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Farmer Characteristics And Agricultural Extension Access As Determinants Of Technology Adoption In Smallholder Corn Farming: Evidence From Pulubala District, Gorontalo Regency, Indonesia

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Abstract

Agricultural technology adoption is a strategic pathway for improving productivity and household welfare among smallholder farmers in developing economies. Despite sustained public investment in agricultural extension, adoption rates for many modern technologies remain persistently low, and the determinants of adoption are strongly context-specific. This study investigates the influence of farmer characteristics age, formal education level, and farming experience alongside agricultural extension access variables attendance history, information source, and perceived benefit on the adoption of modern agricultural technologies in corn farming in Pulubala District, Gorontalo Regency, Indonesia. A descriptive quantitative survey was administered to 42 corn farmers in Bukit Aren Village, selected proportionally from 35 registered farmer groups (kelompok tani) using the Slovin formula (alpha = 15%). Data were collected through structured interviews and analyzed using frequency distribution, cross-tabulation, and Spearman rank-order correlation. Results indicate that only 35.7% of farmers adopted two or more modern technologies simultaneously. Improved hybrid variety adoption was very high (90.5%), while mechanical technology uptake remained limited (hand tractors: 28.6%; shelling machines: 19.0%). Formal education showed the strongest individual-level association with adoption, with senior high school graduates exhibiting a 66.7% adoption rate versus 19.4% for primary school graduates. Extension attendance was the

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primary institutional discriminating factor: attendees adopted technologies at a rate 4.1 times higher than non-attendees (48.0% vs. 11.8%). A statistically significant moderate positive Spearman correlation was identified between extension frequency and the technology adoption score (rs = 0.487; p = 0.043). Perceived benefit of extension emerged as the strongest mediator of adoption, with a 6.4-fold adoption ratio between the highest and lowest perception subgroups. These findings underscore the urgency of quality-focused extension intensification, participatory curriculum design, and institutional facilitation of mechanical technology access through communal service mechanisms for smallholder corn farmers.

Keywords: agricultural extension; corn farming; diffusion of innovations; farmer characteristics; smallholder agriculture; technology adoption; Indonesia.

INTRODUCTION

Agricultural technology adoption constitutes a fundamental mechanism through which smallholder farmers in developing countries can enhance farm productivity and household welfare. Meta-analytic evidence synthesizing 367 regression models from 218 empirical studies confirms that while adoption responds to favorable farm characteristics and institutional support, no variable is universally predictive across technologies and contexts (Ruzzante et al., 2021). This context-specificity renders local-level empirical investigations indispensable for designing targeted interventions.

Indonesia's corn (Zea mays L.) sector is central to both national food security and rural livelihoods. Gorontalo Province ranks among the country's principal corn-producing regions, with approximately one-third of its 1.2 million hectares under corn cultivation and annual production reaching 692,439 tons in 2022. Pulubala District, within Gorontalo Regency, represents a key sub-regional production center, with harvested area expanding from 13,742 ha (2019) to 15,673 ha (2020). Yet corn yield productivity in Pulubala remains volatile and below potential 4.62 tons/ha in 2023 and 4.88 tons/ha in 2024 against a national average of 5.5–5.9 tons/ha. This persistent yield gap suggests that production growth has been driven by area expansion rather than technology-driven intensification.

The Diffusion of Innovations (DoI) framework provides the theoretical scaffolding for understanding technology adoption dynamics. Dissanayake et al. (2022) systematically reviewed theories and models of technology adoption in agriculture, confirming the centrality of the innovation-decision process and its five stages:

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knowledge, persuasion, decision, implementation, and confirmation. Rate and extent of adoption are jointly shaped by five perceived innovation attributes relative advantage, compatibility, complexity, trialability, and observability and by farmer characteristics and institutional factors, particularly agricultural extension services (Beaman et al., 2021; Wossen et al., 2017) Complementarily, Quarshie et al. (2022), in a study of smallholder maize farmers in Ghana, demonstrate that socio-demographic and economic factors, social networks, and location-specific extension delivery are key determinants of improved seed and technology adoption.

