which includes the newly launched FPO Hub in TCI’s Center of Excellence.

Second, Abraham manages grant-funded projects and oversees related research activities, including the Institute’s involvement in the Innovation Lab for Crop Improvement at Cornell University, which includes measuring the capacity of national crop breeding programs to produce new varieties targeted to the needs of the populations they serve.

Third, he works with students—helping TCI scholars with their research and managing the summer internship program, as well as interactions with several departments around the University. Abraham says that working with and mentoring students—the next generation of scholars working to address food insecurity—is one of the most satisfying parts of working at TCI.

“That has been an extremely fulfilling experience,” he said.

# GENDER & NUTRITION

## Assessing the Pandemic's Impact on Women's Nutrition

As India was placed under a nationwide lockdown to curb the spread of COVID-19 in March 2020, supply chain disruptions caused food price fluctuations that threatened the nutritional security of many in the country. New TCI research shows that women's nutrition, in particular, was negatively affected.

Published in the journal *Economia Politica*, the study shows that women's dietary diversity—the number of food groups consumed—declined during the lockdown, compared to the same period in 2019. Most concerning was that the drop was due mostly to decreased consumption of foods like meats, eggs, vegetables, and fruits, which are rich in micronutrients and are crucial to good health and development.

TCI researchers analyzed surveys of food expenditures, dietary diversity, and other nutrition indicators at the national, state, and district levels in the states of Uttar Pradesh, Bihar, and Odisha. They found that food expenditures significantly declined during the lockdown, especially in less developed districts. Expenditures returned to pre-lockdown levels in June 2020, at the

*The number of women consuming vitamin A-rich fruits and vegetables dropped by 42 percent, while the number consuming other fruits and vegetables declined by 79 percent and 5 percent, respectively.*

national and state levels but remained low at the district levels, suggesting that underdeveloped regions were

disproportionately affected by access and availability constraints.

Nutrition security declined overall during the lockdown, but women's nutrition was disproportionately impacted. The number of women consuming vitamin A-rich fruits and vegetables dropped by 42 percent, while the number consuming other fruits and vegetables declined by 79 percent and 5 percent, respectively.

Surveys also suggest that the quantity and quality of the nutritious foods that women did consume during the pandemic decreased, further damaging their nutritional outcomes. For example, some reported that, compared to before the lockdown, they halved the amount of dal, or red lentils, that they prepared, or that they prepared thinner dals.

In addition to the overall reduction in food availability and expenditures, TCI researchers found that the unequal burden borne by women was caused, in part, by the closure of India's *Aanganwadi* centers during the lockdown. The centers, which provide take-home rations and hot cooked meals to nursing and expectant mothers, are an important source of nutrition for women and children. According to the study, 72 percent of eligible households lost access to those services due to *Aanganwadi* closures during the pandemic.

These findings underscore the need for policies that increase the availability of diverse, nutritious foods in India. To maximize their benefits, such policies should be targeted toward women and other marginalized groups.

“COVID-19 and Women's Nutrition Security: Panel Data Evidence from Rural India,” Soumya Gupta, Payal Seth, Mathew Abraham, and Prabhu Pingali, *Economia Politica*, 2021.

## SCHOLAR SPOTLIGHT



### Vanisha Sharma

A PhD candidate in the field of Applied Economics and Management, Vanisha Sharma aspires to a career as a policy analyst, where she can use empirical research to answer fundamental economic questions in developing countries.

“Through empirical evidence, my work has the potential to inform policymakers in developing countries about a gamut of socioeconomic issues, be they agricultural technology adoption, the benefits of mobile phones, or barriers to policy implementation for rural development,” Sharma said.

At TCI, Sharma is studying how social media usage affects the uptake of agricultural technology by farmers. “I am interested in social networks, and ag-tech adoption, specifically, because social learning in agriculture is a seminal topic in the literature, which has been studied for years from all possible angles, except for digitization of networks,” she said.

Sharma first encountered TCI while working toward her MPA at Cornell University and quickly learned that the Institute's research mirrored her own interests. Now in the fifth year of her doctoral studies, she is leading a field study in Andhra Pradesh and Telangana, India.

