

Technology Adoptions Among Smallholder Rice Farmers: Comparative Attitudes Toward Mechanization and GMO in Surigao del Norte, Caraga Region

Joanna P. Feril*, Benjamin C. Paler

College of Agriculture, Surigao del Norte State University, Surigao del Norte, Philippines

*Corresponding Author Email: joannaferil35@gmail.com

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Abstract. This paper examines comparative attitudes toward farm mechanization and genetically modified organisms (GMOs) in Barangay Pongtud, Alegria, Surigao del Norte, Philippines. A Likert-scale questionnaire was administered from March to May 2024 to 53 rice and corn farmers of the Tongao association of Pongtud via a descriptive survey. The results show a divergence between acceptance of technology: farmers are optimistic about mechanization, rating performance and productivity benefits of machinery as high (>4.0/5.0), but are skeptical about GMOs, with ratings of confidence in safety and likelihood to adopt Genetically Modified Organisms as being low (<2.0/5.0). Aging farmers with economic constraints base adoption decisions on perceived safety, proven benefits, and experience rather than innovation alone. These findings highlight the challenges of agricultural development strategies, underscoring the need for a clear distinction between technologies that address specific farmer concerns and those that provide adequate solutions. Mechanization requires both technical training and maintenance services, whereas evidence-based safety training and open communication are essential to ensure the acceptance of GMOs. These findings inform policy formulation in agriculture by balancing advances in technology and the demands and needs of the farmers, as well as conventions in the rural Philippine setting.

Keywords: Agricultural innovation adoption; Attitudes toward technology; Filipino farmers; Perceptions of GMO; Rural development.

1.0 Introduction

Philippine agriculture is transitioning to a modernized system, driven by concerns over food security, climate change, and the need for advanced technologies, including tractors, machines, and genetically modified organisms (GMOs). Regarding socioeconomic and cultural circumstances, these are accepted to varying degrees. Although farmers recognize that mechanization has enhanced productivity and efficiency, the process is often hindered by financial constraints and limited awareness (Adekanye, 2014; Bautista, 2017; Abad et al., 2023).

Recent research indicated that farmers in the onion sector and piggery owners are aware of the advantages of mechanization. However, social issues and safety aspects contribute to the adoption of mechanization and technologies (Abad et al., 2023; Bacalso et al., 2023). Farmers' judgments about GMO crops depend on their knowledge, information sources, and cultural background. Emotional arguments have arisen due to misinformation and pseudoscientific statements that raise concerns about health and the environment (Karau et

al., 2020; Olomy et al., 2023). Poor communication by scientists has contributed to dissatisfaction and misinformation among farmers (Olomy et al., 2023). The diversity in responses to GM crops confirms the need for education (Zakaria et al., 2022). The negative attitude toward genetically modified foods stems from consumer concerns and distrust of these products (Chagwena et al., 2019). The positive outcomes of GM technology have been acknowledged in the Philippines. However, concerns remain about biodiversity, biosafety standards, and impact on local agriculture, necessitating transparent communication (Aerni, 2002).

Barangay Pongtud, located in Alegria, Surigao del Norte, is a rural, rice-producing barangay with 1,551 residents, accounting for approximately 9.6% of Alegria's population (PhilAtlas, 2020). It sits on elevated terrain near the Pongtud-Magpayang River and is identified among Alegria's irrigated areas suitable for rice production (LGU Alegria, n.d.). Local government plans prioritize Pongtud for organic rice and technology adoption programs, while Alegria is one of the province's "rice baskets" (LGU Alegria, n.d.). At the same time, Pongtud faces climate-related risks; flood events have affected households along the national highway during recent tropical storms (Alegria MDRRMO, 2021). Infrastructure such as the potable water system turned over in 2009 has also improved farming resilience (Alegria LGU, 2009). These strong rice orientation and irrigation access, paired with hydrometeorological hazards, make Pongtud a relevant micro-setting for examining how farmers weigh mechanization and GMOs under constraints and opportunities. This setting provides context for technology adoption research, as the area experiences aging farmers, limited access to credit, and climate vulnerability, while benefiting from irrigation infrastructure. The ongoing debates over GMO commercialization and mechanization programs make farmers' attitudes in such communities crucial for understanding agricultural modernization in similar rural contexts.

Despite research on individual technology adoption, there is limited comparative analysis of farmer attitudes toward different agricultural technologies within the same community context. Most studies examine either mechanization or GMO adoption separately, failing to capture how farmers evaluate technologies. Understanding the attitudes of smallholder farmers is crucial for developing effective agricultural policies in the Philippines. The intersection of aging farmer demographics, economic constraints, and dual technology choices has not been explored in Philippine agricultural contexts. This knowledge gap limits understanding of how to design technology promotion strategies for diverse rural communities.

