



Photo credit: Michael Major/Crop Trust

SPIA Briefing Note: Environmental Externalities of Agricultural Intensification



Standing Panel on Impact Assessment

November 2024

Increasing agricultural productivity is important for CGIAR, as it is central to the achievement of a range of development outcomes, which may arise through crop or commodity-specific causal pathways. These potential pathways include raising farmer incomes, lowering food prices for consumers, changing employment shares, altering land use patterns, creating demand for processing services, and more. The process of agricultural intensification can take several complementary forms, but there is typically an association with the adoption of new agricultural innovations wherein farmers increase their productivity¹ through the use of new inputs, higher cropping intensity (i.e., two or more crops) per unit of land, and/or shift to higher-value crops. These processes of change may alter the environmental damages from agriculture, both directly (e.g., pollution from more use of inputs) or indirectly (e.g., increased productivity can lead to more (“Jevons’ paradox”) or less (“Borlaug hypothesis”) land conversion at the margin). Understanding these direct and indirect effects is important for designing agricultural policies and interventions in ways that consider potential tradeoffs and minimize negative consequences.

In a recent literature review, commissioned by SPIA, Garcia (2020) identified the following gaps:

1. a lack of rigorous causal evidence on direct environmental impacts of specific agricultural innovations
2. insufficient evidence on competing land conversion hypotheses (Borlaug hypothesis vs. Jevons paradox)
3. open questions about the contextual conditions and mechanisms through which agricultural intensification impacts the environment

To support research addressing these gaps in the literature, SPIA issued a joint call for proposals with the Environmental Markets Lab ([emLab](#)) at UC Santa Barbara in 2019. Four impact assessment studies were commissioned under this call. Two studies offer valuable insights on the prospects for what is sometimes referred to as “sustainable intensification” (Godfray and Garnett, 2012; Cassman and Grassini, 2020) in which innovations are introduced to farmers that are designed to have positive environmental externalities, thereby addressing existing environmental concerns related to agricultural production.

Krishna et al. (2024) aimed to estimate the impact on air quality of the adoption of the Happy Seeder technology – an implement fitted to the back of tractors that allow farmers to plant wheat into fields with rice straw left intact (i.e., not burned, as conventional practice). During the period of their study

¹ Productivity can be framed in terms of output per unit of land; or, output per some other constraining factor such as labor; or, across an index of all factors of production as in Total Factor Productivity estimation.

fieldwork (i.e., 2000–2022) the Punjab government heavily subsidized a different machine (the “Super Seeder”) that is similar but that produces a shallow tillage in the field. The Super Seeder was produced with no known CGIAR research contribution. Owing to the lower-than-expected adoption of the Happy Seeder, their study instead examines how both zero tillage (with) and shallow tillage (with Super Seeder) adoption affects rice residue burning. Krishna et al. (2024) find zero-tillage adoption averages 17%, and that places with higher adoption also engage in less agricultural burning, though a causal interpretation of this relationship requires further analysis.

Aker and Jack (2023) used a village-level randomized trial in Niger to evaluate a training intervention for constructing *demi-lunes*: half-moon shaped depressions in the soil for concentrating rainwater and reducing soil runoff, thereby helping to rehabilitate degraded land. They find that adoption is responsive to the training intervention, increasing from 4% in the control group to around 95% in the treatment group. They show that rainwater harvesting increases agricultural output per farmer, improves self-reported soil quality and reduces land retirement and recruitment of new land into production. The findings are consistent with a land-sparing result, supporting the Borlaug hypothesis.

Two other studies evaluated the potential indirect environmental impacts of innovations that were not designed with a specific environmental focus. Wilcox et al (2024) examined the long-run ecological impacts of index-based livestock insurance (IBLI) in East Africa, and Abeygunawardane et al (2024) examined the impact on land-use / land-cover change of a program promoting intensification of sorghum and millet in Mali. In both these cases, the environmental impacts of these examples of agricultural intensification are entirely ambiguous, open questions – competing theories, along the lines of Borlaug vs Jevons, could argue for either result in the absence of strong empirical evidence.

