

Gender-responsive versus gender-transformative socio-technical innovation bundles and reported crop-loss buffering under agricultural shocks in Kenya

Eileen Bogweh Nchanji

International Center for Tropical Agriculture

Oscar Ingasia Ayuya

Egerton University

Dessalegn Molla Ketema

D.Ketema@cgiar.org

International Center for Tropical Agriculture

Cosmas Kweyu Lutomia

International Center for Tropical Agriculture

Research Article

Keywords: Gender-transformative innovations, gender-responsive innovations, socio-technical innovation bundles, agricultural shocks, climate change, crop loss buffering, climate resilience, smallholder farmers, Kenya

Posted Date: September 29th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10976635/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Agricultural and development research interventions are increasingly bundling technological innovations and services to address multiple challenges across agri-food systems in sub-Saharan Africa. Less is known about whether bundling technologies and technical innovations with gender-responsive and transformative components is associated with their performance under agricultural shocks. This study compares the association between farmer-reported crop loss reduction probability for gender-transformative socio-technical innovation bundle (GT-STIB) plots and gender-responsive socio-technical innovation bundle (GR-STIB) plots. The analysis is restricted to 108 shock-exposed plots from 85 farm households in Embu, Makueni and Nakuru counties.

Results

Farmers reported 90% and 67% crop loss reduction on GT-STIB and GR-STIB plots, respectively. County, season, crop and shock category-adjusted logistic regression results showed a difference of 18.7 percentage points in the predicted probability of farmers reporting crop loss reduction between GT-STIB (0.891) and GR-STIB (0.704) plots (95% CI – 1.0 to 38.4; $p = .063$). When the model was further adjusted for technological or practice breadth, technical innovation breadth, gender-responsive social breadth and institutional support, the differences between the predicted probabilities of crop reduction on GT-STIB and GR-STIB plots declined to 14.9 percentage points (95% CI – 2.5 to 32.3; $p = .094$). Greater agronomic practice intensity was also associated with reported crop loss reduction, with every additional agronomic practice on a six-practice score associated with a 7.2 percentage point (95% CI 1.8 to 12.6; $p = .010$) increase in predicted probability or reduced crop losses under agricultural shocks. Soil or water and diversification practices were associated with increases of 9.1 and 11.2 percentage points in probability of crop loss avoided under agricultural shocks, respectively. Monetary avoided-loss estimates were positive in most specifications but imprecise and sensitive to the strongly right-skewed upper tail.

Conclusions

GT-STIBs were associated with a higher probability of farmer-reported crop-loss avoided than GR-STIBs, but this association does not establish that gender-transformative components caused the difference or generated higher monetary returns. However, the findings suggest that the social and gender organisation surrounding agricultural technologies may form part of the productive architecture of agricultural risk management. Gender-transformative innovations should therefore be tested and promoted alongside agronomic and technical interventions, but any causal relationship should be based on repeated observations and objectively measured production and economic losses.

1. Introduction

Smallholder farming is exposed to weather, biological, market and input shocks that can reduce production and weaken households' capacity to maintain their livelihoods. Resilience has therefore become an important concept in agrifood systems transformations and research, although there is less agreement on how to measure it. Some approaches define resilience in terms of individuals', households', or systems' capacities to withstand or recover from shocks, while others define the concept in terms of the probability of maintaining an acceptable level of welfare over time [1, 2]. Consequently, there is greater variation in both the definitions of resilience and the methods for measuring it [3]. Much of the available evidence on the measurement of resilience is based on cross-sectional data under a limited range of agricultural shocks and settings. A study by Phadera et al. [4], which used repeated observations from rural Zambia to examine resilience to shocks, shows the value of longitudinal data for assessing whether interventions alter the probability of maintaining welfare after shock. However, such data remain largely unavailable, limiting observation of changes in welfare trajectories from interventions designed to build resilience to agricultural shocks. The current study, therefore, does not estimate resilience in the broader longitudinal sense but examines whether different social and gender architectures of STIBs are associated with reductions in reported crop loss among shock-exposed plots.

Combining technologies and services rather than promoting them separately is increasingly common in agricultural and development research, in recognition that constraints to agricultural production are complementary and that addressing one constraint may change the returns to addressing another. Bundling of farm inputs such as improved seeds and fertilizers with mechanisation and financial services such as credit and insurance has been promoted in sub-Saharan Africa to increase technological adoption and productivity in the face of climate change [5, 6]. Farmers themselves also combine agronomic practices, and results are often reported to be positive. In Southern Africa and Kenya, for example, Mutenje et al. [7] and Nyarindo et al. [8] find substantial differences in yield, costs, revenue and net income when farmers combine sustainable climate-smart practices and conclude that bundling is economically viable. Smallholder farmers consequently prefer agricultural inputs and services that can be bundled for improved farm production [9]. Much of this literature, however, concerns combinations of technological, agronomic or financial innovations. Evidence on whether the social and gender composition of a bundle is also associated with its productive performance remains less visible.

Social arrangements influence access to resources, information, labour and decisions over their use. This makes gender and inclusion relevant questions in bundling technological and technical innovations for resilient systems. It is therefore inadequate to represent gender solely by the sex of the farmer or household head, as this can obscure rather than clarify the underlying distribution of resources and responsibilities needed to build resilience to shocks [10]. Agricultural innovations affect women and men through both separate and joint interests within the same farming system, and gender norms can constrain women's ability to respond to new opportunities [11]. Research also indicates that gender norms are part of the enabling environment for agricultural innovation and ought not to be treated as an external issue to the system [12]. From a policy perspective, Ampaire et al. [13] argue that agricultural and climate policies may be gender-responsive yet still inadequate to address the structural inequalities underlying observed gender gaps in agri-food systems. Gender-transformative interventions move

beyond accommodation of women in policies and programmes to addressing norms, power relations and other structural constraints they face within existing arrangements [14]. The distinction between gender-responsive and gender-transformative innovations is therefore not a simple distinction between women and men farmers, but rather a distinction in the social architecture surrounding agricultural production.

This, however, should not be misinterpreted as implying that gender-transformative interventions must improve agricultural performance under shock, because much of the existing literature has focused more on empowerment, attitudes, access to services and changes in gender relations than on production losses after agricultural shocks. In Zambia, Cole et al. [15] found that larger improvements in gender-equitable attitudes and women's empowerment occurred under the transformative approach compared with gender-accommodative arrangements. Nyamolo et al. [16] likewise report higher empowerment among farmers exposed to co-designed innovation bundles in Kenya. However, none of these studies establishes whether the transformative component itself improves the performance of agricultural technologies under agricultural shock. The association between gender-transformative socio-technical innovation bundles (GT-STIBs) and resilience to agricultural shocks may differ from that of gender-responsive STIBs (GR-STIBs), given that gender-transformative interventions are designed to address social norms surrounding adoption and decision-making. However, existing studies have not addressed this; therefore, any comparison of gender-responsive and gender-transformative STIBs must distinguish how these two gender architectures can perform alongside technological and technical innovation in a shock-prone production environment.

