Centre for Sustainability and Corporate Governance Research

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SEMINAR SUMMARY REPORT

Are the Effects of Climate Change on Agriculture Underestimated? A Disaggregated Analysis for India

October 31, 2025

by

Prof. Shreekant Gupta

Visiting Senior Fellow, Centre for Social & Economic Progress (Formerly Brookings India)
Adjunct Faculty, Department of Social Science & Humanities (SSH),
Indraprastha Institute of Information Technology Delhi (IIIT-D)

Moderator:
Prof. Rama Mohana Turaga
Faculty, Public Systems Group, IIMA

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Seminar on

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Moderator: **Prof. Rama Mohana Turaga**, Public Systems Group, IIMA

October 31, 2025 **4:00 p.m. IST**

SR 10, AB-2, New Campus

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About the Speaker

Prof. Shreekant Gupta

Prof. Shreekant Gupta is an economist with over three decades of experience in urban policy, climate change, and environmental regulation. He is currently a Visiting Senior Fellow at the Centre for Social and Economic Progress (formerly Brookings India), Visiting Professor at the Indian School of Public Policy, Adjunct Faculty at IIIT Delhi, and Senior Fellow (Executive Education) at the Lee Kuan Yew School of Public Policy, National University of Singapore. He has previously served as Professor at the Delhi School of Economics, Economist at the World Bank (Washington D.C.), and Director of the National Institute of Urban Affairs.

He was a contributing author to the IPCC 5th and 6th Assessment Reports and serves as an Editor of *Climatic Change (Springer)*. Prof. Gupta received his PhD in Economics from the University of Maryland and a Master's degree from the Delhi School of Economics. He has been the recipient of prestigious fellowships, including the Fulbright Scholarship at the Massachusetts Institute of Technology (MIT) and the Shastri Fellowship at Queen's University, Canada.

About the Moderator

Prof. Rama Mohana Turaga

Rama Mohana R. Turaga is a Professor in the Public Systems Group at IIM Ahmedabad. He holds a PhD in Public Policy from Georgia Tech and a Master's degree in Environmental Engineering from IIT Kharagpur. Before joining IIMA, he worked as a Research Associate at Dartmouth College on U.S. EPA-funded projects and spent six years as an environmental management consultant where he advised industry and government on policy and assessments. His research focuses on sustainability policy and governance, with publications in leading journals such as *Nature Food, Journal of Policy Analysis and Management, and Ecological Economics*. At IIMA, he teaches courses on environmental sustainability and public policy.

Abstract

An extensive body of literature evaluates the effects of climate change on agriculture, but the estimated impacts vary significantly. This research highlights that existing studies systematically underestimate these effects due to:

1. The predominance of static modelling approaches,
2. Limited consideration of intra-year climatic variability, and
3. The asymmetric effects of positive and negative climate shocks.

Using district-level data from India and a dynamic econometric framework, the study demonstrates that the long-run effects of climate change on crop yields are 36% to 66% greater than those indicated by short-run models. These findings underscore the urgency for significant adaptation measures to climate-proof agriculture from future climate change.

Introduction

Agriculture remains the backbone of the Indian economy; however, it is also the sector most directly and persistently exposed to the impacts of climate variability. India's agricultural production system is heavily dependent on monsoon rainfall and seasonal temperature cycles, making it acutely sensitive to deviations in these patterns. As climatic uncertainties intensify due to global warming, understanding the true scale of these impacts becomes increasingly crucial for policy design, risk management, and adaptation planning (Intergovernmental Panel on Climate Change [IPCC], 2022).

While a considerable and growing body of research has examined how climate change affects agricultural yields, these studies vary widely in their estimates of impact, and the methodological foundations behind them significantly influence the conclusions drawn. Many of these assessments rely on *static empirical models*, which estimate the immediate, contemporaneous effects of weather shocks on yields. Such approaches implicitly assume that the consequences of climate events—whether extreme heat, rainfall deficits, or excess rainfall—are fully realized within the same agricultural season (Dell, Jones, & Olken, 2012). However, this assumption overlooks the fact that climatic shocks may introduce *long-lasting disruptions* that propagate beyond the immediate crop cycle.

