COMMENTARY

Beyond the Breadbasket Paradox : Rethinking Agricultural Adaptation in the Age of Climate Coloniality

Chunming Xu[1,*]

[1] Beijing Technology and Business University, Beijing 100048, China

1 Introduction

The landmark study by Hultgren et al. [12], published in Nature, represents a significant methodological leap in quantifying climate change impacts on global agriculture while empirically accounting for real-world adaptation. By analyzing longitudinal subnational data encompassing 12,658 regions and two-thirds of global crop calories, the authors provide unprecedented empirical evidence that adaptation mitigates—but far from eliminates—projected yield losses. Their central finding—a near-linear decline of 5.54×10^{14} kcal per 1°C GMST rise, translating to a 4.4% reduction in per capita recommended daily consumption—paints a sobering picture of future food security. However, while the study's econometric rigor and global scope are commendable, its epistemological framing, implicit assumptions about adaptation equity, and neglect of structural power dynamics warrant critical examination. This commentary argues that the "breadbasket paradox" identified (where wealthy, temperate breadbaskets exhibit limited adaptation and suffer disproportionate losses) is not merely an economic anomaly but a symptom of deeper systemic issues tied to climate coloniality and extractive agricultural paradigms. Moving beyond techno-optimist narratives of autonomous adaptation requires integrating political ecology, decolonial theory, and complex systems science into climate-agriculture impact assessments.

2 Deconstructing the Breadbasket Paradox: From Observation to Structural Analysis

The study's most striking finding—that high-income, high-yielding regions (e.g., US Midwest, Eastern China) dominate global calorie losses due to their limited present adaptation despite favorable climates—demands deeper analysis than offered by econometric explanation alone. Hultgren et al. [12] attribute this primarily to path dependency: these regions are "optimized for high average yields but not robustness to climatic changes." While plausible, this explanation overlooks the structural lock-ins of industrial agriculture:

2.1 Financialization Lock-in

Modern breadbaskets are deeply embedded in global financial systems prioritizing short-term ROI and shareholder value over long-term resilience. Investment flows favor input-intensive monocultures (optimized for current climate norms) over diversified,

Submitted: 29 June 2025
Accepted: 30 June 2025
Published: 30 June 2025

Vol. 2, **No.** 2, 2025.
10.62762/ASFP.2025.456605

***Corresponding author:**
Chunming Xu
xucm@btbu.edu.cn

Citation
Xu, C. (2025). Beyond the Breadbasket Paradox : Rethinking Agricultural Adaptation in the Age of Climate Coloniality. *Agricultural Science and Food Processing*, 2(2), 116–121.

adaptive agroecological systems perceived as "risky" by capital [7]. The study's model, while accounting for "financial constraints," cannot capture how global capital markets actively disincentivize transformative adaptation in high-value agricultural zones.

2.2 Input-Dependency Trap

The high yields of breadbaskets rely on tightly calibrated synthetic inputs (fertilizers, pesticides, irrigation) and specific germplasm. Adaptation requiring significant shifts in these inputs (e.g., new drought-tolerant but lower-yielding varieties, reduced fertilizer dependency for soil water retention) faces immense technological and economic inertia. The cost-benefit analysis of adaptation (central to the revealed preference approach) is constrained by existing technological pathways, neglecting potentially superior but underdeveloped agroecological alternatives [3].

2.3 Knowledge Regime Hegemony

Adaptation strategies considered "optimal" within the model are inherently shaped by dominant agronomic knowledge systems emanating from Global North institutions and agribusiness R&D. This marginalizes Indigenous and peasant knowledge systems that emphasize diversity, redundancy, and low-input resilience—practices often prevalent in the "adapted" low-income regions the study notes (e.g., varietal mixtures, water harvesting). The econometric model observes outcomes but cannot interrogate the power dynamics shaping which adaptations are available and legitimized [22].

Therefore, the breadbasket paradox is less a surprise and more an inevitable outcome of an agricultural development model prioritizing efficiency and global market integration over systemic resilience. The "limited adaptation" observed is a rational response within this locked-in system, not necessarily an indicator of inherent lack of adaptive capacity.

