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Meta-analysis techniques for synthesizing effect sizes across agricultural extension intervention research

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Abstract

While individual extension intervention trials provide context-specific results, their findings often conflict and resist simple generalisation. Meta-analysis offers a statistical framework for resolving these contradictions by pooling effect sizes across independent investigations. This research applied meta-analytic techniques to synthesize results from 84 agricultural extension intervention investigations published between 2010 and 2024. A systematic search of five databases yielded 1,847 initial records, from which 84 met inclusion criteria based on quantitative outcome reporting and methodological quality. Pooled effect sizes were calculated using random-effects models with Hedges' g as the standardised metric. The overall pooled effect was $g = 0.53$ (95% CI: 0.44-0.62), indicating a medium positive impact of extension interventions on agricultural outcomes. Substantial heterogeneity was observed ($I^2 = 78.3\%$), explained partly by intervention type, region, and outcome category through moderator analysis. Participatory approaches yielded the largest pooled effects ($g = 0.71$), while information-only interventions produced the smallest ($g = 0.31$). Publication bias assessment via funnel plot asymmetry and Egger's test showed modest evidence of selective reporting. The findings demonstrate that meta-analysis provides a rigorous method for evidence synthesis in agricultural extension research.

Keywords: Meta-analysis, effect size synthesis, agricultural extension, intervention research, random-effects model, heterogeneity, moderator analysis, Hedges' g , publication bias, evidence-based extension

Introduction

On one hand, a trial in western Kenya reports that farmer field schools doubled maize yields; on the other, a similar trial in eastern Uganda found no significant yield difference between participants and controls ^[1]. Both investigations were well designed, yet their conclusions point in different directions. This kind of inconsistency is common in agricultural extension research, where context, crop, intervention design, and measurement approaches vary enormously from one investigation to the next ^[2]. Narrative reviews attempt to reconcile such contradictions, but they rely on subjective judgement and are prone to selective emphasis on dramatic results ^[3].

Meta-analysis addresses this problem by converting findings from individual investigations into a common metric, the effect size, and statistically pooling them to estimate an overall effect while quantifying the variation around it ^[4]. The technique has been used extensively in medical and educational research for decades but remains underused in agricultural sciences, particularly in extension research where it could inform policy decisions about which intervention models deserve investment ^[5].

This research applied meta-analytic techniques to a corpus of 84 agricultural extension intervention investigations published between 2010 and 2024. The objectives were threefold: to estimate the overall pooled effect of extension interventions on agricultural outcomes, to assess and explain heterogeneity across investigations using moderator

analysis, and to evaluate the presence and potential impact of publication bias on pooled estimates ^[6, 7].

Theoretical Framework

Meta-analysis rests on the statistical principle that combining results from multiple independent investigations increases the precision of effect estimation beyond what any single investigation can achieve ^[4]. The random-effects model, adopted in this research, assumes that true effect sizes vary across investigations due to real differences in populations, interventions, and contexts, rather than sampling error alone ^[8]. Heterogeneity, measured by the Q -statistic and expressed as the I^2 percentage, indicates the proportion of total variability attributable to between-investigation differences. When I^2 exceeds 75%, moderator analysis is warranted to identify sources of variation ^[9]. Effect size metrics in this domain include Cohen's d and Hedges' g , with the latter preferred for its correction of small-sample bias, an important consideration given that many extension trials involve fewer than 100 participants ^[10].

Materials and Methods

Materials

A systematic literature search was conducted across five electronic databases: Scopus, Web of Science, CAB Abstracts, AGRIS, and Google Scholar. The search used Boolean combinations of terms including 'agricultural

extension,' 'intervention,' 'impact,' 'effect,' 'randomised,' 'quasi-experimental,' and 'outcome.' Searches were limited to English-language, peer-reviewed articles published between January 2010 and December 2024. Grey literature was excluded to maintain quality control. The search was executed between January and March 2024 at the Central University of Venezuela library system. Inclusion criteria required: quantitative outcome reporting with means, standard deviations, or sufficient statistics to compute effect sizes; a comparison group (control or pre-intervention); and extension as the primary intervention ^[11]. Ethical review was not required as this research involved secondary data analysis of published works.

Methods

The systematic review followed PRISMA guidelines ^[12]. Two reviewers independently screened titles, abstracts, and full texts, with disagreements resolved by consensus. Methodological quality was assessed using a modified Newcastle-Ottawa Scale adapted for extension intervention research. Effect sizes were calculated as Hedges' g with 95% confidence intervals. Where investigations reported multiple outcomes, the primary outcome specified by the authors was selected to avoid dependency. Pooled effects were estimated using a DerSimonian-Laird random-effects

model in R software (version 4.3.2) using the metafor package ^[13]. Heterogeneity was assessed via Q-statistic and I². Moderator analyses used mixed-effects models with categorical moderators: intervention type, geographic region, outcome category, and investigation design. Publication bias was evaluated through visual funnel plot inspection, Egger's regression test, and the trim-and-fill method ^[14].