The closest existing studies also indicate where the present analysis's contribution should be situated. Mutenje et al. [7] provide substantially stronger evidence on the profitability of climate-smart technology combinations using two years of data from Malawi, Mozambique and Zambia, and incorporate women's bargaining power as a determinant of investment choice. Gender in that study helps explain which technological bundle farmers choose but is not itself a constituent component of the technological bundle being evaluated. FAO [17] provides a stronger basis for estimating avoided agricultural losses by comparing disaster-risk-reduction practices with previously used practices on farms under hazard and non-hazard conditions. Its design, therefore, offers a counterfactual for the avoided damage that the present study lacks. The present study does not improve on these studies in causal identification, formal cost-benefit analysis or measurement of avoided loss. It addresses a different margin by asking whether the GT-STIB or GR-STIB is associated with farmers' shock buffering.

This study examines that question using plot-level data from farmers in Embu, Makueni and Nakuru counties in Kenya. GR-STIBs combine technological and technical innovations with gender-responsive social and/or institutional components. GT-STIBs share the same basic technological and technical architecture, along with at least one gender-transformative social innovation. Technological, technical, and social innovations (gender-responsive and gender-transformative components) that constitute a STIB are identified in section 2.2. The analysis asks whether the probability of farmer-reported crop loss reduction differs between the two social and gender architectures, and whether any observed difference

remains after accounting for measured technological, technical, gender-responsive social and institutional composition. The study also examines whether the architectures differ in the reported monetary value of avoided loss. A separate analysis examines whether crop-loss reduction is associated with the agronomic intensity of the bundles. The resulting estimates are interpreted as conditional associations rather than causal effects because allocation to GR-STIBs and GT-STIBs was not randomized and the shock-buffering outcomes are farmer-reported. The empirical contribution of the present study is, consequently, the performance of bundled innovations under shocks, differentiated by the social and gender architecture of their components.

The remainder of the paper is organized as follows. Section 2 describes the classification of gender-responsive and gender-transformative socio-technical innovation bundles, study design and analytical sample, outcome measures and the econometric specification. Section 3 presents descriptive characteristics of the shock-exposed plots and reports the association between bundle architecture and both the probability of a reported reduction in crop loss and the value of avoided losses. Section 4 discusses these findings in relation to the existing literature, and Section 5 concludes.

2. Materials and methods

2.1 Study design and analytical sample

Data used are drawn from a study that targeted farmers who participated in the HER + and Ukama Ustawi socio-technical innovation bundling work in Embu, Makueni and Nakuru counties between 2022 and 2024. The sample comprised 213 participants from the earlier baseline cohort of 376 project farmers [18]. Where a target participant was unavailable, a replacement was drawn from the original project roster.

Plot eligibility was determined before the shock analysis. A plot was retained if a household planted at least one target crop (maize, common bean or vegetables) and applied at least one relevant technological and one technical innovation linked to the initiatives. These are crops targeted by the socio-technical innovation-bundling work in the three counties. Data were collected from 417 plots, out of which 310 met these crop and innovation conditions. Social and gender-transformative components were measured at the household level and linked to the household's eligible plots. The analysis then conditioned on realised production shocks: 108 plots, belonging to 85 households, reported a shock and were retained for the crop-loss analysis. The conservative monetary outcome was observed for 107 of the 108 shock-exposed plots.

2.2 Classification of socio-technical innovation bundles

STIBs were defined from four innovation domains. Technological innovations comprised material technologies and production practices, including improved seed varieties, mechanisation, conservation agriculture, and other climate-smart agronomic practices. Technical innovations comprised demonstrations, field days, agronomic and crop protection training, soil and water management training

(including minimum or no tillage, moisture management practices, and mulch or residue retention), post-harvest training, mechanisation guidance, extension advice, and digital advisory services. Social innovations captured collective and relational arrangements around farming and household decision-making. Gender-responsive social innovations included membership in farmer groups, peer learning, collective access to inputs, collective marketing, savings mechanisms, leadership or governance support and other non-transformative social arrangements. Gender-transformative innovations were gender training, gender-transformative nutrition, household dialogue or couple planning, and support for inclusion in farming decisions. Subsidy was treated separately as an institutional innovation.

A plot was classified as a STIB when technological and technical innovations were combined with at least one social or institutional enabling innovation [18]. GR-STIBs contained technological and technical innovations together with gender-responsive social and/or institutional innovations and no recorded gender-transformative component. GT-STIBs shared the same basic technological and technical architecture, with at least one gender-transformative component; they could also include gender-responsive social and institutional innovations. Among the 108 shock-exposed plots, 39 were classified as GR-STIBs and 69 as GT-STIBs.

2.3 Outcome measures

The main non-monetary outcome indicated whether the farmer reported that the practices or innovations used on the plot reduced crop losses during the realised shock relative to usual practice under similar conditions. This operational definition of resilience corresponds to the absorptive resilience dimension targeted by the project. It represents respondent-attributed buffering of crop output conditional on shock exposure rather than an observed output. The monetary outcome measured conservatively reported avoided loss per hectare. It was the sum of the reported value of harvest preserved, avoided replanting or re-establishment costs, and avoided extra remedial expenditure. Avoided labour costs were excluded from this measure and examined only in sensitivity analyses. An explicit 'no' to an avoided cost component was assigned a value of zero; where the farmer reported an avoided cost but did not provide an amount, the value was left missing. The monetary regressions used the inverse hyperbolic sine (IHS) transformation because the distribution of the screened values in Kenyan shillings per ha contained zeros and was strongly right-skewed. A quasi-Poisson log-link specification on the raw non-negative outcome was used for sensitivity checks.

2.4 Econometric specification

Binary crop loss reduction model

The empirical analysis relates the gender architecture of the STIB to farmer-reported shock buffering at plot level. Let p index plots and h households. The main explanatory variable, G_{ph} , equals one (1) for a GT-STIB and zero (0) for a GR-STIB. The principal binary outcome, Y_{ph} , equals 1 when the farmer reported that the practices or innovations used on plot p reduced crop losses during the realised shock, and 0 otherwise. For the binary outcome, the conditional probability of reported crop loss reduction was estimated using a logistic response model:

$$\Pr(Y_{ph} = 1 \mid G_{ph}, X_{ph}) = \Lambda(\alpha + \beta G_{ph} + X'_{ph}\gamma)$$

1

where $\Lambda(\cdot)$ is the logistic cumulative distribution function, X_{ph} contains county indicators, reference season, a maize-versus-non-maize indicator, and shock category. The shock category distinguishes weather or rainfall shocks (drought or long dry spell, excess rainfall or flooding, and late onset of rain), pest or disease shocks, and input or other shocks (input shortage or late input access, and other specified shocks). The coefficient β captures the conditional difference between GT-STIB and GR-STIB plots on the log-odds scale. Because log-odds coefficients are not directly interpretable as probability differences, results are reported as average marginal effects (AME).