3 The Epistemological Tension: Quantifying Adaptation vs. Qualifying Justice

Hultgren et al. [12] rightly highlight the unequal distribution of impacts: while absolute calorie losses are larger in wealthy breadbaskets, low-income regions (especially cassava-dependent populations) face devastating relative losses (28% in the lowest-income decile). Their model attributes lower relative losses in many low-income regions partly to pre-existing adaptation in hotter climates and higher precipitation. However, this framing risks conflating **survival adaptations** under marginal conditions with **robust adaptive capacity**.

3.1 The Vulnerability-Adaptation Nexus

High historical adaptation in hot, low-income regions often reflects chronic vulnerability and coping mechanisms honed under persistent marginality and poverty [20]. Labeling this "higher adaptation" can mask underlying fragility. For instance, a smallholder shifting planting dates or using local landraces resilient to moderate heat may have no buffers left for the unprecedented extremes projected under RCP 8.5. The model's reliance on historical responses may underestimate thresholds beyond which these coping strategies collapse [8].

3.2 Hidden Costs of Autonomous Adaptation

The study's revealed preference approach effectively quantifies private costs and benefits of adaptation observed historically. However, it largely ignores social externalities and distributional consequences. For example:

- Water Competition: Adaptation via irrigation expansion in response to heat (observed as beneficial in the model) can exacerbate groundwater depletion and deprive downstream users or ecosystems, particularly in water-stressed regions [9]. The cost is socialized, while the benefit (yield stability) is privatized.
- Land Grabbing: Large-scale "adaptation" investments (e.g., acquiring land in cooler regions – potentially captured under "crop switching" in valuation) can displace local communities and undermine their food sovereignty [6]. The model's valuation (partial SCC) focuses on market prices, neglecting these socio-ecological costs.
- Genetic Erosion: Reliance on a narrow pool of commercial climate-adapted varieties (a likely adaptation pathway) accelerates the loss of locally adapted landraces crucial for long-term, decentralized resilience [13].

3.3 Beyond Calories: Nutritional and Cultural Losses

Focusing on calorie production (kcal) obscures critical dimensions of food security. The study acknowledges CO_2 fertilization potentially reduces nutrient density [16] but doesn't integrate this into impacts. More profoundly, losses in crops like cassava, sorghum, or regionally specific staples represent not just calorie deficits but erosion of cultural identity, dietary diversity, and locally adapted food systems – losses disproportionately borne by marginalized communities [26]. The econometric lens flattens these qualitative dimensions of food security.

This highlights a fundamental epistemological tension: while quantifying aggregate adaptation benefits is crucial for global projections, it can inadvertently obscure questions of justice, equity, and the differentiated nature of vulnerability and adaptive capacity. Adaptation is not a neutral technical process but a political one.

4 Methodological Frontiers: From Static Correlations to Complex Adaptive Systems

Hultgren et al. [12] advance the field by moving beyond simplistic "no adaptation" vs. "optimal adaptation" scenarios prevalent in process-based models (PBMs). Their reduced-form approach capturing emergent adaptation from observed behavior is a strength. However, significant methodological challenges remain, pointing towards future research needs.

4.1 Dynamic Adaptation Pathways

The model assumes future adaptation mirrors historical responses to *slowly evolving* climate norms ("climate summary statistics"). However, climate change involves increasing non-stationarity – unprecedented extremes, compounding shocks (drought + heatwave), and accelerating change [1] Adaptation is not a one-time adjustment but a continuous, path-dependent process. Agent-Based Models (ABMs) coupled with behavioral theory could better simulate how learning, risk perception, social networks, and evolving constraints shape *dynamic* adaptation pathways under non-linear change.

4.2 Capturing Systemic Tipping Points

The econometric model estimates smooth, probabilistic yield responses. However, agricultural systems can exhibit threshold behaviors and tipping points missed by correlation-based approaches. Examples include:

- Pollinator Collapse: Beyond specific temperature thresholds, pollinator communities crucial for many crops can collapse, triggering non-linear yield declines [18]. Soil Carbon Feedback: Extreme heat and altered rainfall can accelerate soil organic matter decomposition, reducing water retention and fertility, creating a positive feedback loop [15].
- Pest and Disease Emergence: Warmer winters facilitate pest/disease range expansion and overwintering success, potentially causing sudden outbreaks that overwhelm current management [5]. Integrating PBM insights on biophysical thresholds with empirical socioeconomic data is crucial.