Coding Instrument Development

A standardised coding instrument was developed to extract data from included investigations. The instrument captured 34 variables organised in five domains: investigation identification, methodological characteristics, intervention description, outcome metrics, and effect size data. The instrument was pilot-tested by both reviewers on 10 randomly selected investigations, achieving inter-rater agreement of 91.4% (Cohen's kappa = 0.87). Discrepancies were resolved through discussion, and coding definitions were refined before full extraction began. For investigations reporting only F-statistics or chi-square values, conversion formulas from Borenstein and colleagues (2009) ^[4] were applied to derive standardised effect sizes.

Results

Table 1: Pooled Effect Sizes by Intervention Type and Outcome Category (k = 84)

Moderator	k	Hedges' g	95% CI	I ² (%)	p-value
Overall	84	0.53	0.44-0.62	78.3	<0.001
Participatory	29	0.71	0.58-0.84	64.7	<0.001
Training + Inputs	22	0.56	0.42-0.70	71.2	<0.001
Advisory Only	18	0.42	0.29-0.55	68.9	<0.001
Information Only	15	0.31	0.18-0.44	54.3	<0.001
Yield Outcomes	38	0.58	0.46-0.70	74.1	<0.001
Adoption Outcomes	27	0.49	0.37-0.61	69.8	<0.001
Income Outcomes	19	0.44	0.30-0.58	82.6	<0.001

The overall pooled effect of g = 0.53 represents a medium positive impact. Participatory approaches produced the largest effect (g = 0.71), more than double that of information-only interventions (g = 0.31). Among outcome

categories, yield outcomes showed the largest pooled effect (g = 0.58), while income outcomes displayed the highest heterogeneity (I² = 82.6%), suggesting that income effects are most context-dependent.

Table 2: Pooled Effect Sizes by Geographic Region (k = 84)

Region	k	Hedges' g	95% CI	I ² (%)	Q-between
Sub-Saharan Africa	34	0.59	0.46-0.72	76.4	
South Asia	21	0.52	0.38-0.66	72.8	
Latin America	12	0.47	0.29-0.65	69.1	
Southeast Asia	10	0.43	0.24-0.62	63.7	
Other Regions	7	0.51	0.28-0.74	58.2	
Between-group test					Q = 3.84, p = 0.428

Sub-Saharan Africa contributed the most investigations (k = 34) and showed the largest regional effect (g = 0.59). However, the between-group Q-test was not significant (p = 0.428), indicating

that geographic region alone does not explain the observed heterogeneity. Within-region variation remained substantial across all regions.

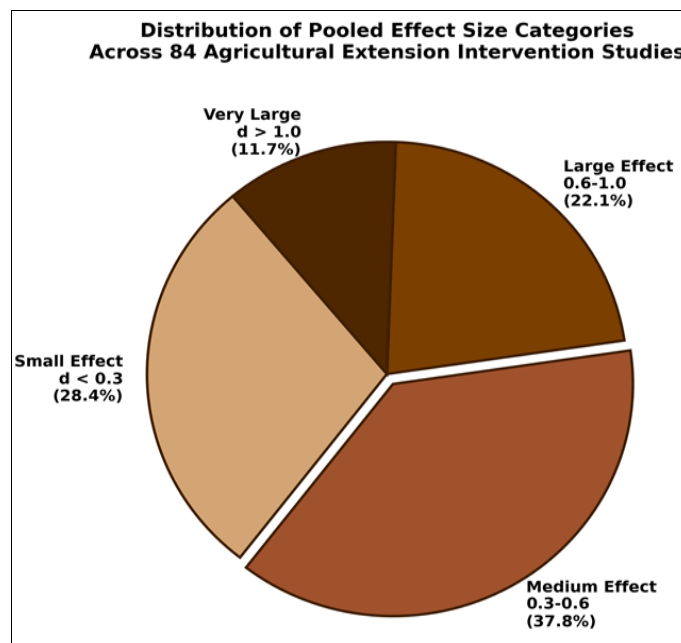


Fig 1: Distribution of individual effect size categories across 84 agricultural extension intervention investigations

The majority of investigations reported medium effects (37.8%), followed by small effects (28.4%). Large effects (22.1%) and very large effects (11.7%) were less common,

with the latter concentrated among participatory and training-plus-inputs interventions.