“TCI has been a strong pillar of support for my research over the last five years, and I am grateful for all the resources I have received so far to pursue my research interests as a development economist, including independently leading a field experiment in rural India,” she said.

# FOOD SAFETY

## WATER & SANITATION

### Mitigating Arsenic Contamination

As underground aquifers become a more important source of fresh water, pollutants like arsenic have the potential to make them unsuitable for use for long periods of time, causing health problems and limiting agricultural productivity. TCI Scholar Natasha Jha is helping to uncover the causes of such contamination by assessing the potential of agricultural intensification as a driver of arsenic contamination across water basins in India.

Found in groundwater aquifers across Southeast Asia, arsenic is a known carcinogen. Researchers have found evidence that people can be exposed to arsenic by eating crops irrigated with contaminated water.

Rehabilitating water sources contaminated with arsenic is costly, as is adaptation. Water purification methods are limited and often unaffordable for developing countries. Worse, there is a lack of obvious markers for



Groundwater irrigation is increasingly important as above-ground water sources dwindle due to climate change. (Photo by CRS Photo on Shutterstock)

identifying contaminated water sources. Coupled with limited surveillance and testing, arsenic contamination of groundwater sources is a worrying prospect in developing countries.

As climate change limits the surface-level supply of fresh water, populations are increasingly reliant on groundwater resources. The usage of groundwater for irrigation has increased rapidly in recent years and already accounts for one-third of the total irrigated area worldwide. Increased usage, coupled with a long recharge time, makes groundwater a critical, yet scarce, future commodity.

*Using data from districts across India, Jha is testing whether changes in exposure to arsenic contamination are linked with varying levels of usage of agricultural inputs, such as fertilizers, pesticides, and groundwater extraction.*

Jha's research tests the possibility of anthropogenic causes of arsenic contamination, which previously has been studied predominantly as resulting from geochemical processes. Using data from districts across India, Jha is testing whether changes in exposure to arsenic contamination are linked with varying levels of usage of agricultural inputs, such as fertilizers, pesticides, and groundwater extraction.

Research like Jha's is crucial to informing groundwater usage strategies to minimize the risk of arsenic contamination rendering some sources unusable.



## ALUMNI SPOTLIGHT



### Shiuli Vanaja

After earning her doctorate in Applied Economics and Management in 2020, TCI alumna Shiuli Vanaja is now an Assistant Professor of Economics at the Azim Premji University in Bangalore, India.

Vanaja is part of a small but growing Economics Department at the University, where she teaches undergraduate and graduate courses on topics like Development Economics and Research Methods. She says that TCI's diverse research group taught her how to present her work to audiences with different areas of expertise, which has proven to be useful when teaching students who are pursuing degrees in a variety of fields other than economics.

As a TCI Scholar, Vanaja's research focused on household water access—specifically, how people in rural India choose water sources and the impact that safe, piped water has on how women use their time. She found that people judge the quality of water by its color and taste when objective information is missing. She also found that households with piped water saved about 60 minutes per day on water collection, which gave women more time to spend in their primary occupations.

During her studies, Vanaja spent 18 months doing fieldwork in rural Jharkhand, which was made possible through TCI's support of a project providing piped water systems to villages in the state. She credits TCI with teaching her the importance of policy-driven work, rooted in extensive fieldwork, in addition to the value of working within an interdisciplinary framework.

"I believe that I could not have received a better training and learning experience than what I received at TCI to succeed as an empirical economist with interests in issues of development, resources, and gender in rural areas of developing countries like India," Vanaja said.

Vanaja is continuing the research that she began at TCI. She is also pursuing new projects related to COVID-19's impact on women's health and the inequality of access to water services in rural India.

# ICTS, DATA SYSTEMS & AG TECH

## Supporting FPO Research

Farmer producer organizations (FPOs) serve as vital infrastructure for promoting market access among India's smallholder farmers. To support research on small-farm aggregation, TCI created the Database for Indian FPOs, a new platform that brings together information on thousands of FPOs. The database is the only centralized source of data on Indian FPOs currently available. It currently has information on at least 4,400 FPOs and will be regularly updated and expanded by TCI researchers.

