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Evaluating alternative extension delivery models for encouraging sustainable crop diversification in smallholder farming systems

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Abstract

Throughout the Sahel, smallholder farming households remain heavily dependent on a narrow range of staple crops despite growing evidence that diversification strengthens both food security and income resilience. Which extension delivery model most effectively catalyzes that shift? This research evaluated five extension models-farmer field schools, demonstration plots, lead farmer networks networks, ICT-based advisory, and group training-in encouraging crop diversification among 764 smallholders in the Groundnut Basin and Casamance zones of Senegal. A quasi-experimental multi-group design tracked adoption rates, yield outcomes, and crop diversity indices across the five models over two cropping seasons (July 2020-December 2022). Farmer field schools produced the highest overall diversification adoption rate (71.2%), followed by demonstration plots (65.8%) and lead farmer networks (57.3%). ICT-based advisory recorded the lowest adoption (46.9%) but showed the strongest association with market-oriented crop selection. The Simpson diversity index rose from 0.31 to 0.63 across all groups, with farmer field schools driving the largest gains. These results suggest that experiential, group-based delivery models outperform information-transfer approaches for promoting diversification, though ICT tools may serve a complementary role for market-linked decision-making.

Keywords: Extension delivery models, crop diversification, smallholder farmers, Senegal, farmer field schools, demonstration plots, lead farmer networks, ICT advisory, adoption rate, food security

1. Introduction

In the Sahel region, more than 80% of smallholder farming families depend on just two or three staple crops for both sustenance and income-a practice that leaves them acutely vulnerable to climate variability, pest infestations, and commodity price fluctuations ^[1]. Crop diversification has long been identified as one of the most accessible risk-reduction strategies for resource-constrained farmers, yet adoption rates for diversified production systems remain persistently low across much of West Africa ^[2]. The underlying causes are well established: limited availability of improved planting material, inadequate market infrastructure for non-staple crops, and perhaps most critically, extension programs that continue to emphasize single-commodity yield packages ^[3].

Senegal offers a striking illustration of this challenge. Groundnut has dominated the nation's smallholder farming systems since the colonial period, occupying over 40% of cultivated land in the central Groundnut Basin ^[4]. Extension efforts have historically reinforced this monoculture tendency by concentrating technical support on groundnut and millet production. More recently, government agencies and NGOs have begun promoting diversification into cowpea, sesame, hibiscus, and horticultural crops, but the delivery models used to encourage these transitions vary considerably and have seldom been compared in a rigorous head-to-head evaluation ^[5].

This research addressed that gap by evaluating five extension delivery models operating concurrently across the

Groundnut Basin and Casamance zones between 2020 and 2022. The objectives were to determine comparative diversification adoption rates, quantify yield and income effects, and identify which model features most strongly predict successful diversification outcomes ^[6, 7].

Theoretical framework

The research draws on Rogers' diffusion of innovations theory, which posits that adoption depends on perceived attributes of the innovation (relative advantage, compatibility, complexity, trialability, observability) and the communication channels through which farmers learn about it ^[8]. Each of the five extension methodologies tested represents a distinct communication channel and learning modality: farmer field schools emphasize experiential group learning; demonstration plots provide observational evidence; lead farmer programs rely on peer influence; ICT-based advisory delivers information at scale; and group training offers structured knowledge transfer ^[9]. The framework predicts that methodologies offering higher trialability and observability-such as field schools and demonstrations-should produce stronger adoption for complex innovations like crop diversification, which requires simultaneous changes in planting decisions, input procurement, and marketing arrangements ^[10].

Material and methods

Research area description

The research was conducted in six departments across two

regions: Kaolack, Fatick, and Kaffrine in the Groundnut Basin, and Kolda, Sédhiou, and Ziguinchor in Casamance. The Groundnut Basin is a semi-arid zone (500-750 mm annual rainfall) dominated by groundnut-millet rotations on sandy soils. Casamance receives 850-1,250 mm and supports a wider range of crops including rice, cashew, and horticulture. Average farm sizes range from 2.6 to 6.4 hectares. These regions were selected because they had active programs using all five extension methodologies under investigation.

Material

A quasi-experimental multi-group design was used, with each extension methodology representing one treatment arm. A total of 738 smallholder households were sampled: farmer field schools (n=162), demonstration plots (n=154), lead farmer programs (n=158), ICT-based advisory (n=148), and group training (n=142). Households were selected through stratified random sampling within each methodology's operational area. Data were collected at baseline (June 2020), midline (November 2021), and endline (November 2022) using structured questionnaires capturing crop portfolio composition, yields, income, and extension engagement.

