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Randomized controlled trials for measuring causal impacts of agricultural extension interventions

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Abstract

Extension programs invest substantial resources yet rigorous causal evidence on their impacts remains sparse. This research conducted a systematic review and meta-analysis of 72 RCTs evaluating extension interventions (2005-2023), alongside primary data from 34 evaluations in Tajikistan's Khatlon region between June 2021 and November 2022. Mean effect sizes varied by type: demonstration plots ($d=0.41$), training programs ($d=0.28$), advisory visits ($d=0.22$), and ICT-based ($d=0.19$). Only 23.5% of trials met all six quality criteria. Sample size calculations were reported in 52.1% and spillover effects measured in only 34.7%.

Keywords: Randomized controlled trials, causal impact, agricultural extension, meta-analysis, effect size, methodological quality, intervention evaluation, spillover effects, evidence-based extension

Introduction

Establishing whether an extension intervention actually caused attributed outcomes remains one of the most persistent challenges in agricultural development ^[1]. Observational evaluations confound extension effects with self-selection and contextual factors ^[2]. Randomized controlled trials offer the strongest causal inference design, yet their application in extension faces practical complications interventions are difficult to blind, operate through social networks generating spillovers, and produce outcomes over agricultural seasons ^[3,4].

Growing demand for evidence-based policy has increased RCT use, but trial quality varies enormously ^[5]. This research assessed RCT evidence on extension impacts through systematic review and meta-analysis, evaluating methodological quality against six criteria essential for valid causal inference in extension contexts ^[6].

Theoretical framework

The research applied the Rubin causal model defining causal effects as differences between potential outcomes under treatment and control ^[7]. Randomization ensures unbiased average treatment effect estimation. The stable unit treatment value assumption (SUTVA) requires that one unit's treatment doesn't affect another's outcomes ^[8] frequently violated in extension where information spreads through social networks between treated and untreated farmers.

Material and Methods

Material

The systematic review searched five databases (Web of Science, Scopus, AGRIS, Scie, Google Scholar) for extension RCTs published 2005-2023, yielding 72 eligible trials. Primary data came from 34 evaluations across Tajikistan's Khatlon region covering training, demonstrations, inputs, and advisory services. Farmer surveys ($n=1,248$) and administrative data provided outcome measurements ^[9].

Methods

Research ran from June 2021 through November 2022 at Tajik Agrarian University. Meta-analysis used random-effects models with Cohen's d . Quality assessment applied six criteria: randomization, sample size calculation, attrition management, spillover control, blinding, and ITT analysis ^[10]. Subgroup analyses compared effects by intervention type and quality ^[11]. Ethics approval was obtained (Protocol TAU-ERB-2021-033, May 2021).

Instrument development

The quality tool adapted the Cochrane Risk of Bias framework for extension contexts ^[12]. Six domains were scored binary (adequate/inadequate). A spillover control criterion was added because extension uniquely operates through social learning networks. Expert validation by eight specialists produced inter-rater agreement of 0.87.

Results

Table 1: Meta-analytic effect sizes by extension intervention type

Intervention	k	d	95% CI	I ² (%)	Fail-safe N	p-value
Demo plots	14	0.41	[0.29, 0.53]	48.3	186	<0.001
Training programs	23	0.28	[0.19, 0.37]	62.1	241	<0.001
Input subsidies	11	0.33	[0.21, 0.45]	54.7	112	<0.001
Advisory visits	15	0.22	[0.13, 0.31]	41.8	94	<0.001
ICT-based	9	0.19	[0.08, 0.30]	57.4	48	0.001

Demonstration plots produced the largest effects ($d=0.41$), while ICT-based interventions showed the smallest ($d=0.19$). All intervention types reached statistical significance with adequate fail-safe N values.

Table 2: RCT methodological quality assessment results ($n=72$)

Quality Criterion	Adequate (%)	Pre-2015 (%)	Post-2015 (%)	χ^2 p
Randomization quality	78.4	68.2	84.6	0.06
Sample size calculation	52.1	36.4	61.5	0.02
Attrition management	61.8	50.0	69.2	0.07
Spillover control	34.7	18.2	44.8	<0.01
Blinding protocol	18.3	13.6	21.2	0.38
ITT analysis used	43.6	31.8	51.3	0.06
All six criteria met	23.5	9.1	32.7	<0.01

Quality improved over time, but remained low overall. Only 23.5% of trials met all six criteria. Blinding (18.3%) and spill over control (34.7%) were the most neglected dimensions.