For the binary GT-STIB indicator, the reported AME is the sample-average discrete change in predicted probability when the archetype is changed from GR-STIB to GT-STIB, holding the observed covariates at their sample values:

$$AME_{GT} = \frac{1}{N} \sum_{ph} \{\Lambda(\alpha + \beta + X'_{ph}\gamma) - \Lambda(\alpha + X'_{ph}\gamma)\}$$

2

Equation (1) compares the two STIB archetypes conditional on observable production context. A second specification additionally controls for observed differences in the non-transformative composition of the bundles:

$$\Pr(Y_{ph} = 1 \mid G_{ph}, X_{ph}, Z_{ph}) = \Lambda(\alpha + \beta G_{ph} + X'_{ph}\gamma + Z'_{ph}\delta)$$

3

where Z_{ph} contains technological or practice breadth, technical innovation breadth, gender-responsive social breadth, and an indicator for institutional subsidy or in-kind support. This specification is a composition-adjusted comparison between the two observed bundle archetypes and should not be interpreted as a causal effect or as a formal mediation model. Respondent sex was added to Eq. (3) in a further sensitivity specification. Robust standard errors were clustered at the household level to allow arbitrary correlation in the regression errors across plots reported by the same household.

Monetary avoided loss model

Let M_{ph} denote conservative farmer-reported avoided loss in KES per hectare. M_{ph} is non-negative, contains zero values, and is strongly right-skewed. The principal monetary specification therefore uses the IHS transformation:

$$M_{ph}^* = \text{asinh}(M_{ph}) = \ln \left[M_{ph} + \sqrt{M_{ph}^2 + 1} \right]$$

4

The transformed outcome was estimated by linear regression using the same contextual covariates as the binary model:

$$M_{ph}^* = \alpha_m + \theta G_{ph} + X'_{ph} \gamma_m + \varepsilon_{ph}$$

5

with a composition-adjusted specification obtained by adding Z_{ph} to Eq. (5). The coefficient θ is reported in inverse-hyperbolic-sine units and is not mechanically interpreted as a percentage effect. Household-clustered robust standard errors were used.

Two sensitivity checks were used for the monetary outcome. First, Eq. (5) was re-estimated after screening observations flagged by the pre-specified plausibility checks. Second, a quasi-Poisson pseudo-maximum-likelihood specification with a log link was estimated on the raw non-negative KES/ha outcome:

$$E(M_{ph} | G_{ph}, X_{ph}, Z_{ph}) = \exp(\alpha_q + \theta_q G_{ph} + X'_{ph} \gamma_q + Z'_{ph} \delta_q)$$

6

The quasi-Poisson model is used as a conditional-mean robustness check and does not require the monetary outcome to be count data. With robust clustered inference, the coefficient on GT-STIB is interpreted after exponentiation as a conditional mean ratio.

Agronomic practice-intensity models

To examine whether reported shock buffering varied with the agronomic content of the bundles, A_{ph} was defined as the number of six practices used on the plot: minimum or no tillage, moisture management, intercropping, crop rotation, mulching, and integrated pest management. The association with reported crop loss reduction was estimated as:

$$\Pr(Y_{ph} = 1 | A_{ph}, X_{ph}) = \Lambda(\alpha_a + \rho A_{ph} + X'_{ph} \gamma_a)$$

7

The marginal effect of A_{ph} is reported as the average change in predicted probability associated with one additional agronomic practice. To distinguish broad agronomic domains, the count was decomposed into soil and water practices (SW_{ph}), diversification practices (intercropping and crop rotation) (D_{ph}), and integrated pest management (IPM_{ph}), which were entered jointly:

$$\Pr(Y_{ph} = 1 | SW_{ph}, D_{ph}, IPM_{ph}, X_{ph}) = \Lambda(\alpha_d + \rho_1 SW_{ph} + \rho_2 D_{ph} + \rho_3 IPM_{ph} + X'_{ph} \gamma_d)$$

8

All models are estimated on the shock-exposed analytical sample. Accordingly, the coefficients describe conditional associations among plots that experienced a realised shock. They do not identify the causal effect of assignment to GT-STIBs, of individual bundle components, or of shock exposure itself.

3. Results

3.1 Descriptive characteristics

Table 1 presents summary statistics for variables constructed from surveys of farmers and used in the analysis. Of the 108 shock-exposed plots, 69 (64%) were GT-STIBs, and 39 (36%) were GR-STIBs. Among GT-STIB plots, 39% were in Makueni compared with 18% among GR-STIB plots, whereas 49% of GR-STIB plots were in Embu compared with 30% of GT-STIB plots. About 36% of GT-STIB plots experienced pest or disease shocks compared to 13% of GR-STIB plots. GR-STIB plots were more exposed to weather or rainfall shocks than GT-STIB plots. Female respondents represented 71% of GT-STIB plots and 77% of GR-STIB plots.

The GT-STIB group also had higher mean technological or practice breadth (10.35 versus 9.62 components), technical innovation breadth (5.77 versus 5.13), gender-responsive social breadth (3.42 versus 1.90), and agronomic practice intensity (4.61 versus 4.08). Institutional subsidy or in-kind support was less common among GT-STIB plots (41%) but more common among GR-STIB plots (64%). Crop loss reduction was reported on 62 of 69 GT-STIB plots (90%) and 26 of 39 GR-STIB plots (67%). However, this pattern was not universal, as shown by seven GT-STIB plots and 13 GR-STIB plots that reported no reduction in crop loss (Table 1).