Previous research in Gorontalo and the broader Sulawesi region has primarily focused on marketing channel analysis and farm income in corn production (Mangge et al., 2023; Chandra et al., 2023), leaving the triadic relationship among farmer characteristics, extension access, and technology adoption in Pulubala District corn farming unexamined. Adoption studies in comparable Indonesian contexts including Bone Bolango (Suhana et al., 2023) and East Kupang as well as international evidence from Tanzania (Lasway et al., 2020) and Nigeria (Haruna et al., 2023) confirm that adoption determinants are highly context-specific. The research gap motivating this study is the absence of an integrated empirical analysis linking farmer-level and extension-level predictors to multidimensional technology adoption outcomes in smallholder corn farming in Pulubala.

This study makes three contributions. First, it provides the first integrated triadic analysis of farmer characteristics, extension access, and technology adoption for this specific production context. Second, it employs a multidimensional adoption index capturing both mechanical and agronomic technologies simultaneously. Third, it quantifies perceived extension benefit as a mediating variable between extension access and actual adoption behavior. The study pursues four specific objectives: (1) to profile modern agricultural technology adoption in Pulubala District corn farming; (2) to examine associations between farmer characteristics and technology adoption; (3) to document extension access patterns and information source utilization; and (4) to quantify the correlation between extension frequency and the technology adoption score.

LITERATURE REVIEW

Diffusion of Innovation Theory and Agricultural Technology Adoption

The DoI theory remains the most widely applied theoretical framework in agricultural technology adoption research. Dissanayake et al. (2022) identify five core attributes that determine adoption velocity: relative advantage (the degree to which an

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innovation outperforms the practice it supersedes), compatibility (alignment with existing values and practices), complexity (difficulty of understanding and use), trialability (the extent to which partial experimentation is possible), and observability (the visibility of outcomes to others). Technologies with high relative advantage, strong compatibility, low complexity, and high observability diffuse more rapidly a pattern empirically confirmed in both improved variety and mechanization adoption contexts (Khonje et al., 2015)

The large-scale meta-analysis by Ruzzante et al. (2021), drawing on 218 adoption studies across Africa, Asia, and Latin America, establishes that access to extension services consistently substitutes for formal education in predicting improved variety adoption. However, effects are heterogeneous across technology types what consistently predicts adoption of improved seeds may not apply to mechanical technologies or sustainable land management practices. This heterogeneity underlines the necessity of technology-specific and context-specific investigation, particularly in data-sparse sub-national settings such as Pulubala District.

Evidence from sub-Saharan Africa confirms the productivity and welfare dividends of technology adoption among smallholder maize farmers. Jaleta et al. (2018) find that adoption of improved maize varieties significantly increases per capita food consumption expenditure and perceived food security among 2,327 Ethiopian farm households. Khonje et al. (2015) demonstrate that improved maize adoption generates significant income, consumption, and poverty-reduction gains in Eastern Zambia. Sigigaba et al. (2021), analyzing open-pollinated maize variety adoption in South Africa, confirm that access to extension services and formal education are the key determinants of improved variety adoption, providing direct comparative evidence for the present study.

Farmer Characteristics as Determinants of Technology Adoption

Three farmer-level characteristics consistently appear as adoption determinants in the literature: formal education, farming experience, and age. Formal education enhances the cognitive capacity to evaluate unfamiliar technologies, process technical recommendations, and manage the information asymmetries inherent in technology markets (Akzar et al., 2023). Lasway et al. (2020), using three waves of Tanzanian National Panel Survey data from 1,839 maize-producing households, find that education level significantly and positively influences the likelihood of adopting improved seeds: a unit increase in education level raises the probability of improved seed adoption by 2.6 percentage points. Sigigaba et al. (2021) similarly report that each additional year of

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schooling increases the probability of OPV maize adoption, with the effect significant at the 5% level.

Farming experience presents a more ambiguous relationship with adoption. Extended experience accumulates practical agronomic knowledge that may facilitate adoption of compatible technologies; however, without concurrent access to updated information channels, experience can entrench traditional practices and reduce openness to novel innovations (Dissanayake et al., 2022) Age follows a directionally consistent but empirically weak pattern younger, productively-age farmers tend to exhibit greater openness to change, a pattern confirmed in Indonesian (Akzar et al., 2023) and South African (Ngcinela et al., 2019) contexts, though the magnitude of the effect is typically modest and sensitive to sample composition.

