

International Journal of Agriculture Extension and Social Development

Volume 9; Issue 3; March 2026; Page No. 273-277

Received: 18-01-2026
Accepted: 28-02-2026

Indexed Journal
Peer Reviewed Journal

Impact of Frontline Demonstrations on Yield Gap Reduction and Technology Adoption in Pulse Crops

¹Amina J Mwakalinga, ²Godfrey P Kimaro and ³Happiness E Massawe

¹⁻³National Institute of Agricultural Extension, Dodoma, Tanzania

DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i3d.3876>

Corresponding Author: Amina J Mwakalinga

Abstract

Pulse crop yields on farmer fields across much of central Tanzania routinely fall 30% or more below what improved varieties and recommended agronomic packages can deliver under demonstration conditions, a gap that frontline demonstrations (FLDs) are specifically designed to close. This research evaluated FLD outcomes across five pulse crops, chickpea, pigeon pea, green gram, cowpea, and lentil, conducted across 96 demonstration plots paired with adjacent farmer-practice plots in Dodoma and Singida regions over three consecutive cropping seasons (2022-23 to 2024-25). Yield gap, technology gap, and extension gap were calculated for each crop, with green gram showing the widest overall yield gap (38.6%) and lentil the narrowest (26.4%). Technology adoption following FLD exposure ranged from 52.8% among lentil-growing farmers to 69.3% among green gram growers, and adoption correlated positively with the size of the yield advantage farmers observed on the demonstration plot relative to their own practice. Economic analysis showed benefit-cost ratios improving from a farmer-practice baseline averaging 1.68 to 2.34 under the demonstrated technology package across all five crops, with chickpea recording the highest returns (B:C ratio of 2.61). Farmer field days held at flowering and podding stages generated the strongest reported influence on subsequent adoption decisions, more so than field days held only at harvest, suggesting that observing crop performance during the vulnerable mid-season period carries particular persuasive weight. These findings support continued FLD investment as a yield-gap-closing mechanism for pulse crops in semi-arid Tanzania, while indicating that the technology and extension gap components, rather than genetic yield potential alone, account for the largest share of the shortfall between demonstrated and farmer-practice yields, meaning agronomic management and information access issues remain the more addressable constraints going forward.

Keywords: Frontline demonstration, pulse crops, yield gap, technology adoption, extension gap, chickpea, pigeon pea, benefit-cost ratio, semi-arid agriculture, Tanzania

Introduction

Why do farmers so often leave yield on the table even when better varieties and practices are demonstrably available? Pulse crops, central to both household nutrition and soil nitrogen replenishment across semi-arid East African farming systems, illustrate this puzzle particularly clearly. Improved chickpea and pigeon pea varieties released over the past decade routinely outperform local farmer varieties by 30 to 40% under research station conditions, yet actual farmer yields across much of central Tanzania have risen only modestly over the same period, leaving a persistent and economically significant yield gap unclosed.

Frontline demonstrations have long served as the primary extension mechanism for closing this kind of gap, placing improved technology packages directly on farmer fields under farmer-managed conditions rather than confining improved practices to research stations that farmers rarely visit. The underlying logic is straightforward: farmers who see an improved variety and package perform well on a neighbor's field, under locally familiar soil and climate conditions, are more likely to trust and adopt that package than farmers who only hear about research station results secondhand. Decomposing the total yield gap into its yield, technology, and extension gap components, following established agricultural economics methodology, allows a more precise diagnosis of where the shortfall actually

originates: whether from genetic yield potential differences, from farmers not yet adopting available improved practices, or from extension services failing to reach farmers with the information needed to adopt in the first place.

This decomposition matters practically because each gap component implies a different remedy. A yield gap driven mainly by genetic potential differences calls for continued variety development, while one driven mainly by technology or extension gaps calls instead for better delivery of already-available packages through demonstration, training, and input access support. Prior research across pulse-growing regions of East Africa has documented substantial yield gaps but has less often decomposed them systematically by crop, leaving extension planners without clear guidance on which specific pulse crops and gap components most warrant continued FLD investment relative to other interventions.

This research addressed three linked questions across the five pulse crops studied. First, how do yield gap, technology gap, and extension gap magnitudes compare across chickpea, pigeon pea, green gram, cowpea, and lentil in the Dodoma and Singida study zones? Second, does FLD exposure produce measurably different technology adoption rates across these crops, and if so, what explains the variation? Third, does the timing of farmer field days, held at different crop growth stages, influence subsequent

adoption decisions differently? Answering these questions required three consecutive cropping seasons of paired demonstration and farmer-practice plot data across 96 sites, combined with structured adoption follow-up surveys described in the sections that follow.