Through the interactive web-based dashboard, researchers can access a wealth of data on FPOs, such as crops produced, founding years, and sponsoring agencies. The flexible dashboard allows users to take a wide view of FPOs across states, or dig deep into the cropping, legal, and basic financial information of individual FPOs.

Using the database, TCI researchers are working to formulate a metrics-based evaluation framework to assess FPO performance and economic viability. Ultimately, the data will allow researchers to formulate models to boost smallholder farmer income and welfare.

The database is part of the FPO Hub of TCI's Center of Excellence. Supported by a grant from the Walmart Foundation, the Hub serves as a dissemination platform through which stakeholders can access information, technical help, and guidance for promoting successful FPOs.

**Visit the TCI Database for Indian FPOs at [fpo.tci.cornell.edu](http://fpo.tci.cornell.edu)**

## Measuring Capacity for Crop Improvement

TCI is part of a multidisciplinary team within the Innovation Lab for Crop Improvement (ILCI). Funded by the United

States Agency for International Development (USAID), the Lab aims to empower national breeding programs in Africa, Latin America, and the Caribbean to set their own goals to enhance genetic improvement in crops, which will address the specific needs of vulnerable populations to advance economic growth, crop resilience, and food security. The project facilitates global and regional collaboration and responds to pressing challenges in agricultural research and inclusive development, such as climate change, nutrition, poverty, gender and youth inclusivity, and natural resource conservation.

*Accurately measuring capacity is crucial for assessing the successes and multidimensional impacts of agricultural research through technology implementation and adoption of new practices, in addition to revealing bottlenecks that may hamper progress.*

TCI is tasked with evaluating the institutional components that contribute to the ability of national programs to implement innovative tools, technologies, and methodologies that lead to genetic gains. Accurately measuring capacity is crucial for assessing the successes and multidimensional impacts of agricultural research through technology implementation and adoption of new practices, in addition to revealing bottlenecks that may hamper progress.

Institutional capacity of breeding programs is composed of resources, human capital, collaboration, institutional management, and the technical expertise to innovate and implement sustained crop improvement research. TCI has established a conceptual framework and indicators of capacity to develop a survey instrument that assesses

the impact of ILCI interventions on the capability of crop improvement programs, to be able to set priorities, incorporate diverse stakeholder input, and achieve genetic gain.

The tool was implemented in partnering with national crop improvement programs to measure baseline institutional characteristics that enable innovative interventions. Results of the survey were converted into an index, using a scoring method for evaluation, and ranked to compare breeding programs. Upon project completion,



*National breeding programs conduct research aimed at genetically improving crops to enhance economic productivity and food security. (Photo by WAYHOME Studio on Shutterstock)*

breeding programs will be reevaluated to measure the impact of adopting ILCI-related tools, technologies, and methodologies.

TCI will continue to work closely with national breeding programs to measure the strategies and protocols in place so as to facilitate and sustain innovative crop improvement

research in response to dynamic food security needs, which are aligned with regionally specific, emerging environmental, economic, and social challenges.

## Utilizing Ag-Tech to Meet Future Food Needs

With India on track to become the most populous country globally by 2030, agricultural technology will play a vital role in ensuring the country meets its future food security needs. To help elucidate how ag-tech can help, TCI published a new report, *Technological Interventions in Indian Food Systems and the Future of Food Security*. Funded by the Innovation Centre of the Royal Embassy of Denmark in New Delhi, India, the report assesses the challenges facing Indian food systems in the 21st century, from seed production to retail, and introduces the technological interventions that can potentially address them.

The report has four core sections. The first centers on the challenges of India's approach to improving genetic gains through crop breeding. Modern techniques in genomic services and analysis, phenomics, and breeding informatics can increase genetic gains and reduce the breeding cycle time to be able to respond to food security needs in a timely fashion. New plant breeding technologies, such as gene-editing, can also be exploited for increased genetic gains.

The second section focuses on farm management practices, information communication technologies (ICTs), and sustainable intensification. It lays bare the significant production-level challenges facing smallholder food systems in India since the Green Revolution, highlighting how ICTs can close the information gap through data availability and enable sustainable intensification practices that increase productivity with reduced environmental and resource depletion.