The heterogeneity of adoption across technology types adds a further dimension. Quarshie et al. (2022), in their mixed-methods study of smallholder maize farmers in Ghana, show that while awareness of hybrid seeds is high, actual adoption remains low due to cost barriers, limited access to credit, and insufficient targeted extension services patterns directly analogous to the mechanical technology adoption constraints documented in the present study. Haruna et al. (2023) confirm in a Nigerian maize-farming context that educational level, cooperative membership, and farm size are the strongest determinants of technology adoption level, reinforcing the multi-factorial character of adoption decisions.

Agricultural Extension and Technology Adoption

Agricultural extension services function as the primary institutional mechanism bridging the information gap between technology developers and smallholder farmers. Wossen et al. (2017), using household data from rural Nigeria combined with propensity score matching and endogenous switching regression, find that extension access exerts a positive and statistically significant effect on both technology adoption rates and household welfare. The impact on poverty reduction is substantially stronger for smallholders with concurrent access to formal credit, signaling critical complementarities between extension and rural financial services.

The channel through which agricultural information is delivered critically shapes adoption outcomes. Wang et al. (2020), studying Chinese farmers' water-saving irrigation technology adoption, find that professional extension services and peer-based social learning are competitive rather than purely complementary channels at the aggregate level. Professional extension generates superior adoption efficiency for complex

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technologies because agents supply credible, context-specific, and actionable technical information. Social network channels through farmer groups, while effective at information diffusion, may transmit incomplete or misapplied technical messages. Beaman et al. (2021) further show that theory-driven network targeting of seed farmers in Malawi selecting key network nodes to maximize information diffusion can outperform conventional extension approaches, suggesting that social network architecture matters as much as extension intensity.

The quality and relevance of extension content are as consequential as contact frequency. Gao et al. (2020) demonstrate that participatory and technology-mediated extension approaches produce significantly higher adoption rates than conventional top-down transfer methods among Chinese farmers. The design of extension curricula in alignment with local farming realities is identified as the primary lever of extension effectiveness, a finding directly relevant to this study's documentation of the perceived-benefit gradient.

Digital transformation increasingly shapes the extension landscape. Fabregas et al. (2019) synthesize meta-analytic evidence showing that mobile-based agricultural information delivery in sub-Saharan Africa and India increased crop yields by an average of 4% and raised the odds of adopting recommended inputs by 22%, at a cost-to-benefit ratio favorable by an order of magnitude. Xu et al. (2023), in a scoping review of 54 studies on technology use in agricultural extension, confirm that digital tools consistently enhance the effectiveness of extension programming in stimulating technology adoption. Tomoki et al. (2023) provide especially robust evidence from a quasi-experimental study in the Occupied Palestinian Territories: agricultural extension significantly increased the adoption probability of five technology categories by 3.8–7.7 percentage points even under conditions of geopolitical conflict, underscoring the resilience and generalizability of extension effects.

The structural constraints on extension effectiveness are documented by Amoussouhoui et al. (2024), who, in a PRISMA-based scoping review of 87 studies in developing countries, identify capital cost barriers, inadequate extension worker-to-farmer ratios, and weak farmer feedback mechanisms as the principal systemic constraints on extension-driven adoption. These findings are directly contextually relevant to smallholder corn farming in Gorontalo, where low extension coverage (59.5% in the present study), limited professional extension agent reach (28.6%), and a predominantly primary-school-educated farming population converge to suppress adoption rates.

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METHODOLOGY

Study Area and Research Design

This study employed a descriptive quantitative survey design. The research was conducted in Bukit Aren Village, Pulubala District, Gorontalo Regency, Gorontalo Province, Indonesia, purposively selected for its status as a principal corn production center in the province. Primary data collection was carried out during September-October 2024 through structured interviews using a pre-validated questionnaire. Content validity was confirmed through expert review by two agricultural extension specialists at Universitas Muhammadiyah Gorontalo.