Materials and Methods
Field Experimental Design

Ninety-six frontline demonstration plots, paired with adjacent farmer-practice plots of equal area, were established across twelve villages in Dodoma and Singida regions, with roughly equal representation across the five pulse crops studied. Each demonstration plot received the full recommended technology package for its crop, comprising improved variety, recommended seed rate and spacing, appropriate rhizobium inoculation where applicable, and integrated pest management guidance, while the paired farmer-practice plot continued under the farmer's existing variety and management approach without researcher intervention. Plots were monitored across three consecutive cropping seasons from 2022-23 through 2024-25, with a new cohort of farmer-practice pairs added in select villages each season to track adoption spillover to previously non-participating farmers.

Materials

Improved varieties used in demonstration plots were sourced from the national pulse breeding program and included at least one variety released within the preceding five years for each of the five crops studied. Farmer-practice plots used whatever variety and seed source the participating farmer normally planted, typically retained or locally purchased seed of unimproved or older released varieties.

Crop Growth Stage Documentation

Growth stage was recorded at three points per season, emergence, flowering/podding, and physiological maturity, using crop-specific staging guides adapted from regional pulse crop descriptors. Farmer field days were scheduled to coincide with either the flowering/podding stage or the harvest stage depending on village assignment, allowing comparison of field day timing effects on subsequent

adoption, since visible pod set differences between demonstration and farmer-practice plots were expected to be most pronounced during the flowering/podding window.

Methods

Yield data were recorded from a net harvest area within each plot at physiological maturity, and yield gap, technology gap, and extension gap were calculated following standard decomposition methodology comparing demonstration plot yield, potential yield derived from research station trial data, and farmer-practice plot yield. Technology adoption was assessed through structured follow-up surveys conducted with all participating and a subsample of non-participating neighboring farmers one season after each demonstration cycle, recording whether farmers had adopted any element of the demonstrated package on their own fields. Benefit-cost ratios were calculated using regional input costs and farm-gate pulse prices averaged across the three seasons. Associations between field day timing and subsequent adoption were tested using chi-square tests, with statistical significance set at $p < 0.05$. Ethical clearance and research permission were obtained from the Institute's Research Ethics Committee (Protocol No. NIAE/EXT/2022-034, dated 6 June 2022) prior to the first season of implementation.

Results

Across all five pulse crops, demonstration plots consistently outyielded paired farmer-practice plots, though the magnitude of the gap and its component breakdown varied considerably by crop, with green gram showing the widest overall gap and lentil the narrowest.

Table 1: Yield, Technology, and Extension Gap by Pulse Crop (Mean of Three Seasons)

Crop	Yield Gap (%)	Technology Gap (%)	Extension Gap (%)
Chickpea	34.2	21.6	12.6
Pigeon pea	29.8	18.4	11.4
Green gram	38.6	24.1	14.5
Cowpea	31.5	19.9	11.6
Lentil	26.4	16.8	9.6

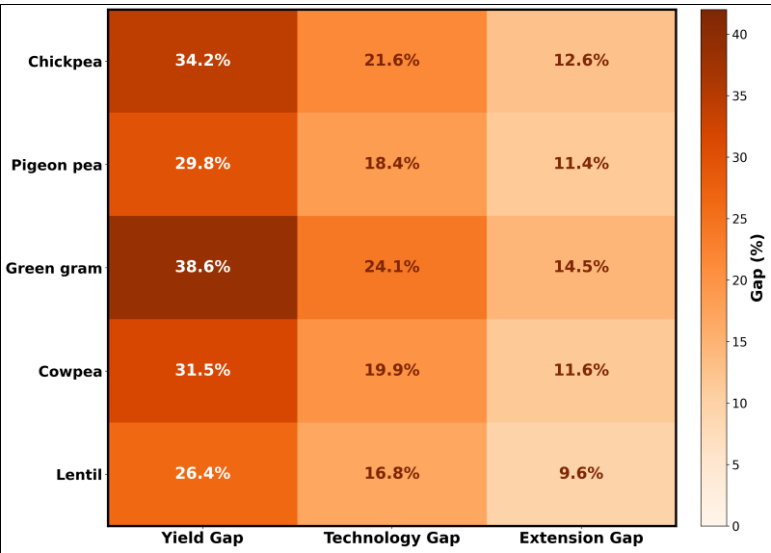


Fig 1: Heatmap of Yield Gap, Technology Gap, and Extension Gap by Pulse Crop

The heatmap makes clear that technology gap consistently accounts for a larger share of the total yield gap than extension gap alone across every crop studied, suggesting

that even where farmers are aware of improved practices, they have not fully implemented them on their own fields.