The third section examines the stages and extent of food loss and waste at the harvest and postharvest stages and explores how technology can improve storage and transportation facilities to reduce loss, ensure safety, and reduce emissions.



*A farmer uses a smartphone app to assess the health of his crop. (Photo by Singh Lens on Shutterstock)*

The final section investigates how new platforms and technology can improve smallholder market participation. It assesses the scope of technologies for increasing the uptake of alternative market platforms, such as electronic markets, commodity futures markets, and warehouse receipt systems. It also discusses how progress in ICT, made possible by the expansion of inexpensive mobile phone networks, creates conditions rife for interventions to improve information access and market participation on alternative platforms.

The report makes the critical point that a responsive food system will adapt to shifting demand for healthier foods and society's socioeconomic and environmental needs. Technology will play a vital role in meeting these changes in a contemporized food system.

## Expanding Digital Ag-Tech Usage through Social Networks

In recent years, digital agriculture in India has developed in multiple ways. First, online communications, between farmers, agricultural institutes, and traders have increased. Second, innovative smartphone apps for farmers, including features, such as pest diagnosis and accurate weather predictions, have proliferated. However, qualitative research has shown that farmers have some hesitancy toward using smartphones for agriculture. TCI Scholar Vanisha Sharma is exploring this topic to determine whether participation in social media networks has increased the use of digital agricultural technology like smartphone apps.

As part of her research, which involves a survey of more than a thousand farmers in the Chittoor district of Andhra Pradesh, as part of a randomized control trial, Sharma created Whatsapp groups to connect farmers from different parts of the region, thereby enabling digital information sharing between them. When a cyclone caused devastating crop and cattle losses across the region, farmers used the Whatsapp groups to voluntarily share tips on how to prevent and mitigate damages.

This anecdote reveals how farmers can use digital communications to learn from each other and points toward a hopeful future wherein policymakers can take advantage of the timely and cost-effective scalability of such technology to help farmers across borders.

Ultimately, Sharma's research may help demonstrate whether social media networks like Whatsapp are an effective pathway for boosting farmers' productivity through the expanded use of web-based agricultural technology.



## STAFF SPOTLIGHT



### Tanuj Chawla

TCI's Database for Indian Farmer Producer Organizations (FPOs) would not have been possible without the efforts of Tanuj Chawla, an associate researcher based at the Institute's Center of Excellence in New Delhi. Chawla joined TCI in 2019, and was tasked with determining

the number of active FPOs in India and constructing a database of information about them.

With no single source of information on Indian FPOs, Chawla's task was difficult, but one for which he was well suited. Using his experience as a technology consultant and his education in bioeconomics, Chawla developed an online platform featuring comprehensive information on 4,400 FPOs. He is now working to update the technology that the database is built upon and expand its directory of FPOs.

"I could see clearly that this was an intersection point where I can bridge the gap between social sciences and technology," Chawla said. "I could design a product to serve the masses, to serve policymakers, researchers, and the farmers, all combined together."

Chawla joined TCI out of a desire to improve people's lives by providing the information necessary for improved policymaking. The FPO database, for example, provides crucial information to support India's drive of encouraging FPOs and ultimately improving the livelihoods of smallholder farmers.

"If there are better FPOs and they are helping to successfully aggregate smallholder farmers, it is helping a lot of people at the bottom of the pyramid," Chawla said.



# CLIMATE CHANGE & SUSTAINABLE AGRICULTURE

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

As the effects of a warming earth are felt more strongly, the need to curb climate change is coming into conflict with the need to address hunger and malnutrition. Agriculture currently contributes 25% of global greenhouse gases each year, and as the world's population grows, farming's carbon footprint will expand along with it. Simultaneously, rising temperatures and more frequent extreme weather events will threaten agricultural production. To address this dilemma, TCI has embarked on an ambitious initiative aimed at reducing agricultural emissions while meeting increasing nutritional demands.