Population, Sampling, and Variable Operationalization

The study population comprised 819 corn farmers enrolled in 35 registered farmer groups (kelompok tani) in Bukit Aren Village. Sample size was determined using the Slovin formula with a margin of error (alpha) of 15%, yielding n = 42 respondents. This tolerance was applied in recognition of the study's exploratory scope, the relative homogeneity of the target population (all members of registered farmer groups), and established sampling practice in Indonesian smallholder farming surveys. Respondents were selected proportionally from all 35 farmer groups to preserve inter-group representativeness.

The dependent variable was technology adoption, operationalized in two complementary forms: (a) adoption status: a binary indicator coded 1 if a farmer simultaneously adopted a minimum of two modern technologies and 0 otherwise; and (b) adoption score: an ordinal count variable ranging from 0 to 5 reflecting the total number of adopted modern technologies. This dual operationalization aligns with the multi-technology adoption framework recommended by Akzar et al. (2023), who argues that simultaneous multi-technology adoption better captures the productive upgrading of farm systems than single-technology indicators.

Independent variables comprised: (1) age in years; (2) formal education level (ordinal: primary school/SD, junior high/SMP, senior high or vocational/SMA-SMK); (3) farming experience in years; (4) extension attendance frequency (sessions per year); (5) primary technology information source (nominal categorical); and (6) perceived benefit of extension participation (3-level Likert scale: not beneficial, moderately beneficial, highly beneficial). Five technology categories were assessed across two typological classes: mechanical technologies hand tractors, corn shelling machines, and simple irrigation

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systems; and agronomic technologies improved hybrid corn varieties and balanced fertilization.

Analytical Framework

Data were analyzed in two stages. First, descriptive analysis using frequency distributions and percentages profiled the adoption landscape, farmer characteristics, and extension access patterns. Second, bivariate association analysis was conducted via: (a) cross-tabulation to identify adoption rate differentials across categorical characteristic subgroups; and (b) Spearman rank-order correlation (rs) to quantify the association between extension frequency (ordinal) and adoption score (ordinal count). Spearman's rho was selected over Pearson's r given the ordinal measurement scale of both variables and the small sample size (n = 42), which does not reliably satisfy the normality assumptions of parametric correlation (Ruzzante et al., 2021) Statistical significance was assessed at alpha = 0.05. All analyses were conducted using SPSS Version 25.

RESULTS AND DISCUSSION

Modern Agricultural Technology Adoption Profile

Table 1 presents the adoption profile of five modern agricultural technologies. The data reveal a pronounced disparity across technology types, consistent with DoI predictions that different innovation attributes determine differential rates of diffusion (Dissanayake et al., 2022)

Table 1. Modern Agricultural Technology Adoption Profile Corn Farmers in Pulubala District (n = 42)

Technology Type	Description / Function	n	%	Cat.
Hand Tractor	Mechanical land preparation	12	28.6	M
Corn Shelling Machine	Post-harvest grain separation	8	19.0	M

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Technology Type	Description / Function	n	%	Cat.
Simple Irrigation System	Dryland water management	3	7.1	M
Improved Hybrid Varieties	High-yielding certified seed	38	90.5	A
Balanced Fertilization	Recommended nutrient dosage	14	33.3	A
Total Adopters (≥2 technologies)		15	35.7	
Non-Adopters / Minimal Adoption		27	64.3	

Note. M = Mechanical technology; A = Agronomic technology; Cat. = Technology category. Adopter = farmer adopting a minimum of two technologies simultaneously. Source: Primary data, 2024.

Merely 35.7% of farmers qualified as adopters. The near-universal adoption of improved hybrid varieties (90.5%) starkly contrasts with the limited uptake of mechanical technologies hand tractors (28.6%) and shelling machines (19.0%). This pattern aligns with a fundamental DoI prediction: technologies with high relative advantage, strong compatibility with existing practices, low per-season cost, and a long history of government promotional support diffuse more rapidly and broadly. Hybrid varieties in Gorontalo satisfy all four criteria yield superiority is clearly observable, seed purchase is already integrated into planting routines, per-season costs are relatively accessible, and Gorontalo Province has consistently promoted hybrid corn through seed subsidy programs since 2001. These dynamics are empirically consistent with the rapid hybrid seed diffusion documented by Khonje et al. (2015) in Zambia and Jaleta et al. (2018) in Ethiopia.