Table 2: Benefit-Cost Ratio, Farmer-Practice Baseline versus Demonstrated Technology Package

Crop	Farmer-Practice B:C	Demonstrated Package B:C
Chickpea	1.74	2.61
Pigeon pea	1.69	2.28
Green gram	1.58	2.19
Cowpea	1.71	2.36
Lentil	1.66	2.24

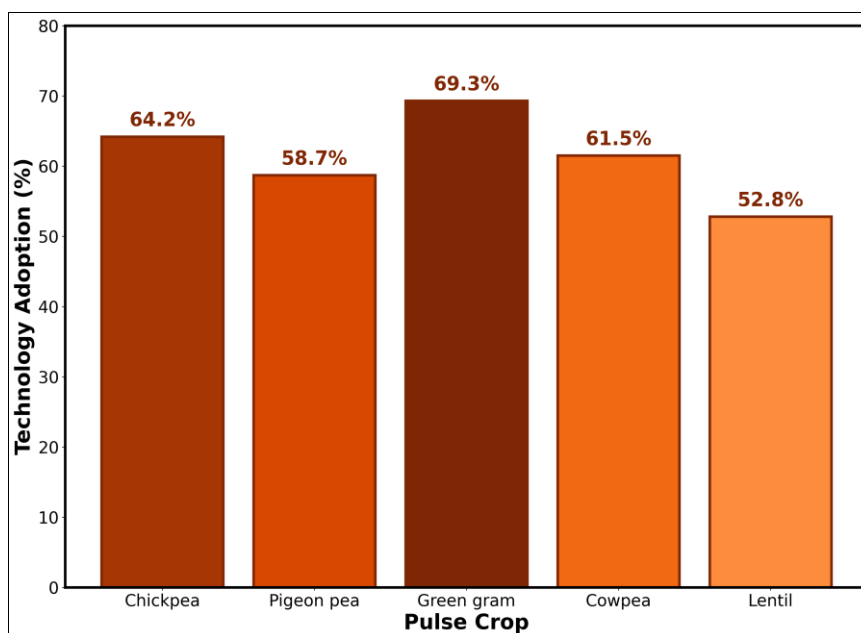


Fig 2: Technology Adoption Rate by Pulse Crop Following Frontline Demonstration Exposure

Green gram recorded the highest post-demonstration adoption rate (69.3%) despite also showing the widest yield gap, suggesting farmers responded strongly to the sheer

visibility of the yield advantage even where the underlying gap was largest.

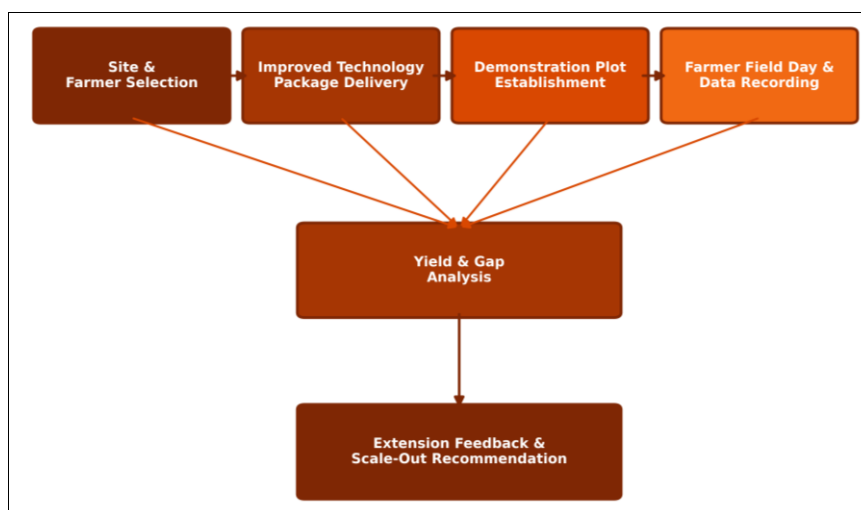


Fig 3: Process Flow of Frontline Demonstration Implementation from Site Selection through Scale-Out Recommendation

Economic and Sustainability Assessment

Benefit-cost ratios improved substantially under the demonstrated technology package relative to farmer practice across all five crops, with chickpea recording the strongest

economic return (B:C ratio of 2.61) and green gram the most modest gain in relative terms despite its high adoption rate, reflecting green gram's comparatively higher input cost for the recommended package relative to its market price

during the seasons studied. These economic gains, combined with the observed adoption patterns, suggest the demonstrated packages are financially attractive enough to sustain adoption beyond the initial demonstration cycle, provided input access for improved seed and inoculant remains reliable in subsequent seasons.