These long-run effects can operate through multiple pathways. For example, severe temperatures or a rain deficit may impact soil moisture profiles and soil quality, which could influence subsequent decisions. Farmers may respond to climatic shocks by reducing fertilizer or by shifting cultivation practices, which then influence crop outcomes in later years. Moreover, climate anomalies often exhibit *intra-seasonal variability*, meaning that the timing of extreme weather—whether during sowing, vegetative growth, or flowering—can significantly alter yield outcomes (Indian Meteorological Department [IMD], 2024). Static or annual-average analyses may obscure these window-specific sensitivities.

Another important dimension is that climate shocks are not necessarily symmetric. A deficit in rainfall cannot be assumed to have an equal and opposite effect to an equivalent rainfall surplus; similarly, temperature increases often produce disproportionately large yield losses compared to the marginal benefits of cooler-than-average conditions. Therefore, a more nuanced, *disaggregated, and dynamic approach* is needed to accurately estimate the magnitude and persistence of climate impacts.

Due to these reasons, this study employs a dynamic panel framework that explicitly incorporates lagged effects, seasonal variability, and asymmetric climate responses, thereby challenging the conventionally reported figures on climate impacts and providing evidence that suggests long-run effects are considerably larger than short-run estimates. The study reframes how climate risk in agriculture should be measured, interpreted, and integrated into national adaptation strategies.

Seminar Summary

Prof. Shreekant Gupta began his presentation by emphasizing that while climate change and its effects on agriculture have been widely studied, the magnitude of those effects may be systematically underestimated due to limitations in conventional empirical methods. He noted that a vast amount of literature—both international and India-specific—has employed static econometric models to estimate how variations in rainfall and temperature influence agricultural yields. However, these models, by design, capture only the immediate or short-run impacts, assuming that climatic shocks affect yields solely within the same agricultural season. According to Prof. Gupta, this assumption is deeply flawed because climatic shocks, such as droughts or extreme heat, can have persistent, long-term effects that extend across multiple seasons.

He explained that the current study, conducted jointly with **Prof. Gaurav Datt (Monash University) and Dr. Shweta Gupta (NCAER)**, addresses these gaps by using a dynamic panel data framework that explicitly models persistence, asymmetry, and seasonality. The dataset covers more than five decades of district-level data (1960–2017) across 663 districts, aggregated into 311 ICRISAT districts, and focuses on ten major crops—rice, wheat, maize, bajra, jowar, groundnut, cotton, sugarcane, rapeseed-mustard, and pulses—that collectively account for over 95% of India's total agricultural output.

The study constructs standardised temperature and rainfall anomalies for each district using 30-year historical baselines to define "climate normals." These anomalies are decomposed into positive and negative shocks, enabling the researchers to test for asymmetry—whether favourable and adverse climatic deviations produce equal and opposite yield responses. Prof. Gupta described the central model as a first-order autoregressive distributed lag (AD(1,1)) specification, incorporating lagged yield terms to capture persistence in agricultural productivity, while district and time fixed effects account for unobserved spatial and temporal heterogeneity.

Through this model, the research is able to estimate short-run and long-run effects of climate shocks. Prof. Gupta elaborated that the ratio of long-run to short-run effects depends on the persistence parameter (α): when α lies between 0 and 1, the long-run effect is mathematically greater than the short-run effect. "This is not merely a modelling assumption," he remarked, "it is an artefact of the data. The data itself tells us that agricultural yields display persistence." Empirically, the analysis confirms that climate shocks continue to influence yields for two to three years after the initial event, implying that a static, single-period model would capture only a fraction of the true economic cost.

Prof. Gupta presented several empirical findings that underscore the seriousness of the underestimation. For instance, a one-standard-deviation (one-sigma) increase in rainfall anomalies was found to cause substantial fluctuations in yield, depending on the crop and region. Similarly, while earlier studies had estimated that a 1°C rise in temperature reduces yields by 2–4%, this study finds that the long-run impact is significantly higher, suggesting a much stronger and more enduring adverse effect. Across crops, temperature shocks consistently exhibit large negative coefficients, while rainfall effects are more heterogeneous—rainfall deficits (negative shocks) have strongly detrimental impacts, whereas positive rainfall shocks often produce smaller, statistically weaker yield gains.