Mechanical technology adoption is limited by the opposite constellation of innovation attributes: high capital requirement (low trialability for resource-constrained

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smallholders), operational complexity, and absence of local support ecosystems. Amoussouhoui et al. (2024) identify these barriers as systemically prevalent across developing country agricultural extension contexts. Quarshie et al. (2022) similarly document in Ghana that even awareness of improved technology does not translate into adoption when cost barriers and credit constraints remain unaddressed. The relatively low adoption of balanced fertilization (33.3%) further suggests that knowledge-intensive agronomic practices requiring dosage precision remain incompletely disseminated despite not requiring capital investment beyond fertilizer purchase.

Farmer Characteristics and Technology Adoption

Table 2 presents cross-tabulation results linking farmer characteristics to adoption status.

Table 2. Farmer Characteristics and Technology Adoption Status (n = 42)

Characteristic	Category	n	Adopters (%)	Non-Adopters (%)
Age Group	30-40 years	5	40.0	60.0
	41-50 years	22	31.8	68.2
	≥51 years	15	33.3	66.7
Formal Education	Primary school (SD)	31	19.4	80.6
	Junior high school (SMP)	6	50.0	50.0
	Senior high school (SMA/SMK)	5	66.7	33.3
Farming Experience	5-15 years	11	27.3	72.7
	16-30 years	8	37.5	62.5

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Characteristic	Category	n	Adopters (%)	Non-Adopters (%)
	>30 years	23	39.1	60.9

Note. Adopter = farmer simultaneously adopting ≥2 modern technologies. Source: Primary data, 2024.

Formal education exhibits the strongest and most consistent gradient in adoption. Senior high school or vocational graduates demonstrate an adoption rate of 66.7%, approximately 3.4 times higher than primary school graduates (19.4%), with junior high school graduates occupying an intermediate position (50.0%). This stepwise pattern confirms the meta-analytic finding of Ruzzante et al. (2021) that formal education consistently promotes improved variety adoption. Lasway et al. (2020), in their Tanzanian panel study, similarly document that higher education levels raise the probability of improved maize seed adoption by 2.6 percentage points per unit increase. Sigigaba et al. (2021) confirm a significant and positive education effect on OPV maize adoption in South Africa, while Ngcinela et al. (2019) identify education as a significant positive predictor of GM maize adoption at the 1% level. Critically, 73.8% of respondents in the present study hold only primary school education, indicating that the educational structure of this farming population constitutes a systemic impediment to broad-based technology adoption.

Farming experience shows a weaker, non-linear relationship with adoption. Farmers with more than 30 years of experience exhibit the highest adoption rate (39.1%), marginally higher than the 16-30 year group (37.5%) and the 5-15 year group (27.3%). The modest differentials suggest that practical knowledge accumulated over time does not strongly drive adoption of novel technologies without concurrent access to updated information channels. This finding aligns with Dissanayake et al. (2022) argument that experiential capital may reinforce established routines rather than stimulating technological openness, unless complemented by engagement with extension programs or knowledge networks Beaman et al. (2021). The implication for extension programming is that experienced farmers should not be assumed to be inherently innovative; rather, they require targeted exposure to technology-specific information just as much as younger, less experienced farmers.

Age group differences are modest (31.8-40.0%), with the youngest cohort (30-40 years) displaying the highest adoption rate (40.0%). This directional pattern is consistent

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with Akzar et al. (2023) and the broader literature suggesting that younger farmers exhibit greater openness to technological change. However, the small cell size in the youngest group (n = 5) limits the inferential weight assignable to this finding, and future research with larger samples is needed to reliably estimate age effects in this context.

Agricultural Extension Access and Technology Adoption

Table 3 presents the extension access profile and corresponding adoption rates by subgroup.

