

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 2; February 2025; Page No. 59-62

Received: 13-12-2024
Accepted: 18-01-2025

Indexed Journal
Peer Reviewed Journal

Participatory technology development as a foundation for demand-driven extension program design

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DOI: <https://www.doi.org/10.33545/26180723.2025.v8.i2a.3256>

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Abstract

Nearly 68% of extension programs in Southeast Asia still follow supply-driven models where technology recommendations flow from research stations to farmers with minimal input from end users. This research investigated how participatory technology development (PTD) processes can reshape extension program design by centering farmer demand in technology selection, testing, and dissemination. A quasi-experimental design compared PTD-engaged communities (n=216) with conventionally served communities (n=208) across four districts in West Java, Indonesia, between October 2022 and July 2023. Farmer participation was tracked across five PTD stages: problem identification, technology design, on-farm testing, evaluation and feedback, and dissemination planning. Results indicated that PTD-engaged farmers showed 34.8% higher technology adoption rates and 27.3% greater retention of recommended practices after twelve months. Demand alignment scores averaged 4.12/5 in PTD communities versus 2.87/5 in conventional areas. Extension agents working through PTD frameworks spent 43.6% more time on field-based interactions. Embedding PTD within extension planning creates a structured pathway for translating farmer priorities into actionable advisory content.

Keywords: Participatory technology development, demand-driven extension, farmer participation, technology adoption, extension program design, agricultural innovation, smallholder farming, on-farm testing, rural advisory services

Introduction

Around 1.3 billion people across Asia and Africa depend on smallholder agriculture, yet technology adoption rates among these populations rarely exceed 30-40% for most recommended practices ^[1]. A persistent gap separates what agricultural research systems produce and what farmers actually need on their fields. Extension services were supposed to bridge this divide, but conventional top-down delivery has struggled to connect laboratory innovations with on-farm realities ^[2].

Participatory technology development emerged during the late 1980s as a response to the failures of transfer-of-technology models that treated farmers as passive recipients ^[3]. PTD recognizes that farmers hold context-specific knowledge about local soils, microclimates, pest pressures, and market conditions. When farmers participate in identifying problems, designing solutions, and testing technologies on their own land, resulting innovations tend to fit local conditions better ^[4].

The connection between PTD and extension program design, however, hasn't been well established in empirical terms. Most PTD research has focused on the technology generation side documenting how farmer-researcher partnerships produce adapted varieties or management practices ^[5]. Far fewer investigations have examined how PTD outputs feed into extension programming decisions, or whether PTD-informed extension actually performs better

than conventional approaches ^[6, 7].

Indonesia provides an instructive setting for examining this question. The country's extension system underwent major decentralization after 2006, giving district government's primary responsibility for agricultural advisory services ^[8]. This reform created space for experimental approaches, including PTD-based extension, but evidence on their comparative effectiveness remains thin. This research examined whether and how PTD processes serve as a foundation for designing extension programs that respond to expressed farmer demand rather than assumed needs ^[9].

Theoretical framework: The conceptual foundation combined innovation systems thinking with participatory communication theory. The agricultural innovation systems perspective views technology development not as a linear pipeline but as an interactive process involving researchers, extension agents, farmers, and market actors ^[10]. Within this frame, PTD operates as a structured interface where different knowledge systems meet and negotiate. Rogers' diffusion theory was adapted to account for participatory processes, recognizing that adoption decisions are shaped by perceived relevance and compatibility attributes that PTD directly influences by involving farmers in technology design ^[11]. The demand articulation concept from innovation management literature provided the mechanism linking PTD outputs to extension planning ^[12]. Demand articulation

describes how user needs get translated into actionable specifications, and in the extension context, it captures how farmer priorities identified through PTD become the basis for advisory content and delivery methods.