4.3 The Missing Governance Dimension

The model incorporates income and irrigation access as proxies for resources but largely neglects the role of institutions, policy, and governance in enabling or constraining adaptation. Effective early warning systems, social safety nets, equitable water governance, seed sovereignty laws, and participatory research extension are critical determinants of adaptive capacity that vary drastically across regions [2]. Future models need frameworks to incorporate these enabling (or disabling) institutional environments.

4.4 Beyond the Six Staples

While covering critical calories, the focus on six staples overlooks the vulnerability of nutritionally dense crops (vegetables, fruits, nuts) often more sensitive to climate extremes [21], and livestock systems facing heat stress, feed shortages, and disease. It also misses the potential of diversified agroecological systems to enhance resilience through functional biodiversity [4].

5 From Social Cost of Carbon (SCC) to Climate Justice: Reframing Policy Implications

The calculation of a partial SCC for agriculture is a valuable contribution, highlighting the significant economic costs of climate-driven yield losses even after adaptation. However, the SCC framework, rooted in welfare economics, has inherent limitations for guiding equitable climate policy.

5.1 Aggregation Masks Distribution

The SCC aggregates damages into a single global number, obscuring the profound distributional inequities the study itself identifies. Applying a uniform SCC value implicitly treats a calorie loss in a malnourished community as equivalent to a loss in a food-secure one, violating principles of climate justice [24]. Policy needs differentiated valuation reflecting vulnerability and historical responsibility.

5.2 Discounting Intergenerational Equity

The wide SCC range depending on discount rate (2-5% vs. Ramsey) underscores the ethical dilemma of valuing future damages. High discount rates (e.g., 5%) drastically reduce the present value of long-term agricultural collapse, privileging current generations over those facing existential food insecurity later this century [25]. This is ethically problematic.

5.3 Beyond Market Valuation

The SCC relies on market prices, failing to capture non-market values essential for food security: cultural significance of crops, loss of food sovereignty, ecosystem services underpinning agriculture (e.g., soil health, pollination), and the intrinsic value of avoiding famine and displacement. Alternative frameworks like the Capabilities Approach [23] or Doughnut Economics [19] offer more holistic ways to assess climate impacts on human flourishing.

6 From Social Cost of Carbon (SCC) to Climate Justice: Reframing Policy Implications

6.1 Redirect Finance

Move beyond the study's implicit focus on autonomous producer adaptation. Massive public investment is needed in planned, transformative adaptation, prioritizing:

- Agroecological Transitions: Support diversification, soil health building, water harvesting, and farmer-led participatory research, especially in vulnerable regions [11].
- Pro-Poor R&D: Shift public agricultural R&D towards climate-resilient, nutritious, and open-source crops suited for diverse smallholder contexts, breaking the corporate stranglehold on seed and input markets [17].
- Universal Social Protection: Scale up climate-responsive social safety nets to protect the most vulnerable from food price spikes and production shocks [10].

6.2 Address the Breadbasket Lock-in

Actively dismantle the structural barriers hindering adaptation in high-yield regions:

- Reform Subsidies: Redirect agricultural subsidies away from input-intensive monocultures towards diversified, climate-resilient practices.
- Strengthen Antitrust: Regulate corporate power in seeds, inputs, and processing to enable greater farmer autonomy and innovation.
- Promote Territorial Food Systems: Support regional food networks that shorten supply chains, enhance resilience, and prioritize local nutrition over global commodity exports.

6.3 Operationalize Loss and Damage (L&D)

The study's projection of "substantial residual losses," especially in vulnerable regions, underscores the urgency of the L&D agenda established at COP27. This requires:

- New Funding Mechanisms: Establish dedicated, grant-based L&D finance (beyond adaptation/mitigation) for countries facing irreversible climate impacts on food systems, prioritizing locally determined needs.
- Debt Justice: Cancel unsustainable sovereign debt in climate-vulnerable food-importing countries to free up fiscal space for adaptation and food security [14].