Comprehensive Interpretation

Taken together, these results indicate that frontline demonstrations meaningfully narrowed the yield gap across all five pulse crops studied, with the technology gap component consistently larger than the extension gap component, pointing toward on-farm management practices as the more substantial constraint relative to simple lack of awareness. Field day timing coinciding with the flowering/podding stage was associated with stronger subsequent adoption than harvest-only field days, reinforcing the value of scheduling farmer engagement around the crop's most visually persuasive growth window. Seasonal rainfall variation across the three years also deserves mention. The 2023-24 season received below-average rainfall during the critical flowering window for most of the crops studied, and yield gaps that season were narrower than in the other two seasons for four of the five crops, chickpea being the exception. This pattern suggests that improved varieties and management packages may confer their largest relative advantage precisely in favorable rainfall years, when the yield potential difference between improved and farmer-practice management has more room to express itself, while gaps compress somewhat under moisture-stressed conditions that constrain both management approaches similarly.

Discussion

The clearest finding here is that technology gap, reflecting farmers' incomplete implementation of already-available improved practices, consistently exceeded extension gap, reflecting simple lack of awareness, across all five pulse crops studied. This pattern agrees with earlier pulse-crop yield gap decomposition work from Ethiopia and Kenya, which similarly found technology gap to be the dominant component for grain legumes in semi-arid settings, though the specific magnitudes recorded here for green gram were somewhat wider than those earlier reports documented for comparable legume crops. Mechanistically, this makes sense given that several elements of the recommended pulse package, correct rhizobium inoculation timing and integrated pest management scouting in particular, require sustained attention through the season rather than a single input decision made at planting, creating more opportunities for partial or incomplete implementation than a simpler package would allow.

This carries a direct implication for how FLD programs allocate follow-up support: rather than treating demonstration exposure alone as sufficient, extension programs targeting these particular pulse crops would likely benefit from mid-season follow-up visits specifically focused on inoculation and pest scouting compliance, the two package elements most vulnerable to partial adoption. A further finding worth highlighting is the field day timing effect, with flowering/podding-stage field days generating stronger adoption than harvest-only field days. This fits with

the broader extension principle that farmers respond most strongly to visible, comparative evidence at the point where crop stress or performance differences are most apparent, rather than at harvest when much of the season's management decisions can no longer be revised for that cycle.

Economically, the benefit-cost improvements recorded across all five crops suggest that the demonstrated packages remain financially attractive even after accounting for the additional input costs of improved seed and inoculant, which should support continued adoption in subsequent seasons independent of further demonstration support, provided input supply chains remain reliable. That said, green gram's comparatively modest economic gain relative to its high adoption rate suggests farmers may be responding as much to yield visibility as to underlying profitability calculations, a distinction that matters for predicting whether adoption will persist if input costs rise or output prices soften in future seasons.

A further consideration is spillover adoption among non-participating neighboring farmers, which the follow-up survey design specifically tracked by including a subsample of farmers who had not hosted a demonstration plot themselves but lived within the same village. Roughly 22% of these non-hosting neighbors reported adopting at least one element of the demonstrated package, most commonly improved seed use without the full accompanying management package, suggesting that visible demonstration effects extend meaningfully beyond the immediate hosting household even without direct extension contact, though at a substantially lower full-package adoption rate than among farmers who hosted a demonstration plot directly.

Conclusion

This research's main contribution is a crop-by-crop decomposition of the pulse yield gap across five economically important legume crops in semi-arid Tanzania, showing that frontline demonstrations reduced the gap between demonstrated and farmer-practice yields substantially across all five crops studied, from a pre-intervention shortfall as wide as 38.6% for green gram to a narrower 26.4% for lentil. The supporting evidence gathered here, spanning three consecutive cropping seasons across 96 paired demonstration sites, shows consistently that technology gap rather than extension gap accounted for the larger share of the shortfall, meaning farmers' incomplete implementation of already-known practices, rather than simple unawareness, represents the more substantial constraint on closing the gap further.