Table 3. Agricultural Extension Access Profile and Technology Adoption Rates by Subgroup (n = 42)

Extension Dimension	Category / Indicator	n	%	Adoption Rate (%)
Attendance History	Attended extension	25	59.5	48.0 (12/25)
	Never attended	17	40.5	11.8 (2/17)
Information Source	Field Extension Agent (PPL)	12	28.6	75.0 (9/12)
	Farmer Group (Kelompok Tani)	21	50.0	38.1 (8/21)
	Peer Farmers	15	35.7	26.7 (4/15)
	Internet / Social Media	3	7.1	66.7 (2/3)
Perceived Benefit	Highly beneficial	14	33.3	64.3 (9/14)
	Moderately beneficial	8	19.0	25.0 (2/8)
	Not / rarely beneficial	20	47.6	10.0 (2/20)

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Note. One respondent may report multiple information sources. Adoption rate = proportion of subgroup meeting the adopter criterion (≥2 technologies). Source: Primary data, 2024.

Extension attendance history proved the most discriminating institutional factor in adoption: 48.0% of farmers who had attended extension activities adopted modern technologies, compared with only 11.8% of non-attendees a 4.1-fold differential. This magnitude of effect is consistent with the positive and significant extension impacts documented by Wossen et al. (2017) in Nigeria and Nakamura et al. (2023) in Palestine. Importantly, only 59.5% of respondents had attended any extension activity, meaning that 40.5% of the farming population was systematically excluded from structured technology dissemination a coverage gap consistent with the structural constraints identified by Amoussouhoui et al. (2024).

The information source findings reveal a striking quality-reach trade-off. Farmer groups (kelompok tani) were the most widely accessed information channel (50.0% of farmers) yet produced a moderate adoption rate (38.1%). By contrast, field extension agents (PPL), accessible to only 28.6% of farmers, were associated with the highest adoption rate (75.0%). This pattern is precisely consistent with Wang et al.'s (2020) finding that professional extension and peer-based social learning are competitive channels, with professional extension generating superior adoption efficiency for complex technologies. The implication for policy is that scaling professional agent reach rather than simply relying on farmer group horizontal diffusion is more likely to improve the quality of adoption outcomes. Internet and social media, though currently accessed by only 7.1% of farmers, yielded an adoption rate of 66.7%, corroborating (Fabregas et al., 2019; Xu et al., 2023) evidence of the adoption-enhancing potential of digital information channels even in low-penetration environments.

Perceived benefit of extension exhibits the steepest adoption gradient of all measured variables: farmers who perceived extension as highly beneficial adopted technologies at a rate of 64.3%, compared with 25.0% among those who found it moderately beneficial and 10.0% among those who found it not beneficial. The 6.4-fold adoption ratio between the highest and lowest perception subgroups establishes perceived extension quality as the most powerful mediating mechanism documented in this study. This finding is directly consistent with Gao et al. (2020), who demonstrate that the relevance and quality of extension content are more influential than contact frequency alone. The implication is fundamental: reforming the content and design of extension

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programming is more consequential for adoption outcomes than simply increasing the number of contact sessions.

Spearman Correlation: Extension Frequency and Technology Adoption Score

Table 4 presents the Spearman correlation result between extension attendance frequency and the technology adoption score.

Table 4. Spearman Rank-Order Correlation: Extension Frequency and Technology Adoption Score (n = 42)

Variable Pair	Spearman rs	p-value	Interpretation
Extension frequency (sessions/year) × Technology adoption score (0-5)	**0.487**	0.043*	*Moderate positive; statistically significant (p < 0.05)*

Note. * Statistically significant at alpha = 0.05 (two-tailed). Analysis conducted using SPSS Version 25. Source: Primary data, 2024.

The Spearman coefficient rs = 0.487 (p = 0.043) indicates a statistically significant moderate positive correlation between extension attendance frequency and the technology adoption score. By Cohen's conventions, this magnitude classifies as a medium effect, confirming that greater intensity of extension engagement is associated with the adoption of a broader portfolio of modern technologies. The moderate rather than strong effect size also implies that extension frequency alone does not fully determine adoption farmer characteristics, innovation attributes, and structural access barriers jointly shape the adoption trajectory (Ruzzante et al., 2021). This interpretation is reinforced by the finding that extension perceived as highly beneficial generates far higher adoption than high-frequency extension perceived as not beneficial, indicating that intensity and quality are jointly necessary conditions for effective extension.