Solar panels power irrigation pumps on a paddy field in West Bengal, India. (Photo by Babai Baitalik on Shutterstock)

The Zero-Hunger, Zero-Carbon Food Systems project will develop accurate and precise metrics to measure the emissions of various agricultural production systems in India. Based on that analysis, researchers will generate a roadmap of mitigation methods designed to decrease emissions without sacrificing productivity. While tailored to

India's agricultural sector, the roadmap will offer a model to other developing countries.

TCI researchers will use a combination of data, field-based research, and consultations with policymakers and other stakeholders to create the roadmap for emissions reduction. In the first stage of the project, they will identify the primary production, nutrition, and emissions challenges facing the agricultural sector in India, in addition to measuring the emissions associated with different types of production systems, such as rice and wheat, livestock, and horticulture. They will also predict future emissions levels if no action is taken. They will then identify potential mitigation strategies for each production system and model the emissions reductions that would result from their implementation.

Climate change presents a significant threat to the world, including its ability to feed people nutritious diets. Increasing agricultural productivity while reducing emissions is an enormous challenge; through its research, TCI hopes to show that zero-hunger, zero-carbon food systems are attainable.

## From Farm Waste to Furniture

The burning rice stubble by farmers—that is, the burning of the straw left behind after harvest—has been a big problem in northern India for many decades, contributing to severe air pollution that is attributable to 20% of deaths nationwide and damages costing billions of dollars a year. TCI is supporting research aimed at upcycling rice stubble into inexpensive, environmentally friendly composite panels, which can replace wood products, and be used for everything from housing to furniture. Along with preventing air pollution and its ill-effects on people, the project is also aimed at creating technical and manufacturing jobs, reducing the harvest of trees for lumber, and generating additional income for farmers.

A team led by Cornell University Professor Anil Netravali has developed a process that combines mild chemical-treated rice straw with jute fabrics to form bilayer mats. These mats are then infused with plant-based resins and hot molded into desired shapes. The composite panels are stronger than wood-based materials and can be easily engineered to fit different applications.

*The manufacturing process is water-based, uses relatively little energy, generates almost no waste, and can be easily transferred to India for large-scale production.*

The manufacturing process is water-based, uses relatively little energy, generates almost no waste, and can be easily transferred to India for large-scale production. It also eliminates the formaldehyde-based resins used to make wood-based products, such as particleboard and medium-density fiberboard. Off-gassing of formaldehyde is a known carcinogen.

By creating a profitable alternative to stubble burning, this innovative product has the potential to significantly improve air quality while improving the livelihoods of smallholder farmers.

## Assessing Atmospheric Carbon's Impact on Farm Yields

As one of the main factors in photosynthesis, carbon dioxide plays an important role as an agricultural input. Past trials have established carbon dioxide's role in determining yields, but because of a lack of real-world data, the long-term impact of carbon dioxide on yields has yet to be thoroughly studied. With newly available data on atmospheric carbon dioxide, TCI Scholar Anna Thottappilly

is working to improve our understanding of the relationship between carbon dioxide and agricultural yields.

Agricultural yields in India have grown significantly since the 1960s. Researchers have extensively studied the role that inputs, like fertilizer and high yield varieties, have played in that increase. More recently, weather-related variables, like temperature and precipitation, have also been evaluated. A 2021 study of maize yields and atmospheric carbon dioxide in the United States established a causal relationship between the two.

Thottappilly is using data on atmospheric carbon dioxide from NASA's Orbiting Carbon Observatory-2 (OCO-2) and data on farm yields from the TCI-ICRISAT District-Level Database on Indian Agriculture and Allied Sectors to chart the impact that relative changes in carbon dioxide have on farm yields in India. Launched in 2014, OCO-2 uses remote sensors to measure atmospheric carbon dioxide on a regional scale (greater than 1,000 km) and quantify carbon variability from over seasonal cycles from year to year.

Thottappilly's use of the innovative data will assist policymakers and other researchers in better understanding the relationship between atmospheric carbon dioxide and farm yields and help to predict future agricultural production in India.



The Orbiting Carbon Observatory (OCO)-2 makes precise, regional measurements of carbon dioxide. (Image by NASA)

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