Table 1
Descriptive statistics of shock-exposed plots by STIB archetype

Variable	All plots	GR-STIB	GT-STIB
Number of plots	108	39	69
Female respondents, n (%)	79 (73.1)	30 (76.9)	49 (71.0)
Panel A. County, n (%)			
Embu	40 (37.0)	19 (48.7)	21 (30.4)
Makueni	34 (31.5)	7 (17.9)	27 (39.1)
Nakuru	34 (31.5)	13 (33.3)	21 (30.4)
Panel B. Shock category, n (%)			
Weather or rainfall	60 (55.6)	26 (66.7)	34 (49.3)
Pest or disease	30 (27.8)	5 (12.8)	25 (36.2)
Input or other	18 (16.7)	8 (20.5)	10 (14.5)
Panel C. Bundle composition			
Technological/practice count, mean (SD)	10.08 (1.61)	9.62 (1.74)	10.35 (1.48)
Technical innovation count, mean (SD)	5.54 (0.88)	5.13 (1.22)	5.77 (0.49)
GR social count, mean (SD)	2.87 (1.49)	1.90 (0.97)	3.42 (1.45)
Institutional subsidy/in-kind support, n (%)	53 (49.1)	25 (64.1)	28 (40.6)
GT social count, mean (SD)	1.24 (1.21)	0.00 (0.00)	1.94 (0.95)
Six-practice agronomic intensity, mean (SD)	4.42 (1.32)	4.08 (1.26)	4.61 (1.32)
Panel D. Outcomes			
Reported crop-loss reduction, n (%)	88 (81.5)	26 (66.7)	62 (89.9)
Conservative avoided loss, median [IQR], KES/ha	21,004	18,121	21,473
	[9,514 – 43,985]	[3,212 – 47,148]	[10,523 – 43,491]
<i>Notes: Values are n (%) for categorical variables and mean (SD) for continuous counts unless otherwise indicated. GR = gender-responsive; GT = gender-transformative; STIB = socio-technical innovation bundle; IQR = interquartile range. The conservative avoided-loss measure is available for 107 plots overall (39 GR-STIB and 68 GT-STIB).</i>			

3.2 GR-STIB versus GT-STIB and reported crop-loss reduction

Results in Table 2 are obtained from logistic regression model that adjusted for county, season, main crop and shock category. The average marginal difference was 0.187, equivalent to 18.7 percentage points (95% CI -1.0 to 38.4 percentage points; $p = .063$). The predicted probability of reported crop loss reduction was 0.704 for GR-STIB plots and 0.891 for GT-STIB plots (Fig. 1). The confidence interval included zero, indicating that both estimates were statistically imprecise at the conventional 5% level.

Table 2
Association between STIB archetype and reported crop-loss reduction

GT-STIB (ref. GR-STIB), AME	Model 1	Model 2	Model 3
	0.187*	0.149*	0.149*
	(0.101)	(0.089)	(0.089)
Adjusted probability: GR-STIB	0.704		
Adjusted probability: GT-STIB	0.891		
Contextual controls	Yes	Yes	Yes
Technological, technical, GR-social and institutional composition	No	Yes	Yes
Respondent sex	No	No	Yes
Plots	108	108	108
Household clusters	85	85	85
<i>Notes: Entries for GT-STIB are average marginal effects from logistic regression; delta-method standard errors are in parentheses. Model 1 adjusts for county, reference season, maize versus non-maize main crop, and shock category. Model 2 additionally adjusts for technological/practice breadth, technical-innovation breadth, GR-social breadth and institutional subsidy/in-kind support. Model 3 additionally adjusts for respondent sex. Standard errors are clustered by household. * $p < .10$, ** $p < .05$, *** $p < .01$.</i>			

When the breadth of use of technological or climate-smart practice, technical, gender-responsive social, and institutional innovations were added to logistic regression were added to the model, the estimated difference declined to 14.9 percentage points (95% CI -2.5 to 32.3; $p = .094$). Adding respondent sex changed the estimate little (14.9 percentage points; 95% CI -2.5 to 32.3; $p = .092$). Thus, adjustment for observed bundle composition attenuated the estimated difference, whereas adjustment for respondent sex had little additional influence.

3.3 Monetary value of reported avoided loss

Reported avoided loss was strongly positively skewed as shown in Table 3. The median was KES 18,121/ha for GR-STIB plots and KES 21,473/ha for GT-STIB plots, with overlapping interquartile ranges (Table 1). The corresponding arithmetic means were KES 45,326/ha and KES 247,619/ha, respectively, reflecting a small number of large values in the GT-STIB distribution. In the IHS model with contextual controls, the GT-STIB coefficient was 1.675 (95% CI -0.266 to 3.615; $p = .090$). The coefficient declined to

1.046 after adjustment for bundle composition (95% CI -0.945 to 3.038; $p = .299$). In a sensitivity analysis excluding plots flagged for unusually high unit prices or plot areas below 0.05 acre, the GT-STIB coefficient remained positive but imprecisely estimated (1.507; 95% CI - 0.431 to 3.445; $p = .126$). The quasi-Poisson conditional mean ratio was 1.22 (95% CI 0.17 to 8.87; $p = .845$). The monetary estimates were therefore positive in most specifications but imprecisely estimated and sensitive to the treatment of the upper tail.

Table 3
Association between STIB archetype and conservative reported avoided loss

GT-STIB (ref. GR-STIB)	Model 1	Model 2	Model 3	Model 4
	1.675*	1.046	1.507	1.219
	(0.976)	(1.001)	(0.974)	[0.168–8.866]
Outcome	IHS conservative KES/ha	IHS conservative KES/ha	IHS screened KES/ha	Raw KES/ha
Contextual controls	Yes	Yes	Yes	Yes
Full non-GT bundle composition	No	Yes	Yes	Yes
Plots	107	107	103	107
Household clusters	85	85	83	85
<i>Notes: Models 1–3 report regression coefficients for the inverse-hyperbolic-sine (IHS) transformed avoided loss outcome; robust standard errors are in parentheses. Model 3 uses the screened monetary outcome. Model 4 is a quasi-Poisson log-link sensitivity model and reports the conditional mean ratio with its 95% confidence interval in brackets. Contextual controls are county, reference season, maize versus non-maize main crop, and shock category. Full non-GT composition includes technological/practice breadth, technical-innovation breadth, GR-social breadth and institutional subsidy/in-kind support. Standard errors are clustered by household. * $p < .10$, ** $p < .05$, *** $p < .01$.</i>				

3.4 Agronomic practice intensity and reported crop loss reduction

Reported crop loss reduction also varied with agronomic practice intensity as shown in Table 4. Each additional practice in the six-practice score was associated with a 7.2 percentage point increase in the adjusted probability of reported loss reduction (95% CI 1.8 to 12.6; $p = .010$). In the joint domain model, the corresponding marginal effects were 9.1 percentage points for each additional soil or water practice (95% CI 1.2 to 16.9; $p = .023$) and 11.2 percentage points for each additional diversification practice (95% CI 0.8 to 21.6; $p = .035$). The marginal effect for integrated pest management was - 9.4 percentage points (95% CI -25.9 to 7.1; $p = .263$). A Wald test did not reject equality of the three domain coefficients on the logit scale ($p = .203$).