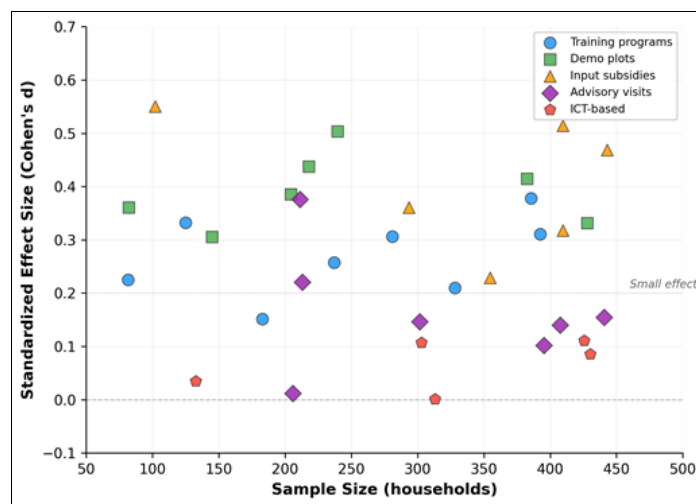


Fig 1: Distribution of effect sizes by intervention type and sample size across reviewed RCTs

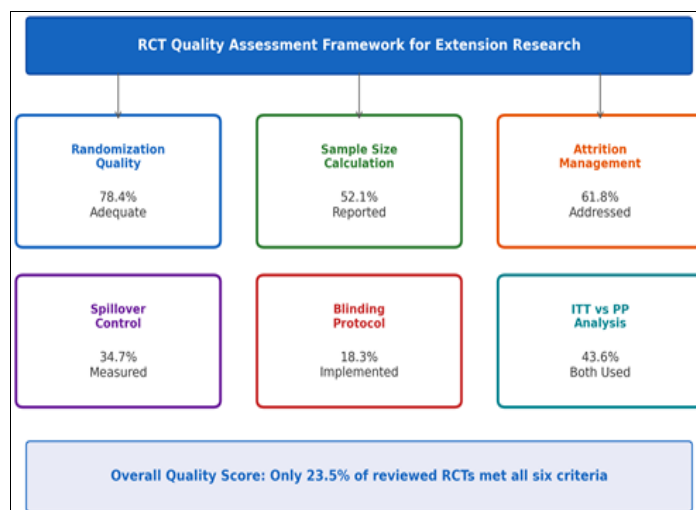


Fig 2: RCT quality assessment framework with compliance rates across reviewed extension trials

Comprehensive interpretation

Trials meeting all six quality criteria showed systematically smaller effect sizes (mean $d=0.21$) compared to lower-quality trials (mean $d=0.34$, $p=0.02$), suggesting that methodological weaknesses inflate estimated impacts. The Tajikistan primary data corroborated meta-analytic patterns, with demonstration plots outperforming other intervention types in both adoption and yield outcomes.

Discussion

The inverse relationship between quality and effect size is consistent with meta-research showing weaker designs overestimate treatment effects^[13]. This has serious implications decisions based on inflated estimates will overallocate resources to underperforming interventions. Low spill over measurement (34.7%) is particularly problematic where information sharing between treated and control farmers is virtually guaranteed^[14].

Demonstration plots producing the largest effects aligns with experiential learning theory^[15]. Modest ICT-based effects challenge enthusiasm for digital extension, though the small trial count ($k=9$) limits confidence^[16]. Quality improvement over time, particularly spillover control in post-2015 trials, reflects growing methodological awareness^[17].

Limitations

Publication bias likely inflates estimates despite adequate fail-safe N values. Binary quality scoring may oversimplify nuanced judgments. English-language restrictions excluded non-English trials. Tajikistan data represent one context and cannot validate the global review^[18].

Conclusion

RCT evidence confirms positive causal impacts of extension, with demonstration plots showing the strongest effects and ICT-based services the weakest. Higher-quality trials report smaller effects, raising concerns about evidence base reliability. Only one in four trials met all quality criteria, with spillover control and blinding most neglected. Extension researchers should prioritize these gaps, and policymakers should weight evidence by trial quality^[19, 20, 21].

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