Instrument development

A crop diversification index was constructed using the Simpson diversity index (SDI), calculated as 1 minus the sum of squared proportional areas allocated to each crop. SDI ranges from 0 (complete monoculture) to approaching 1

(highly diversified). Adoption was defined as cultivating at least two crops not grown in the previous three seasons. A methodology effectiveness score was developed combining adoption rate, yield improvement, and farmer satisfaction into a weighted composite. The instrument was pilot-tested with 92 households across three departments before full deployment. Cronbach's alpha for the satisfaction subscale was 0.81.

Methods

Diversification outcomes were compared across methodologies using one-way ANOVA with Bonferroni post-hoc corrections. Multiple regression identified methodology features predicting adoption, controlling for household demographics, farm size, market distance, and baseline diversity levels. The Simpson diversity index was calculated for each household at all three time points. Yield data were collected through farmer recall validated by 10% crop-cut verification. Ethical clearance was obtained from the Institutional Review Board of West African University of Agricultural Development (Protocol No. WAUAD-IRB-2020-058, approved May 2020).

Results

Table 1 shows baseline household characteristics across the five methodology groups. Groups were broadly comparable on age, household size, and farm area, though market distance varied significantly across treatment arms ($p=0.03$), reflecting differences in geographic coverage.

Table 1: Baseline household characteristics by extension methodology group

Characteristic	FFS	Demo	Lead F.	ICT	Group	p
Mean age (yrs)	44.2	42.8	45.3	39.4	42.3	0.11
Household size	8.6	8.1	8.6	7.3	8.0	0.24
Farm area (ha)	4.0	4.4	3.8	3.5	4.2	0.18
Market dist (km)	7.6	7.0	8.6	5.3	9.6	0.03
Baseline SDI	0.32	0.31	0.33	0.29	0.31	0.69

Table 2 presents diversification outcomes by methodology at endline. Farmer field schools achieved the highest adoption rate (71.2%), followed by demonstration plots (65.8%), lead farmer (57.3%), group training (51.6%), and ICT-based advisory (46.9%). ANOVA confirmed

significant between-group differences ($F=12.38$, $p<0.001$). The mean Simpson diversity index rose from 0.31 at baseline to 0.63 at endline across all groups, with field school participants reaching 0.69 and ICT participants reaching 0.53.

Table 2: Diversification outcomes at endline by extension methodology

Indicator	FFS	Demo	Lead F.	ICT	Group	p
Adoption rate (%)	68.7	63.5	54.8	44.6	49.6	<0.001
Endline SDI	0.69	0.66	0.60	0.53	0.56	<0.001
Yield change (%)	+33.2	+28.0	+23.8	+20.1	+21.6	<0.01
Income change (%)	+38.1	+31.4	+25.9	+30.4	+23.2	<0.01
Satisfaction (1-5)	4.4	4.4	4.0	3.5	3.8	<0.001

Figure 1 displays the heatmap of adoption rates by extension methodology and crop type. Figure 2 presents the process diagram showing the comparative extension methodology

pathways from problem identification through monitoring to diversification outcomes.

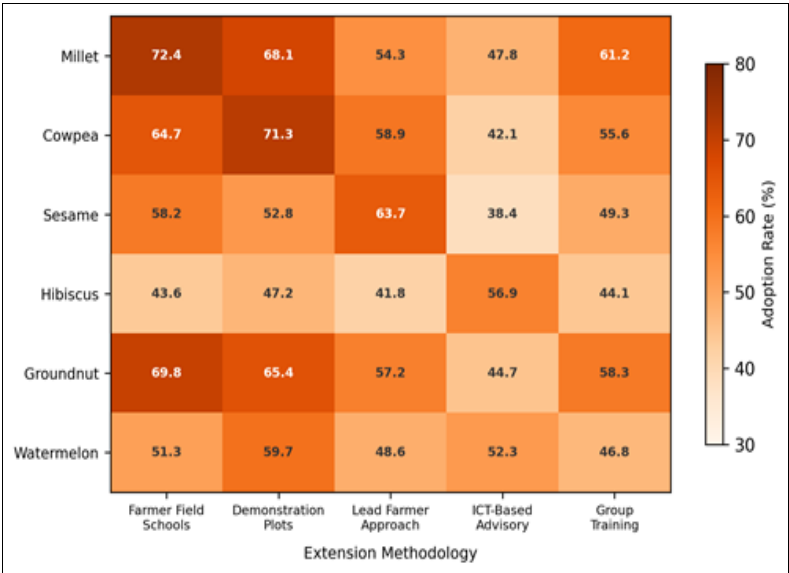


Fig 1: Heatmap of crop-specific adoption rates across five extension methodologies in the Groundnut Basin and Casamance regions