Integrative Synthesis and Policy Implications

The integrative synthesis of findings across the four analytical dimensions reveals that technology adoption in Pulubala District corn farming is jointly shaped by farmer-level human capital (primarily formal education) and institutional access variables (primarily extension quality and frequency). Formal education enhances cognitive capacity for technology evaluation (Akzar et al., 2023; Ruzzante et al., 2021), while quality extension

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functions as an institutional equalizer that partially compensates for educational deficits as demonstrated by the 19.4% adoption rate among primary-school-educated farmers who, despite limited formal education, still adopted technologies when exposed to extension programming.

The pronounced technology-type disparity underlines the necessity of differentiated promotion strategies. For mechanical technologies, reducing capital access barriers through communal Agricultural Machinery Service Units (UPJA Unit Pelayanan Jasa Alsintan) would enable cost-sharing and lower the per-farmer investment threshold, as theorized in the DoI framework (Dissanayake et al., 2022). For agronomic technologies, intensifying participatory extension with on-farm demonstration plots where farmers directly observe yield outcomes addresses the observability attribute that DoI theory identifies as a key diffusion accelerator. Sigigaba et al. (2021) recommend precisely this combination of strengthened extension training and farmer information days to increase improved maize variety uptake, a recommendation directly transferable to the Pulubala context.

The digital extension gap identified in this study (only 7.1% of farmers accessed online information, yet those who did achieved a 66.7% adoption rate) signals a transformative opportunity. Fabregas et al. (2019) demonstrate that agricultural information delivered digitally raises adoption odds by 22% at marginal transmission cost, while confirm that digital tools consistently enhance extension effectiveness. As mobile phone penetration expands in rural Gorontalo, digital extension channels represent a high-leverage, low-marginal-cost pathway for scaling professional-quality technical information to a farming population that is currently underserved by conventional face-to-face extension delivery.

CONCLUSION

This study examined farmer characteristics, agricultural extension access, and modern agricultural technology adoption among 42 smallholder corn farmers in Pulubala District, Gorontalo Regency, Indonesia. Five principal conclusions are drawn. First, overall technology adoption is low: only 35.7% of farmers adopted two or more modern technologies simultaneously, with a marked disparity between very high hybrid variety uptake (90.5%) and limited mechanical technology adoption (19.0–28.6%). Second, formal education is the strongest individual-level determinant, with senior high school graduates demonstrating adoption rates 3.4 times higher than primary school graduates (66.7% vs. 19.4%). Third, extension attendance is the primary institutional discriminating

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factor, with attendees adopting technologies at a rate 4.1 times higher than non-attendees (48.0% vs. 11.8%). Fourth, a statistically significant moderate positive correlation exists between extension frequency and adoption score ($r_s = 0.487$; $p = 0.043$), confirming that more intensive extension engagement is associated with broader technology portfolio adoption. Fifth, perceived benefit of extension is the strongest mediator, with a 6.4-fold adoption ratio between the highest and lowest perception subgroups, demonstrating that the quality and relevance of extension content exert greater influence than contact frequency alone.

Four evidence-based policy recommendations follow. (1) Intensify professional extension reach: develop a hybrid model in which farmer groups serve as geographic distribution platforms for professionally-designed extension content and on-farm demonstrations, combining the broad reach of horizontal peer channels with the technical depth of professional agent delivery. (2) Redesign extension curricula participatorily: co-develop extension content with farmers around locally-relevant challenges particularly mechanical technology operation and balanced fertilization to increase the perceived relevance that this study identifies as the pivotal adoption mediator. (3) Facilitate communal machinery service units (UPJA) at the farmer group level to reduce per-farmer capital barriers for mechanical technology access, enabling cost-sharing while building operational competencies. (4) Invest in digital extension infrastructure to leverage the demonstrated effectiveness of digital information channels, even in currently low-penetration rural environments.

Limitations include the small sample size ($n = 42$) from a single village, the cross-sectional design precluding causal inference, and the absence of multivariate control for confounding variables. Future research should employ larger, multi-village samples with longitudinal or quasi-experimental designs and multivariate inferential methods (binary logistic regression, Tobit models, or structural equation modeling) to identify causal pathways, quantify moderating variables, and generate generalizable findings applicable to the broader Gorontalo corn-farming landscape

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