Table 4
Agronomic practice intensity and reported crop-loss reduction

Average marginal effect	Six-practice intensity	Soil/water count	Diversification count	IPM
	0.072***	0.091**	0.112**	-0.094
	(0.028)	(0.040)	(0.053)	(0.084)
Contextual controls	Yes	Yes	Yes	Yes
Joint agronomic-domain model	No	Yes	Yes	Yes
Plots	108	108	108	108
Household clusters	85	85	85	85
<i>Notes: Average marginal effects are reported with delta-method standard errors in parentheses. The six-practice intensity model is estimated separately. Soil/water, diversification and IPM estimates are from the joint domain model. All models adjust for county, reference season, maize versus non-maize main crop, and shock category, with standard errors clustered at the household level. * $p < .10$, ** $p < .05$, *** $p < .01$.</i>				

4. Discussion

The results indicate that the gender architecture of STIBs may matter for how smallholder farmers experience agricultural shocks. Results after adjusting for county, season, crop and shock type indicated that GT-STIB an average difference of 18.7 percentage points in crop loss reduction due to shocks between GT-STIB plots (0.891) crop loss reduction and GR-STIB plots (0.704). The estimate is economically sizeable, although it is imprecisely estimated and its 95% confidence interval includes zero. Further adjustment after accounting for technological or practice breadth, technical innovation breadth, gender-responsive social innovations and institutional support attenuated the observed difference to 14.9 percentage points and changed little when respondent sex was added. Although this finding is not evidence that adding a gender-transformative component causes greater resilience, it shows that the observed difference between the two bundle architectures is not fully accounted for by the measured technological, technical, gender-responsive social and institutional content of the bundles.

This result extends a growing literature on innovation bundling in agriculture. Recent studies in Kenya find positive associations between STIB adoption and crop productivity, empowerment, and food security [16, 19–23]. However, the present results differ from findings presented in these studies in one important respect. They do not compare bundled interventions with non-bundled technologies or programme participants with non-participants. Instead, they compare two forms of bundling among farmers already exposed to technological and technical innovations. This narrows the empirical question to whether the social and gender architecture accompanying agricultural innovations is associated with their performance under realised shocks. Such a distinction is important because complementarity within bundles may arise from both between technologies and between technologies and the

institutions, knowledge and household arrangements needed to use them. This argument is well founded in the literature. In Mozambique and Tanzania, for example, Boucher et al. [24] found that combining drought-tolerant seed with index insurance protected farmers more fully against varying degrees of drought than either instrument could alone.

The attenuation of the GT-STIB estimate after adjustment for bundle composition deserves particular attention. GT-STIB plots had greater technological, technical, gender-responsive social and agronomic breadth than GR-STIB plots. By contrast, institutional subsidy of seeds, fertilizers, and mechanisation services was more common among GR-STIB plots than GT-STIB plots. A simple comparison of the two archetypes could therefore attribute to the gender-transformative layer what is, in part, a consequence of receiving a more extensive package of socio-technical bundling interventions. The composition-adjusted model reduces this concern but does not eliminate it. The remaining difference may reflect the transformative components, unmeasured differences in programme exposure, farmer selection, household capacity or other attributes correlated with both bundle composition and shock management. This is consistent with agricultural economics evidence showing that access to resources, information, ownership and decision-making authority influence which combinations of climate-smart practices farmers use. Teklewold [25], using plot-level panel data from four African countries, finds that ownership, management and control over agricultural returns are associated with portfolio adoption, while Hailemariam et al. [26] show that gender gaps in climate-smart technology adoption are partly related to information, farm characteristics, resources and social norms. Thus, household decision-making arrangements can plausibly affect choices without implying that any observed difference is attributable solely to gender transformation.

There is nonetheless a plausible economic interpretation for why gender-transformative components could complement technical and technological innovations. Household dialogue, gender training and greater inclusion in farming decisions may change who contributes information, how labour and inputs are allocated, and whether production decisions are coordinated across household members. These mechanisms concern the use of productive resources rather than empowerment as an end in itself. Anderson et al. [27] identify resource access and changes in agricultural decision-making as possible pathways through which women's empowerment could generate economic benefits, although they also conclude that direct estimates of such economic returns remain limited. In the Kenyan STIB programme, Nyamolo et al. [16] reported higher empowerment among farmers in co-designed STIBs. It supports the possibility that social relations affect the ability to access and use agricultural innovations, but they do not establish the pathway observed here from gender-transformative content to shock buffering. The lack of change in the GT-STIB estimate after controlling for respondent sex is also insufficient to conclude that men and women benefit equally. This is because the male subsample in the present analysis is small, and respondent sex does not align with the gender relations captured by the bundle.

The agronomic results provide a more direct link between bundle content and agricultural risk management. There was 7.2 percentage point increase in the probability of reported crop-loss reduction for every additional agronomic practice applied by the farmer. However, this remains an association

between crop loss reduction and the intensity of adoption of agronomic practices. Joint association of agronomic practices showed that every additional soil or water practice was associated with a 9.1 percentage-point higher probability of crop loss reduction. Each additional diversification practice was associated with an 11.2 percentage-point increase in the probability of reducing crop losses. These estimates are consistent with the risk-reduction role attributed to diversified and resource-conserving production systems. Using Kenyan panel data, Bozzola and Smale [28] find that greater crop richness and evenness reduce farmers' exposure to downside crop-income risk, especially among more vulnerable households. Evidence from Malawi and Tanzania similarly shows that rainfall shocks induce farmers to diversify their crop portfolios, although the extent of this diversification depends in part on household assets [29]. More recent Ethiopian panel evidence finds that intercropping is associated with weaker drought-related losses in production, income and food-security outcomes, whereas crop rotation provides more selective protection [30]. The present results are therefore compatible with diversification and soil or water management providing complementary forms of buffering, but do not suggest that diversification is superior to soil and water management in reducing crop losses due to climate shocks.

The monetary results provide weaker evidence than the binary crop loss outcome. The KES 18,121 and KES 21,473 per-hectare median conservative avoided loss between the GR-STIB and GT-STIB plots differed relatively little. On the other hand, the arithmetic mean of GT-STIB plots differed substantially from the arithmetic mean of GR-STIB because of strongly positively skewed GT-STIB observations. The positive GT-STIB coefficient in the IHS specification decreased after adjusting for bundle composition and estimates from the screened and quasi-Poisson specifications remained imprecise.

These results do not justify a claim that GT-STIBs generated a higher monetary return. Rather, they show how quickly inferences about economic magnitude can become sensitive to valuation and to extreme observations when losses are reconstructed from farmers' reports. This distinguishes the present analysis from formal cost-benefit studies. Mutenje et al. [7], using two years of data from Malawi, Mozambique and Zambia, found several combinations of conservation agriculture, improved varieties and crop diversification to be economically viable. They also showed that women's bargaining power influenced investment choices, thereby shaping both farmers' technology bundle choices and their ex-post profitability. The novelty of the current study lies in the conditional agricultural performance following a shock and in the association between gender transformation, as part of the technology bundle, and that performance.