Wilcox et al. (2024) investigated IBLI’s impact on rangeland health among pastoralists in East Africa. The IBLI insurance protects against drought-related livestock mortality and has been shown to enhance herd productivity and household income. This study was motivated by the concern that increased profitability may lead to higher stocking rates and



A farmer in India uses a tractor fitted with a Happy Seeder. (Photo: Dakshinamurthy Vedachalam/CIMMYT)

environmental degradation. The study uses difference in differences analysis with location and time fixed effects, exploiting the quasi-random variation in the timing of roll-out of IBLI. The authors find that IBLI has neutral to slightly positive impacts on various indicators of rangeland health. These results suggest that agricultural intensification through risk reduction can avoid environmental harm, arguably representing another result consistent with the Borlaug hypothesis, and provides valuable insights for scaling IBLI and similar technologies designed to offset increasing variability due to climate change. Scaling decisions for this innovation should also take into account evidence from Barrett et al (2024) that suggests that impacts on herd value and cash income may not endure in the long term.

Abeygunawardane et al. (2024) assessed the land use impacts of a bundled intervention aiming to promote intensification by sorghum and millet farmers in southern Mali, through introduction of improved seeds, seed treatment techniques, and soil and pest management practices. Their study used tree cover as a proxy for land use and focuses on the semi-arid zone. They selected a comparison group through propensity score matching on both pre-program outcomes and time varying covariates and ran a difference in differences analysis with two-way fixed effects. They find a 1.8% decline in tree cover outside cropland and 0.7% within cropland, for treated villages relative to control villages. These results are consistent with the idea of a “rebound” effect, aligning with the Jevons paradox, which raises concerns for similar intensification programs worldwide.

In conclusion, the findings demonstrate that the adoption of agricultural innovations at scale can produce positive environmental externalities (or reduce negative ones) consistent with the principal of sustainable intensification, but that this is innovation- and location-specific. The implication of such context-specificity is that agricultural researchers should try to anticipate the range of possible causal pathways but should also remain open to surprises. It also highlights the value of further work to more systematically explore the conditions that give rise to environmental benefits.

References

- *Abeygunawardane, D., Traore, S., Traore, S., Kerubo, V., Ngungu, S., Reiner, F., Brandt, M., Fensholt, R., & Kumar, P. (2024). LULCC Impacts of Agricultural Intensification in Mali, Borlaug or Jevons. Presentation at the SPIA Fest pre-conference to the International Conference of Agricultural Economists (ICAE), 2 August 2024.
- *Aker, J. C., & Jack, B. K. (2023). Harvesting the rain: The adoption of environmental technologies in the Sahel. *Review of Economics and Statistics*, 1-52.
- *Barrett, C. B., Jensen, N., Morsink, K., Noritomo, Y., Son, H. H., Banerjee, R., & Teufel, N. (2024). Long-run Effects of Catastrophic Drought Insurance. October 2024. Retrieved from https://barrett.dyson.cornell.edu/files/papers/Long_term_effects_of_IBLI%20submitted%2026%20Oct%202024.pdf.
- Cassman, K. G., & Grassini, P. (2020). A global perspective on sustainable intensification research. *Nat Sustain*, 3, 262–268. <https://doi.org/10.1038/s41893-020-0507-8>.
- *Garcia, A. (2020). The Environmental Impacts of Agricultural Intensification. Technical Note N.9. Rome: SPIA. <https://iaes.cgiar.org/spia/publications/environmental-impacts-agricultural-intensification>.
- Godfray, H. C., & Garnett, T. (2014). Food security and sustainable intensification. *Philos Trans R Soc Lond B Biol Sci*, 369(1639): 20120273. doi: 10.1098/rstb.2012.0273. PMID: 24535385; PMCID: PMC3928882.
- *Krishna, V. V., Deshpande, M., Pillai, D., Cariappa, A., Kubitzka, C., Jat, M. L., & Jain, M. (2024). Beyond Fields: Conservation Agriculture as a Public Good in Reducing Air Pollution. SPIA Fest – Presentation at the SPIA Fest pre-conference to the International Conference of Agricultural Economists (ICAE), 2 August 2024.
- *Wilcox, S. W., Barrett, C. B., Jensen, N. D., Clark, P., Fava, F., Kahiu, N., Soto, G. E., & Sun, Y. (2024). The Environmental Impacts of Microfinance: Index-Based Livestock Insurance and East African Rangelands. Presentation at the SPIA Fest pre-conference to the International Conference of Agricultural Economists (ICAE), 2 August 2024.

*study conducted under the 2019–2024 workplan