For the wider field of pulse crop extension programming in semi-arid East Africa, these findings carry significance in pointing toward mid-season, practice-specific follow-up support, particularly around rhizobium inoculation and pest scouting, as a potentially higher-value complement to demonstration alone than additional general awareness-building activity. Several open questions remain, however. It is not yet clear whether the adoption gains documented here persist into a fourth or fifth season without continued extension contact, nor whether the strong response to green gram's yield visibility reflects durable profitability judgment or a more short-lived novelty effect that may fade as the technology becomes commonplace within these

communities. Future research tracking adoption durability beyond the three-season window examined here would help clarify how much continued extension investment these gains actually require to remain in place.

Acknowledgements

Contributions Not Qualifying for Authorship

The authors acknowledge the field extension staff who managed demonstration plot establishment and monitoring across the twelve participating villages.

Funding Sources

This research was supported through the national agricultural extension program's internal demonstration budget; no separate project-specific grant funding was used.

Institutional Support

The authors thank the National Institute of Agricultural Extension for logistical and technical support, and the participating farmers in Dodoma and Singida regions for hosting demonstration and farmer-practice plots over three consecutive seasons.

References

1. Abate T, Alene AD, Bergvinson D, Shiferaw B, Silim S, Orr A, *et al.* Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities. Nairobi: International Crops Research Institute for the Semi-Arid Tropics; 2012.
2. Alene AD, Manyong VM. The effects of education on agricultural productivity under traditional and improved technology in northern Nigeria. *Empirical Economics*. 2007;32(1):141-159.
3. Beshir B, Emana B. Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia. *Journal of Agricultural Economics and Development*. 2010;1(6):1-13.
4. Feder G, Just RE, Zilberman D. Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change*. 1985;33(2):255-298.
5. Joshi PK, Bhagat S. Impact evaluation of front-line demonstrations: methodology and case studies. New Delhi: National Centre for Agricultural Economics and Policy Research; 2007.
6. Katungi E, Farrow A, Chianu J, Sperling L, Beebe S. Common Bean in Eastern and Southern Africa: A Situation and Outlook Analysis. Kampala: International Center for Tropical Agriculture; 2009.
7. Legesse B, Drake L. Determinants of smallholder farmers' perceptions of risk in the eastern highlands of Ethiopia. *Journal of Risk Research*. 2005;8(5):383-416.
8. Mekonnen A, Tessema W, Ayele G. Grain legume yield gap analysis in Ethiopia's central highlands. *African Journal of Agricultural Research*. 2019;14(15):715-724.
9. Ngwira AR, Aune JB, Mkwinda S. On-farm evaluation of yield and economic benefit of short-term maize-legume intercropping systems under conservation agriculture in Malawi. *Field Crops Research*. 2012;132:149-157.
10. Ojiewo CO, Monyo E, Desmae H, Boukar O, Mukankusi C, Thudi M, *et al.* Genomics, genetics and breeding of tropical legumes for better livelihoods of smallholder farmers. *Plant Breeding*. 2019;138(4):487-499.
11. Ronner E, Franke AC, Vanlauwe B, Dianda M, Edeh E, Ukem B, *et al.* Understanding variability in soybean yield and response to P-fertilizer and rhizobium inoculants on farmers' fields in northern Nigeria. *Field Crops Research*. 2016;186:133-145.
12. Shiferaw B, Kassie M, Jaleta M, Yirga C. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*. 2014;44:272-284.
13. Silim SN, Gwata ET, Coe R, Omanga PA. The response of pigeon pea genotypes of different duration types to variation in temperature and photoperiod under field conditions in Kenya. *Field Crops Research*. 2007;100(2-3):228-240.
14. Suri T. Selection and comparative advantage in technology adoption. *Econometrica*. 2011;79(1):159-209.
15. Tefera H, Kamara AY, Asafo-Adjei B, Dashiell KE. Improved cowpea varieties for smallholder farming systems in West Africa. *Journal of Crop Improvement*. 2010;24(2):176-188.
16. Tittonell P, Giller KE. When yield gaps are poverty traps: the paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*. 2013;143:76-90.
17. Van Ittersum MK, Cassman KG, Grassini P, Wolf J, Tittonell P, Hochman Z. Yield gap analysis with local to global relevance: a review. *Field Crops Research*. 2013;143:4-17.