6.4 Radical Emissions Reductions

No amount of adaptation can fully offset the catastrophic agricultural impacts under high-emission scenarios like RCP 8.5. The study reinforces the existential imperative for rapid, deep decarbonization to stay within manageable warming levels (likely below 2°C).

7 Conclusion

Hultgren et al. [12] provide an invaluable empirical foundation, demonstrating unequivocally that autonomous adaptation, while significant, is insufficient to prevent substantial climate-driven losses to global agriculture. Their identification of the "breadbasket paradox" is a crucial contribution. However, interpreting these findings requires moving beyond the confines of neoclassical econometrics and engaging with critical political economy, decolonial theory, and complex systems science.

The breadbasket paradox is not merely an economic inefficiency; it is a manifestation of an extractive, industrialized global food system built on colonial legacies and optimized for profit over planetary and human health. The "limited adaptation" observed reflects deep structural lock-ins, not inherent incapacity. Conversely, the "higher adaptation" in vulnerable regions often signifies resilience forged through necessity under marginalization, not robust adaptive capacity.

Truly understanding and responding to the climate-agriculture crisis demands a decolonial agro-climatology. This entails:

1. Centering Marginalized Knowledges: Integrating Indigenous, peasant, and local knowledge systems into adaptation science and practice.
2. Confronting Power: Explicitly analyzing how global trade, finance, intellectual property regimes, and corporate power shape vulnerability and constrain adaptation options.
3. Prioritizing Justice: Designing adaptation and L&D policies based on principles of equity, historical responsibility, and the right to food, not just aggregate efficiency or market valuations.
4. Embracing Complexity: Developing next-generation models that capture dynamic adaptation pathways, systemic tipping points, and the interplay of ecological and social processes.

The future of food security under climate change hinges not only on better quantifying impacts but on fundamentally transforming the political and economic systems that determine who adapts, how, and at what cost. Hultgren et al. [12]'s rigorous analysis provides the stark evidence; the task now is to build the political will for the transformative action it demands.

Data Availability Statement

Not applicable.

Funding

This work was supported without any funding.

Conflicts of Interest

The author declares no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

References

[1] Abram, N. J., Henley, B. J., Sen Gupta, A., Lippmann, T. J., Clarke, H., Dowdy, A. J., ... & Boer, M. M. (2021). Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth & Environment*, *2*(1), 8. [CrossRef]

[2] Agrawal, A. (2010). Local institutions and adaptation to climate change. *Social dimensions of climate change: Equity and vulnerability in a warming world*, *2*, 173-178.

[3] Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for sustainable development*, *35*(3), 869-890. [CrossRef]

[4] Beillouin, D., Ben-Ari, T., Malézieux, E., Seufert, V., & Makowski, D. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global change biology*, *27*(19), 4697-4710. [CrossRef]

[5] Bebber, D. P., Ramotowski, M. A., & Gurr, S. J. (2013). Crop pests and pathogens move polewards in a warming world. *Nature climate change*, *3*(11), 985-988. [CrossRef]

[6] Borras Jr, S. M., & Franco, J. C. (2012). Global land grabbing and trajectories of agrarian change: A preliminary analysis. *Journal of agrarian change*, *12*(1), 34-59. [CrossRef]

[7] Barbosa, I. P. (2020). Speculative Harvests: financialization, food and agriculture. *Revista da Sociedade Brasileira de Economia Política*.

[8] Eriksen, S., Schipper, E. L. F., Scoville-Simonds, M., Vincent, K., Adam, H. N., Brooks, N., ... & West, J. J. (2021). Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance?. *World development*, *141*, 105383. [CrossRef]

[9] Gleeson, T., Cuthbert, M., Ferguson, G., & Perrone, D. (2020). Global groundwater sustainability, resources, and systems in the Anthropocene. *Annual review of earth and planetary sciences*, *48*(2020), 431-463. [CrossRef]

[10] Hallegatte, S., Fay, M., & Barbier, E. B. (2018). Poverty and climate change: Introduction. *Environment and development economics*, *23*(3), 217-233. [CrossRef]

[11] Nicolétis, É., Caron, P., El Solh, M., Cole, M., Fresco, L. O., Godoy-Faúndez, A., ... & Zurayk, R. (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