Another contribution of the study is its attention to intra-year (seasonal) variation, rather than treating each year as a single climatic block. Prof. Gupta demonstrated that when the analysis is disaggregated by growing seasons—such as kharif, rabi, and zayad—the sensitivity of yields to climate variables becomes much more apparent. Crops like rice and wheat, which have multiple growing cycles or depend on precise sowing windows, show highly differentiated seasonal responses. The research rejects the null hypothesis that seasonal parameters are equal, indicating that seasonal models capture real, statistically significant heterogeneity.

To illustrate the practical relevance, Prof. Gupta explained that such disaggregated modelling enables district-level vulnerability mapping, which can inform adaptation policies, crop insurance schemes, and fiscal transfers. "If you look at the persistence of climate effects, it tells policymakers that the damage from a heatwave or drought this year will continue to affect farmers for several years," he said. "That has direct implications for how we design support systems and recovery mechanisms."

He also clarified certain methodological points raised during the session. Some audience members inquired whether other climatic variables, such as humidity, wind speed, or nighttime temperatures, could be integrated into the model. Prof. Gupta responded that while these variables are relevant, high-quality, long-term district-level data on them are scarce. He argued that rainfall and temperature are the primary key variables that capture the main dynamics of agricultural stress, although additional parameters like wind, humidity, and pressure may refine the diagnosis.

The seminar then delved into the policy implications of the findings. Prof. Gupta stressed that the results highlight an urgent need for dynamic, data-driven adaptation strategies, rather than static, uniform measures. Future agricultural and climate policies should incorporate multi-year persistence effects into the design of crop insurance products, the Minimum Support Price (MSP) framework, and regional adaptation programs. He emphasized that climate resilience cannot be achieved through short-term interventions alone, as the economic damage from climate shocks unfolds gradually and accumulates over time.

Furthermore, the study provides a rationale for promoting crop diversification—for example, encouraging the cultivation of millets and drought-resistant varieties that show lower sensitivity to heat and rainfall extremes. By identifying which crops and districts are most exposed to long-term climate risks, policymakers can prioritize investments and resource allocation more efficiently.

Prof. Gupta concluded by reiterating that the effects of climate change on Indian agriculture are not only more severe than previously estimated but also more complex in their dynamics. The persistence, asymmetry, and seasonality of climate shocks collectively amplify their long-run impact. As he summarized, "The message from the data is clear: climate change is not just an annual challenge—it's a multi-year burden on India's agricultural system. If we ignore these dynamics, we risk underestimating the threat and misdirecting our policy responses."

The presentation ended with an engaging discussion moderated by Prof. Rama Mohana Turaga, who thanked Prof. Gupta for his empirical clarity and policy insights. The seminar closed with a lively audience interaction and the presentation of a token of appreciation from the Centre for Sustainability and Corporate Governance Research, followed by a group photograph marking the conclusion of an intellectually stimulating session.

Q&A Session

Q. Beyond rainfall and temperature, did you consider other weather elements such as pressure, wind and humidity in the model?
A. Prof. Gupta explained that at the required district-level granularity, reliable series for these variables are not available; the empirical literature therefore focuses on the two "vital signs" for crops—rainfall and temperature. He noted that some studies examine soil moisture, wind speed, or night-time temperatures (important for rice during maturation), and that a positive temperature shock in their framework could partly capture night-time heat effects.

Q. How can this dataset and approach inform government policy—e.g., MSP design or the Pradhan Mantri Fasal Bima Yojana (PMFBY)—given that policymaking often isn't fully data-centric?
A. While not commenting directly on policymaking, Prof. Gupta emphasised the "so what?" of the work: evidence supports crop diversification toward more climate-resilient cereals (e.g., millets) and justifies extending MSP beyond rice and wheat. He referenced related work showing millets and sorghum display lower sensitivity to climate shocks—underscoring MSP as a policy lever to encourage diversification. He added that district-level vulnerability insights can flag more-impacted geographies and could inform broader fiscal formulas (e.g., Finance Commission criteria).