Another farm-level study by FAO [17] compared disaster-risk-reduction practices with previously used practices under observed hazard conditions and found benefits from both additional production and avoided damage. This provides stronger avoided-loss counterfactual comparator evidence than the current study because it directly measures disaster-related avoided damage and loss under observed hazard conditions, such as drought, floods, storms, frost, pests and diseases. Although this design provides a substantially stronger basis for estimating avoided losses or economic returns under climate shocks and technological/agronomic factors across multiple countries, the present study addresses a different question: whether adding gender-transformative social innovations to those practices is

associated with greater reported buffering during realized agricultural shocks. Thus, the contribution of the present study is not to provide a new method for valuing avoided agricultural loss, but to provide evidence that introducing gender-responsive or gender-transformative innovations into the bundle may alter the capacity to buffer shocks. Taken together, the strengths of FAO [17] and Mutenje et al. [7] relegates the novelty of the present study to the gender architecture of shock buffering rather than in the valuation of avoided loss itself.

Several qualifications are important in interpreting the results. First, the analysis is conditional on the 108 plots that experienced a reported shock. It therefore addresses buffering among shock-exposed plots and cannot establish whether either archetype reduces the probability of experiencing a shock or performs better in non-shock seasons. Second, both the exposure information and the principal buffering outcome come from farmer reports. Farmers who participated more intensively in socio-technical innovation bundling activities may be more inclined to attribute favourable outcomes to those activities. Objective measures of shock intensity would have addressed this disjuncture but are unavailable. Third, the comparison is observational. County and shock composition differed between GR-STIB and GT-STIB plots, and GT-STIBs contained more technological, technical and gender-responsive social components. Statistical adjustment reduces observed compositional differences but cannot address unobserved selection into the two architectures. These limitations are particularly relevant because gender-responsive innovation processes can themselves influence who participates, who receives information and who is able to sustain the use of innovation [31].

The observed data also provide a useful counterexample to an overly deterministic interpretation. Seven GT-STIB plots did not report reduced losses, whereas 26 GR-STIB plots did. Gender-transformative content was therefore neither necessary nor sufficient for reported shock buffering. The appropriate interpretation is a difference in the conditional probability of reporting reduced losses, not a division between effective GT-STIBs and ineffective GR-STIBs. This distinction also cautions against treating gender transformation as a substitute for agronomy, access to resources or technical support. Rather, the results are consistent with the proposition that these components operate jointly. This echoes recent work on women farmers in India, which finds that climate-smart technologies can fail to deliver lasting benefits when the underlying social and institutional constraints go unaddressed [32]. Research on gender-transformative agricultural programmes makes a related point: adopting transformative language or tools does not, on its own, guarantee structural change [33].

The main contribution of the analysis is therefore not evidence that gender transformation independently raises agricultural resilience. Existing studies have already shown that bundled agricultural technologies can improve productivity, food security and resilience, and that gender relations influence access to and use of agricultural innovations [7, 22–24]. The additional result here is that, within a set of programme-exposed STIBs, bundles containing gender-transformative social components were associated with a higher probability of reported crop loss buffering than bundles containing gender-responsive but no transformative components. That association remains sizeable, though imprecise, after adjustment for observable differences in the other bundle domains. For programme design, this suggests that the social

organisation surrounding climate-smart technologies should be treated as part of the productive system rather than as an ancillary equity component. Establishing its incremental economic return, however, will require designs that prospectively compare otherwise similar bundles with and without gender-transformative components, preferably across repeated shock and non-shock seasons and with independently measured production losses.

5. Conclusion

The study examined the association between gender-transformative components of STIBs and plot-level buffer against agricultural shocks. The results showed that GT-STIB was associated with a higher probability of plot-level reduction in crop losses under shocks than GR-STIB. Although the estimate was statistically imprecise, the difference in the probability of gender-transformative components in reducing crop losses compared with GR-STIB's probability remained sizeable even after adjusting for observed technological and social innovations, gender-responsive social and institutional components, as well as county, season, crop, and shock type. Greater agronomic practice intensity was also associated with a higher probability of reported crop-loss reduction, particularly through soil and water management and diversification practices. Avoided losses estimates were statistically inconclusive due to the strongly positively skewed distribution and the sensitivity of estimated differences between the two gender archetypes of STIBs to adjustments for bundle composition and extreme observations.

These findings, therefore, do not establish that gender-transformative components of STIBs independently buffered crop losses or generated higher monetary returns during shocks. Instead, the present study finds that among farmers already using technological and technical innovations, the social and gender configuration surrounding those innovations is associated with differences in reported performance under realised shocks. Some GT-STIB plots reported no loss reduction, as many GR-STIB plots also did. This suggests that gender-transformative content was neither necessary nor sufficient to buffer, and it cannot substitute for agronomic practices, which were associated with a higher probability of reported reductions in crop losses, particularly through soil and water management and diversification practices. However, the relevant conclusion drawn from the present study is that interventions should recognise the social organisation through which technologies are introduced and used. They should recognise that social innovations form part of the productive architecture of agricultural risk management and therefore gender should not be treated only as an equity consideration alongside agricultural technology. This is because the social and gender architecture surrounding technologies may be associated with how those technologies perform during shocks.

The study findings suggest that policies and interventions should move from treating transformative innovations as a separate social objective added after agricultural investments have been designed. Instead, they should treat gender-transformative innovations as part of the productive architecture, to be tested and promoted alongside agronomic and technical interventions. The study also highlights the value of measuring how different bundle configurations perform under shocks. This would allow

governments and development programmes to distinguish interventions that are widely adopted from those that help farmers buffer shocks.

Declarations

Data availability

The data used in the article can be obtained from the corresponding author upon request, without restrictions.

Author Information

EBN, Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Validation, Funding Acquisition; IOA, Conceptualization, Methodology, Data analysis, Writing – original draft, Writing - review and editing; DMK, Methodology, Investigation, Writing – original draft, Writing – review & editing; CKL, Conceptualization, Methodology, Writing – review & editing, Validation

Funding

We want to thank all funders who support this research through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders.

Acknowledgements

We acknowledge the support of enumerators during the data collection exercise. The views expressed herein are solely those of the authors and not of the affiliated institution.

Ethics declarations

The Institutional Review Board (IRB) of the Alliance of Bioversity International and CIAT approved the study: IRB No. 2026-IRB2. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant institutional guidelines governing research involving human participants. Participation in the subsequent survey was optional, and the questionnaire required informed consent before the interview could continue. All study participants provided informed consent prior to participation in the study. Participation was voluntary, and respondents were informed of the study objectives, confidentiality measures, and their right to withdraw at any time without consequence. We kept the information necessary to identify respondents, such as names and phone numbers, distinct from the analytical data. The manuscript dataset comprises anonymous household IDs and contains no direct personal identifiers. If a spouse or another adult conducted the follow-up interview, we classified the observation as a home follow-up and did not consider it as proof that the same individual had participated in all research rounds.

Consent for publication

Not applicable

Competing interests

The authors declare no competing interests.