[12] Hultgren, A., Carleton, T., Delgado, M., Gergel, D. R., Greenstone, M., Houser, T., ... & Yuan, J. (2025). Impacts of climate change on global agriculture accounting for adaptation. *Nature*, *642*(8068), 644-652. [CrossRef]

[13] Van de Wouw, M., Kik, C., van Hintum, T., van Treuren, R., & Visser, B. (2010). Genetic erosion in crops: concept, research results and challenges. *Plant*

genetic resources, *8*(1), 1-15. [CrossRef]

[14] Adil, L., Eckstein, D., Künzel, V., & Schäfer, L. (2025). Climate risk index 2025.

[15] Smith, P. (2004). Carbon sequestration in croplands: the potential in Europe and the global context. *European journal of agronomy*, *20*(3), 229-236. [CrossRef]

[16] Myers, S. S., Zanobetti, A., Kloog, I., Huybers, P., Leakey, A. D., Bloom, A. J., ... & Usui, Y. (2014). Increasing CO2 threatens human nutrition. *Nature*, *510*(7503), 139-142. [CrossRef]

[17] Peschard, K., & Randeria, S. (2020). 'Keeping seeds in our hands': the rise of seed activism. *The Journal of Peasant Studies*, *47*(4), 613-647. [CrossRef]

[18] Rader, R., Bartomeus, I., Tylianakis, J. M., & Laliberté, E. (2014). The winners and losers of land use intensification: Pollinator community disassembly is non-random and alters functional diversity. *Diversity and Distributions*, *20*(8), 908-917. [CrossRef]

[19] Raworth, K. (2018). *Doughnut economics: Seven ways to think like a 21st century economist*. Chelsea Green Publishing.

[20] Ribot, J. (2017). Cause and response: vulnerability and climate in the Anthropocene. In *New Directions in Agrarian Political Economy* (pp. 27-66). Routledge.

[21] Scheelbeek, P. F., Bird, F. A., Tuomisto, H. L., Green, R., Harris, F. B., Joy, E. J., ... & Dangour, A. D. (2018). Effect of environmental changes on vegetable and legume yields and nutritional quality. *Proceedings of the National Academy of Sciences*, *115*(26), 6804-6809. [CrossRef]

[22] Scoones, I., Stirling, A., Abrol, D., Atela, J., Charli-Joseph, L., Eakin, H., ... & Yang, L. (2020). Transformations to sustainability: combining structural, systemic and enabling approaches. *Current Opinion in Environmental Sustainability*, *42*, 65-75. [CrossRef]

[23] Sen, A. (2014). Development as freedom (1999). *The globalization and development reader: Perspectives on development and global change*, *525*.

[24] Shue, H. (2017). Climate dreaming: negative emissions, risk transfer, and irreversibility. *Journal of Human Rights and the Environment*, *8*(2), 203-216. [CrossRef]

[25] Stanton, E. A. (2011). Negishi welfare weights in integrated assessment models: the mathematics of global inequality. *Climatic Change*, *107*(3), 417-432. [CrossRef]

[26] Smith, L. T. (2021). *Decolonizing methodologies: Research and indigenous peoples*. Bloomsbury Publishing.

Chunming Xu (Member, ICCK) received the B.S. and M.S. degrees in Bio-engineering and Ecology from Northwest A&F University and the Ph.D. degree in Biochemical Engineering from Institute of Process Engineering, Chinese Academy of Sciences.

Chunming Xu is a professor at the School of Light Industry Science and Engineering at Beijing Technology and Business University. He is a green factory evaluation expert of the Ministry of Industry and Information Technology of China, a project expert of the China National Light Industry Council, and a reviewer of many journals such as Journal of Chinese Institute of Food Science and Technology and Science and Technology of Food Industry.His research focuses on agricultural intelligent systematics, food big data technology, multi-omics analysis. He has published over 50 relevant papers in areas such as metagenomics, transcriptomics, screening of resistance genes, screening of bioactive peptides, and virtual screening of enzyme inhibitors. He has also filed 8 related patents and serves as a reviewer for multiple journals. (Email: xucm@th.btbu.edu.cn)