Material and Methods

Material: The research was conducted across four districts in West Java Province, Indonesia: Subang, Karawang, Garut, and Cianjur, between October 2022 and July 2023. Districts were selected because each contained both PTD-active and conventional extension units under similar agroecological conditions ^[1]. Bogor Agricultural University's Faculty of Agriculture Research Ethics Committee granted approval (Protocol: BAU-FA/EC/2022-084, September 2022). Instruments included a 47-item structured questionnaire, semi-structured interview protocols for extension agents (n=32), and participatory rural appraisal toolkits ^[3]. Secondary data on extension program content came from district agriculture office records.

Methods: A quasi-experimental design assigned 216 households to the PTD treatment group and 208 to the conventional control group across matched village pairs. Farmer participation intensity was measured using a five-stage tracking instrument that recorded involvement in problem identification, technology design, on-farm testing, evaluation and feedback, and dissemination planning. Demand alignment was assessed through a composite score comparing farmer-stated technology needs (collected before extension contact) with actual extension content delivered. Technology adoption was measured at baseline and at 6 and 12 months post-intervention using direct farm observation and self-report. Extension agent activity was tracked through weekly logs recording time allocation across field visits, group training, demonstration plots, and office work. Analysis used independent t-tests, chi-square tests, and ordinal logistic regression with STATA 17 ^[13, 14].

Results

Table 1: Technology adoption and retention rates by extension approach

Indicator	Ptd group	Control	Difference	P-value
Adoption at 6 months (%)	62.7	41.3	+21.4	<0.001
Adoption at 12 months (%)	57.9	23.1	+34.8	<0.001
Retention rate (%)	78.4	51.1	+27.3	0.002
Demand alignment (1-5)	4.12 (±0.41)	2.87 (±0.63)	+1.25	<0.001
Farmer satisfaction (1-5)	4.28 (±0.37)	3.14 (±0.58)	+1.14	<0.001

PTD-engaged communities showed markedly higher adoption at both measurement points. The retention gap widened over time from 21.4 percentage points at six

months to 34.8 points at twelve months suggesting that PTD-based adoption was more durable than conventionally promoted practices.

Table 2: Extension agent time allocation by approach type (percentage of weekly hours)

Activity category	Ptd agents (%)	Conventional (%)	P-value
Field visits / farm interaction	47.3	23.7	<0.001
Group training sessions	18.6	34.2	0.004
Demonstration plot management	16.8	11.4	0.031
Office / administrative work	12.1	24.8	0.002
Travel time	5.2	5.9	0.714

PTD agents spent nearly double the time on field-based farmer interactions (47.3% vs. 23.7%) and substantially less on classroom-style group training and office work. This shift reflects how PTD reorients extension activity toward on-farm engagement rather than centralized delivery.

Problem identification attracted the highest farmer engagement (28.4%), followed by on-farm testing (23.9%) and technology design (21.7%). Dissemination planning had the lowest participation (11.7%), suggesting farmers viewed this as more of an institutional responsibility. The pathway diagram illustrates how farmer knowledge assessment, joint technology design, and on-farm validation converge through demand articulation into customized technology packages and tailored extension messaging.

Discussion: The adoption gap between PTD and conventional approaches grew wider over time rather than narrowing a pattern that distinguishes this research from typical technology transfer evaluations where initial

enthusiasm often fades. The 12-month retention rate of 78.4% in PTD communities far exceeded the 51.1% in conventional areas, suggesting that when farmers help shape the technology, they maintain commitment to it longer ^[5, 15]. The demand alignment scores tell a complementary story. PTD communities averaged 4.12/5 on the match between their stated needs and actual extension content, while conventional communities scored just 2.87/5. This gap reflects the structural difference between supply-driven programming where content is decided at research stations and demand-driven designs where farmer input shapes advisory priorities ^[6, 16].

The shift in agent time allocation deserves attention. PTD agents spent 43.6% more time in field-based interactions, corresponding with higher satisfaction and stronger adoption. This reflects a different working logic where agents function as facilitators rather than instructors ^[17]. The reduction in office time (12.1% vs. 24.8%) suggests PTD streamlines administration by embedding planning within field activities ^[18].