References

1. Cissé JD, Barrett CB. Estimating development resilience: a conditional moments-based approach. *J Dev Econ*. 2018; 135:272-84. <https://doi.org/10.1016/j.jdeveco.2018.04.002>.
2. Ansah IGK, Gardebroek C, Ihle R. Resilience and household food security: a review of concepts, methodological approaches and empirical evidence. *Food Secur*. 2019;11(6):1187-203. <https://doi.org/10.1007/s12571-019-00968-1>.
3. Barrett CB, Ghezzi-Kopel K, Hoddinott J, Homami N, Tennant E, Upton J, et al. A scoping review of the development resilience literature: theory, methods and evidence. *World Dev*. 2021; 146:105612. <https://doi.org/10.1016/j.worlddev.2021.105612>.
4. Phadera L, Michelson H, Winter-Nelson A, Goldsmith P. Do asset transfers build household resilience? *J Dev Econ*. 2019; 138:205-27. <https://doi.org/10.1016/j.jdeveco.2019.01.003>.
5. Bulte E, Cecchi F, Lensink R, Marr A, van Asseldonk M. Does bundling crop insurance with certified seeds crowd-in investments? Experimental evidence from Kenya. *J Econ Behav Organ*. 2020; 180:744-57. <https://doi.org/10.1016/j.jebo.2019.07.006>.
6. Mishra K, Gallenstein RA, Sam AG, Miranda MJ, Toledo P, Mulangu F. Does bundling credit with index insurance boost agricultural technology adoption? Evidence from Ghana. *Agric Econ*. 2023;54(6):778-92. <https://doi.org/10.1111/agec.12806>.
7. Mutenje MJ, Farnworth CR, Stirling C, Thierfelder C, Mupangwa W, Nyagumbo I. A cost-benefit analysis of climate-smart agriculture options in Southern Africa: balancing gender and technology. *Ecol Econ*. 2019; 163:126-37. <https://doi.org/10.1016/j.ecolecon.2019.05.013>.
8. Nyarindo WN, Mugera A, Hailu A, Obare GA. Do combined sustainable agricultural intensification practices improve smallholder farmers welfare? Evidence from eastern and western Kenya. *Agric Econ*. 2024;55(2):296-312. <https://doi.org/10.1111/agec.12816>.
9. Abetu TA, Ingenbleek PTM, Giller KE, van der Lans IA, Wolde-Meskel E. Bundling of inputs and services for sustainable smallholder agriculture: the concepts, theoretical arguments and bundle designs using conjoint analysis. *Int J Agric Sustain*. 2024;22(1):2322193. <https://doi.org/10.1080/14735903.2024.2322193>.
10. Doss C, Meinzen-Dick R, Quisumbing A, Theis S. Women in agriculture: four myths. *Glob Food Sec*. 2018; 16:69-74. <https://doi.org/10.1016/j.gfs.2017.10.001>.
11. Rietveld AM, van der Burg M. Separate and joint interests: understanding gendered innovation processes in Ugandan farm systems. *Front Sustain Food Syst*. 2021; 5:666051. <https://doi.org/10.3389/fsufs.2021.666051>.

12. Badstue L, Elias M, Kommerell V, Petesch P, Prain G, Pyburn R, et al. Making room for manoeuvre: addressing gender norms to strengthen the enabling environment for agricultural innovation. *Dev Pract.* 2020;30(4):541-7. <https://doi.org/10.1080/09614524.2020.1757624>.
13. Ampaire EL, Acosta M, Huyer S, Kigonya R, Muchunguzi P, Muna R, et al. Gender in climate change, agriculture, and natural resource policies: insights from East Africa. *Clim Change.* 2020; 158:43-60. <https://doi.org/10.1007/s10584-019-02447-0>.
14. Huyer S, Loboguerrero AM, Chanana N, Spellman O. From gender gaps to gender-transformative climate-smart agriculture. *Curr Opin Environ Sustain.* 2024; 67:101415. <https://doi.org/10.1016/j.cosust.2024.101415>.
15. Cole SM, Kaminski AM, McDougall C, Kefi AS, Marinda PA, Maliko M, et al. Gender accommodative versus transformative approaches: a comparative assessment within a post-harvest fish loss reduction intervention. *Gend Technol Dev.* 2020;24(1):48-65. <https://doi.org/10.1080/09718524.2020.1729480>.
16. Nyamolo VOO, Ayuya OI, Cosmas KL, Nchanji EB. Effect of socio-technical innovation bundles on male and female smallholder farmers' empowerment in selected counties in Kenya. *Front Sustain Food Syst.* 2026; 10:1654751. <https://doi.org/10.3389/fsufs.2026.1654751>.
17. Food and Agriculture Organization of the United Nations. Disaster risk reduction at farm level: multiple benefits, no regrets: results from cost-benefit analyses conducted in a multi-country study, 2016-2018. Rome: FAO; 2019. <https://www.fao.org/3/ca4429en/ca4429en.pdf>. Accessed 26 Aug 2026.
18. Ayuya OI, Jong AO, Alworah GO, Lutomia CK, Nchanji EB, Waswa BS, et al. Identifying and measuring the effectiveness of socio-technical innovation bundles on empowerment and resilience in Kenya: a baseline report. Alliance of Bioversity International and CIAT; 2024. <https://hdl.handle.net/10568/140709>. Accessed 26 Aug 2026.
19. Lutomia CK, Ketema DM, Muriithi C, Nchanji EB. Empowering farmers in Embu County: adoption of gender transformative socio-technical innovation bundles (STIBs) and their impact on resilience, productivity, and food security [Internet]. 2025. 18 p. <https://hdl.handle.net/10568/176556>. Accessed 26 Aug 2026.
20. Lutomia CK, Ketema DM, Morra L, Nchanji EB. Gendered pathways to resilience and food security: insights from gender-transformative socio-technical innovation bundles in Nakuru County [Internet]. 2025. 18 p. <https://hdl.handle.net/10568/176561>. Accessed 26 Aug 2026.
21. Nchanji EB, Ketema DM, Njiru E, Lutomia CK. Building climate-resilient, empowered and food-secure communities: evidence from gender transformative STIBs in Makueni County [Internet]. 2025. 18 p. <https://hdl.handle.net/10568/176560>. Accessed 26 Aug 2026.
22. Mogaka BO, Gitau R, Bett HK, Ortez MA. Drivers and crop productivity impacts of agricultural innovation bundling among smallholder farmers in the drylands of Kenya. *Discov Agric.* 2026; 4:154. <https://doi.org/10.1007/s44279-026-00622-3>.