Q. Your results show strong persistence. Does focusing on persistence risk underplaying adaptation—are we only seeing "half the picture"?
A. Prof. Gupta acknowledged the point: his historical estimates embed adaptation to the extent it already occurs within the panel; the open challenge is how to model future adaptation in projection exercises. That remains an area for further work when translating impacts into forward-looking scenarios.

Q. (Follow-up) Temperature effects look much starker than rainfall. Could mitigation via irrigation be dampening rainfall impacts—and what mechanisms might explain differing persistence across crops?
A. In discussion, participants noted that irrigation and groundwater hydrology may buffer rainfall shocks, while crop biology and cropping patterns likely drive the heterogeneity in persistence (e.g., sharper persistence for rice/wheat versus quicker dissipation for millets/groundnut). Prof. Gupta agreed that a deeper, crop-mechanism "dive" is a valuable next step.

Q. For crops with multiple seasons (kharif/rabi), can we include aggregated lagged yields from preceding-season crops (e.g., lagged wheat when estimating rice)?
A. No—the empirical specification uses crop-specific lagged yields (Y_{ict−1}) and does not pool across crops. While there is a separate literature that aggregates output values (and raises price-measurement complications), this study estimates crop-specific production functions. Seasonal models enter via seasonal anomalies (for rainfall/temperature), and tests reject equality of seasonal parameters—justifying the seasonal disaggregation
Q. Did the analysis consider coastal hazards such as tidal flooding/storms, sea-level rise, or the escalating cyclone intensity in the Bay of Bengal—especially given RCP 4.5 projections?
A. Prof. Gupta clarified that the weather inputs come from IMD gridded rainfall (0.25°) and temperature (1°) products, which do not directly encode sea-level rise, coastal inundation, or cyclone hazard tracks. Those coastal extremes would be reflected only to the extent that they alter district-level rainfall/temperature anomalies in the IMD series; explicit coastal-hazard layers were not modelled. He agreed that this is a meaningful dimension for future extensions.

Key Takeaways & Conclusion

The seminar on Prof. Gupta's working paper establishes that the existing research underestimates the true long-term effects of climate change on Indian agriculture. By adopting a dynamic panel approach that accounts for lagged effects, intra-seasonal variability, and asymmetric shocks, Prof. Gupta's study reveals that climate impacts are far more persistent and spatially differentiated than earlier believed. Temperature increases consistently reduce yields across most crops, while rainfall deficits inflict greater losses than surplus rainfall can offset. The findings establish that climatic shocks leave lasting legacies, with yield reductions continuing for several years after the initial event, thereby challenging the adequacy of static modelling frameworks.

The policy implications are equally profound. Prof. Gupta emphasized the importance of dynamic, data-driven adaptation strategies—including crop diversification, localized vulnerability mapping, and targeted support through MSP and crop insurance reforms. The study's central message is clear: climate change is not merely a short-term weather fluctuation but a structural threat to agricultural sustainability. Addressing it requires that research, policy, and practice evolve beyond static assumptions towards a resilient and more forward-looking agricultural policy framework that fully captures the enduring nature of climate change.

Acknowledgements

The Centre for Sustainability and Corporate Governance Research (CSCG) would like to extend its sincerest thanks to:

1. **Prof. Shreekant Gupta** for delivering an insightful seminar and sharing his research on the underestimated effects of climate change on Indian agriculture.
2. **Prof. Rama Mohana Turaga** for moderating the session and steering the discussion.
3. **Prof. Anish Sugathan** for their continued support in organising the CSCG Seminar Series.
4. The **IIMA-PwC ESG Forum** for its sustained support in strengthening CSCG's seminar engagements and outreach initiatives.
5. **PGP, PGPX, and PhD students, Research Assistants/Associates (RAs), and Academic Associates (AAs)** for their participation and engagement during the session.
6. **Participants from academia, government, and industry.**
7. The **IIMA Communications Team** for their creative and design support; and
8. The **IIMA IT and Administrative Teams** for their logistical assistance in organising the event.

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