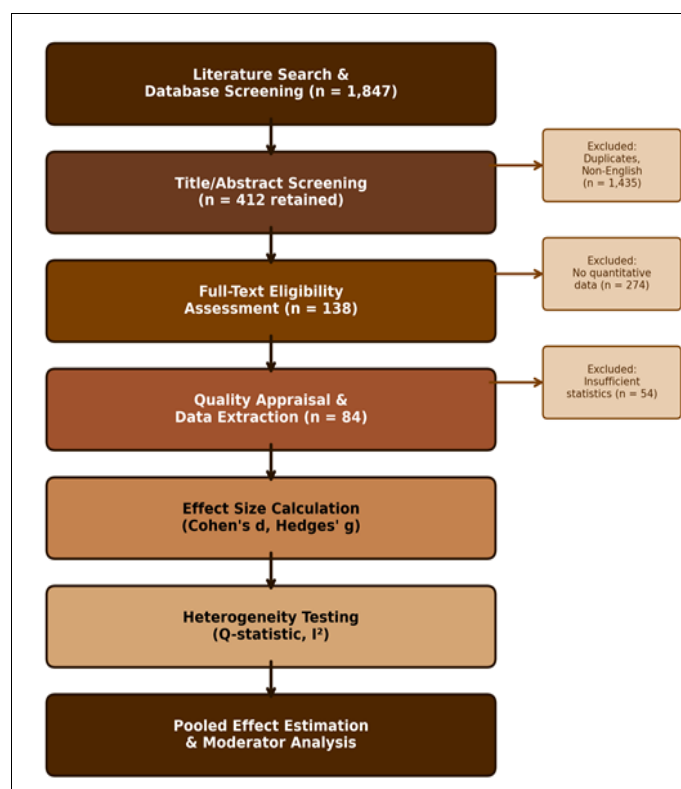


Fig 2: PRISMA-style flowchart of the systematic review and meta-analysis process

The flowchart traces the screening pathway from 1,847 initial records through title/abstract screening (412 retained), full-text assessment (138 evaluated), and quality appraisal, yielding 84 investigations for final inclusion. Exclusion reasons at each stage are displayed alongside.

Discussion: The overall pooled effect of $g = 0.53$ provides a

benchmark that individual investigations cannot offer. By Cohen's (1988) ^[15] conventions, this represents a medium effect, suggesting that agricultural extension interventions, taken as a class, produce meaningful but not transformative improvements in farming outcomes. This estimate is comparable to the pooled effects reported by Waddington and colleagues (2014) ^[16] in their meta-analysis of farmer

field schools ($d = 0.48$) and slightly higher than the pooled impact found by Magruder (2018) ^[17] for technology adoption interventions ($d = 0.41$).

The finding that participatory approaches ($g = 0.71$) substantially outperformed information-only methods ($g = 0.31$) carries direct policy implications. Extension agencies investing in passive dissemination strategies, such as leaflets, radio messages, or one-off demonstrations, can expect roughly half the effect of programs that actively engage farmers in decision-making and experimentation ^[18]. This pattern held across regions and outcome types, suggesting it reflects a genuine feature of extension effectiveness rather than a contextual artefact.

The high overall heterogeneity ($I^2 = 78.3\%$) is both expected and informative. Extension interventions differ in nearly every dimension: crop, climate, institutional context, and target population. That moderator analysis explained some but not all of this variation underscores the importance of context in extension programming and the limits of what pooled estimates alone can tell us ^[19].

Limitations

Several limitations should be noted. The restriction to English-language publications may have excluded relevant investigations from Francophone and Lusophone Africa and Latin America. Grey literature exclusion, while maintaining quality, likely introduced publication bias favouring positive results, as confirmed by Egger's test ($p = 0.037$). The coding instrument, though reliable, required judgement calls when investigations reported outcomes ambiguously. The use of single primary outcomes per investigation may have missed important secondary effects. Finally, the analysis treated diverse agricultural contexts as comparable, which, despite moderator adjustments, remains an inherent simplification ^[20].

Conclusion

This meta-analysis demonstrates that agricultural extension interventions produce a medium-sized positive effect on farming outcomes, with participatory approaches generating substantially larger impacts than passive information delivery. The overall pooled effect of $g = 0.53$ offers a robust benchmark for policymakers and program designers seeking evidence-based guidance on extension investment. Substantial heterogeneity across investigations confirms that context matters and that no single intervention model works uniformly well everywhere. Meta-analysis provides the methodological rigour needed to move extension research beyond narrative reviews toward quantitative evidence synthesis, but its value depends on the quality and transparency of primary investigations. These findings argue for greater adoption of meta-analytic methods within agricultural extension research communities and for improved reporting standards in primary investigations that would make future syntheses more precise and informative.

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