23. Mogaka B, Gitau R, Bett H, Ortez MA. Innovation bundling and food security nexus among smallholder farmers in Kenya's drylands: a triple hurdle approach. *Front Sustain Food Syst.* 2026; 10:1759040. <https://doi.org/10.3389/fsufs.2026.1759040>.
24. Boucher SR, Carter MR, Flatnes JE, Lybbert TJ, Malacarne JG, Marenja PP, et al. Bundling genetic and financial technologies for more resilient and productive small-scale farmers in Africa. *Econ J.* 2024;134(662):2321-50. <https://doi.org/10.1093/ej/ueae012>.
25. Teklewold H. Understanding gender differences on the choices of a portfolio of climate-smart agricultural practices in sub-Saharan Africa. *World Dev Perspect.* 2023; 29:100486. <https://doi.org/10.1016/j.wdp.2023.100486>.
26. Hailemariam A, Kalsi J, Mavisakalyan A. Gender gaps in the adoption of climate-smart agricultural practices: evidence from sub-Saharan Africa. *J Agric Econ.* 2024; 75:764-93. <https://doi.org/10.1111/1477-9552.12583>.
27. Anderson CL, Reynolds TW, Biscaye P, Patwardhan V, Schmidt C. Economic benefits of empowering women in agriculture: assumptions and evidence. *J Dev Stud.* 2021;57(2):193-208. <https://doi.org/10.1080/00220388.2020.1769071>.
28. Bozzola M, Smale M. The welfare effects of crop biodiversity as an adaptation to climate shocks in Kenya. *World Dev.* 2020; 135:105065. <https://doi.org/10.1016/j.worlddev.2020.105065>.
29. Makate C, Angelsen A, Holden ST, Westengen OT. Evolution of farm-level crop diversification and response to rainfall shocks in smallholder farming: evidence from Malawi and Tanzania. *Ecol Econ.* 2023; 205:107736. <https://doi.org/10.1016/j.ecolecon.2022.107736>.
30. Getnet A, Xia X, Mekie TM, Wassihun AN, Mebrahtom S. Can crop diversification buffer drought shocks? Evidence from Ethiopian smallholders. *J Environ Manage.* 2026; 413:130289. <https://doi.org/10.1016/j.jenvman.2026.130289>.
31. McGuire E, Rietveld AM, Crump A, Leeuwis C. Anticipating gender impacts in scaling innovations for agriculture: insights from the literature. *World Dev Perspect.* 2022; 25:100386. <https://doi.org/10.1016/j.wdp.2021.100386>.
32. Mukhopadhyay P, Chadha D, Gartaula HN, Banerjee M, Puskur R. Making climate-smart technologies work for women farmers: insights from cases of bundling innovations in India. *Front Sustain Food Syst.* 2026; 10:1648400. <https://doi.org/10.3389/fsufs.2026.1648400>.
33. Njiru N, Galiè A, Omondi I, Omia D, Loriba A, Awin P. Gender transformative innovation: women's inclusion in livestock vaccine systems in northern Ghana. *Agric Syst.* 2024; 219:104023. <https://doi.org/10.1016/j.agsy.2024.104023>.

Figures

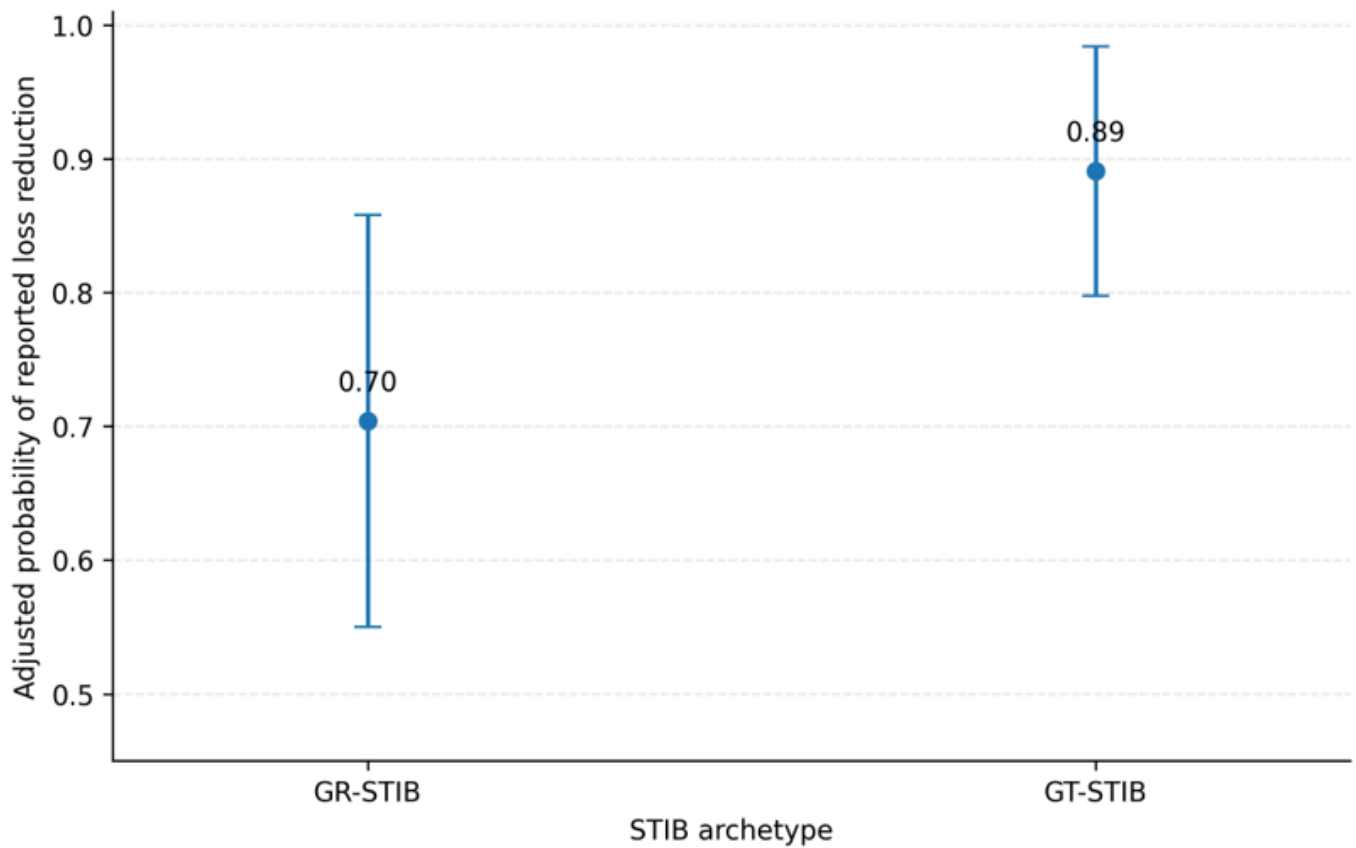


Figure 1

Adjusted probability of reported crop-loss reduction by STIB archetype.

Predicted probabilities are from the primary logistic model adjusted for county, reference season, maize versus non-maize main crop, and shock category. Error bars show 95% confidence intervals.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [CBASurveytoolFINALBMC.docx](#)