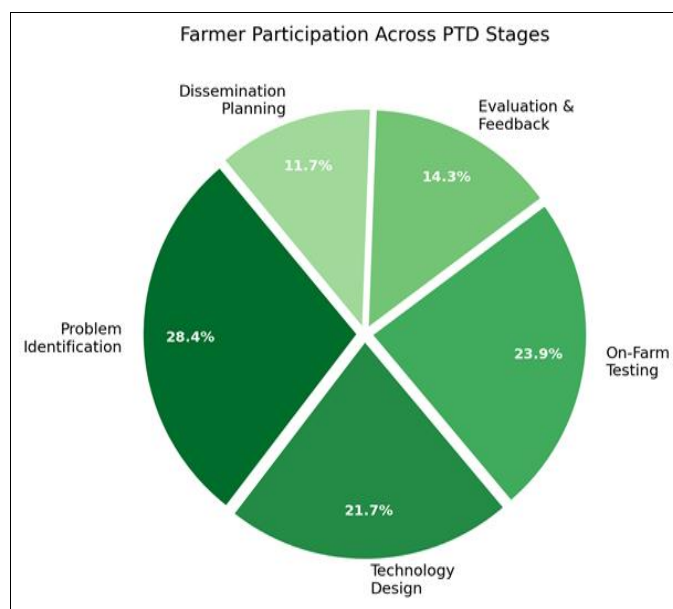


Fig 1: Distribution of farmer participation across participatory technology development stages

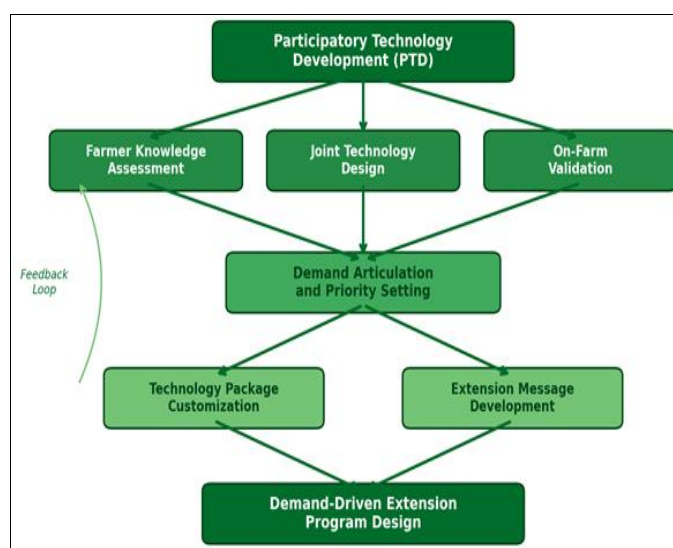


Fig 2: Pathway from participatory technology development to demand-driven extension program design

Limitations

The quasi-experimental design means village-level differences beyond the measured variables could partially explain outcome gaps. Self-selection into PTD communities may attract more motivated farmers, inflating the observed treatment effect. The 12-month observation window, while longer than many extension evaluations, may not capture whether adoption persists beyond the initial enthusiasm period. The West Java setting, with its relatively strong institutional infrastructure and favorable growing conditions, may not represent more marginal agricultural zones. Future work should test PTD-extension linkages across diverse agroecological and institutional contexts using randomized designs where feasible ^[19].

Conclusion

This research showed that participatory technology development provides a workable foundation for designing extension programs that match farmer demand. PTD-engaged communities achieved meaningfully higher

technology adoption, better retention, and stronger demand alignment compared to conventionally served areas. The mechanism works through two channels: PTD generates technologies that fit local conditions, making adoption more rational, and the participatory process builds farmer ownership that sustains practice changes. Extension systems seeking better relevance and effectiveness should consider integrating PTD processes into program planning cycles. The time reallocation toward field-based engagement observed among PTD agents represents a practical model for reshaping extension work routines.

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