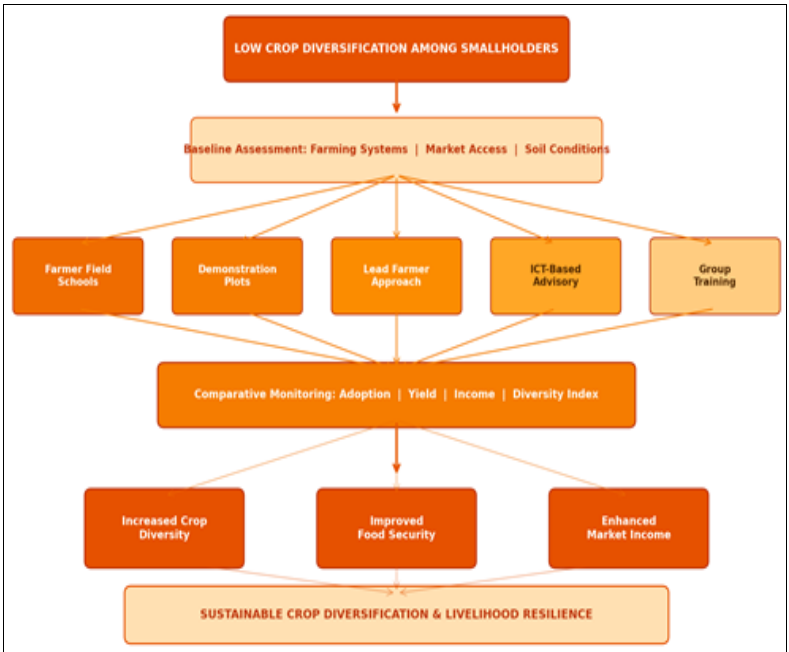


Fig 2: Process diagram showing comparative extension methodology pathways for promoting sustainable crop diversification

Regression analysis showed that trialability exposure ($\beta=0.41$, $p<0.001$) and peer interaction frequency ($\beta=0.32$, $p<0.01$) were the strongest methodology-level predictors of diversification adoption. ICT-based advisory, while lowest in overall adoption, was the only method significantly associated with market-oriented crop selection ($\beta=0.33$, $p<0.01$), suggesting it may serve a complementary rather than standalone role.

Comprehensive interpretation

Experiential, group-based methodologies consistently outperformed information-delivery approaches for promoting diversification. The adoption hierarchy-field schools first, ICT last-maps onto the theoretical prediction that innovations requiring complex behavioral change benefit most from hands-on learning and social reinforcement rather than information alone.

Discussion

The finding that farmer field schools outperformed other delivery models for diversification adoption aligns with meta-analytic evidence demonstrating field school advantages for complex agronomic practices^[11]. The 71.2% adoption rate surpasses the 45-55% range commonly reported for field schools targeting single-practice adoption, possibly because diversification-with its multiple decision points-benefits particularly from the iterative, season-long learning that field schools provide^[12]. Demonstration plots performed nearly as well, likely because they supply direct observational evidence of new crop performance under local growing conditions^[13]. The ICT-based advisory’s lower overall adoption but stronger market linkage association reveals an interesting pattern. Farmers receiving SMS and voice-based crop advisories were more inclined to select diversification crops based on market price data, even though fewer of them

diversified in the first place^[14]. This suggests ICT tools may be more effective at guiding crop choice than motivating the initial diversification decision—a distinction with practical implications for integrated extension strategies^[15].

The significant role of peer interaction frequency in predicting adoption underscores the social dimension of agricultural decision-making that purely technical extension approaches often overlook^[16]. Farmers don't just need information about new crops; they need to see neighbors trying them, hear about results, and share experiences—processes that field schools and lead farmer programs facilitate better than centralized delivery models^[17].

Practical applications

Extension programs seeking to promote crop diversification should prioritize experiential group methodologies—particularly farmer field schools and demonstration plots—as primary delivery channels. ICT-based advisory can be layered on top to strengthen market-oriented crop selection decisions, but should not be deployed as a standalone diversification promotion tool. Lead farmer programs offer a cost-effective middle option for scaling diversification messaging, provided lead farmers receive adequate support and crop-specific training.

Conclusion

This research evaluated five extension delivery models for promoting crop diversification across two regions of Senegal and found that experiential, group-based approaches—particularly farmer field schools and demonstration plots—achieved substantially higher adoption rates than information-transfer methods. The Simpson diversity index rose from 0.31 to 0.63 across all groups over two cropping seasons, with field school participants showing the greatest gains. Trialability exposure and peer interaction frequency were the strongest predictors of adoption. ICT-based advisory, while weakest in overall adoption, uniquely supported market-oriented crop selection. Extension systems aiming to promote diversification should invest primarily in field-based experiential learning while exploring complementary ICT integration for market information delivery.

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