2.0 Methodology

2.1 Study Setting

We surveyed farmers in Pongtud, Municipality of Alegria, Surigao del Norte, from March to May 2024, on members of the Tongao Pongtud Farmers Association (TPFA), a Department of Labor and Employment (DOLE)-registered organization since November 2019. This organization has managed 82.29 hectares of irrigated rice land, 40 hectares of rain-fed land, and five hectares of corn production.

2.2 Research Design and Participants

Descriptive research was employed to investigate farmers' comparative perspectives on farm mechanization and GMO planting. There were 134 individuals (76 males and 58 females), and 53 rice and corn producers were identified as respondents. Following approval from the TPFA president, data collection was conducted during the monthly meeting. The researchers attended, discussed the questionnaire in the vernacular, and allowed the identified respondents sufficient time to complete the questionnaire.

2.3 Inclusion and Exclusion Criteria

Inclusion criteria were: (1) active membership in TPFA for at least one year, (2) primary involvement in rice or corn production, (3) age 18 years or older, (4) ability to provide informed consent, and (5) availability during the data collection period. Exclusion criteria included: (1) farmers engaged only in non-rice/corn crops, (2) members with less than one year of farming experience in the area, (3) those unable to understand the questionnaire despite vernacular translation, and (4) incomplete questionnaire responses.

2.4 Survey Instrument and Measures

Three main questions gathered farmers' demographic information, farming experiences, perceptions of farm mechanization, and acceptance of genetically modified organisms (GMOs). The gathered responses were tabulated and categorized using a Likert scale, as shown in Table 1.

Table 1. *Likert scale categorization for survey responses*

Score Range	Verbal Interpretation	Descriptive Rating
1.00-1.74	Not at All	Very Low
1.75-2.49	Slightly	Low
2.50-3.24	Moderately	Moderate
3.25-3.99	Significantly	High
4.00-5.00	Extremely	Very High

2.5 Instrument Development and Validation

Initial Development and Expert Review

The survey instrument was developed through a literature review of technology adoption frameworks and measures of farmer attitudes. Content validity was reviewed by three agricultural economists and two rural sociologists about the relevance, clarity, and appropriateness of the questions in the Philippine context.

Pilot Testing and Refinement

Pilot testing was conducted with 10 farmers from adjacent barangays with socioeconomic and agricultural characteristics similar to those of Pongtud. Minor modifications were made to improve vernacular clarity while maintaining validity. Test-retest reliability was assessed with 15 pilot participants over a two-week interval ($r = 0.82$, $p < 0.01$).

Reliability and Validity Assessment

Internal consistency was evaluated using Cronbach's alpha coefficients: the mechanization perception scale ($\alpha = 0.847$) and the GMO attitude scale ($\alpha = 0.891$), both of which exceeded the acceptable thresholds for research applications. Face validity was confirmed through feedback from pilot participants.

2.6 Data Collection Procedures

Coordination and Scheduling

Data collection was coordinated with TPFA leadership to schedule administration during the March 2024 monthly meeting. Prior approval was obtained from the association president, establishing a formal research partnership and community consent protocols.

Survey Administration

Researchers attended the TPFA meeting and provided instructions in Cebuano (the local vernacular) to ensure uniform understanding among all participants. The questionnaire was administered individually with the researchers' assistance. Participants completed the surveys independently, while researchers remained available to address any questions or concerns.

Data Verification and Quality Control

Immediate verification was conducted for response completeness, with follow-up clarification obtained for any ambiguous responses. All questionnaires were reviewed on-site before participants departed.

2.7 Ethical Considerations

Verbal informed consent was obtained after the study objectives, principles of voluntary participation, and confidentiality protocols were explained to the participant. Participants were informed of withdrawal rights without penalty. Data anonymity was maintained by excluding personal identifiers and storing data in password-protected files accessible only to researchers. The study design risk involves standard agricultural attitude assessment procedures.

2.8 Statistical analysis

Descriptive statistical tools were utilized for data interpretation. Frequency counts and percentages were used to analyze the demographic profiles of the respondents. Mean scores were calculated to assess respondents' perceptions of various farm mechanization and GMO planting practices.

Associations among socio-demographic variables were tested using Chi-square or Fisher's Exact Test. Links between socio-demographics and perceptions of mechanization and GMO planting were analyzed through t-tests, One-way ANOVA, or non-parametric equivalents, with ordinal predictors assessed via Spearman's correlation. Item-level analyses used descriptive statistics, confidence intervals, Top-2/Bottom-2 box scores, z-tests against

neutrality, and Cohen's *d*. Domain-level means and confidence intervals summarized overall attitudes. All analyses were performed using the Statistical Tool for Agricultural Research (STAR).

3.0 Results and Discussion

3.1 Socio-demographic Characteristics

The socio-demographic profile highlights the challenges of Philippine agriculture. The sample was predominantly male (81.13%) and aging, with 75.47% aged 51 years or older, and no respondents aged 31 years or younger (Figure 1). This exceeds national farmer averages of 57 years (Palis, 2020) and 54 years (Sibayan, 2016), suggesting a faster demographic transition in remote areas.

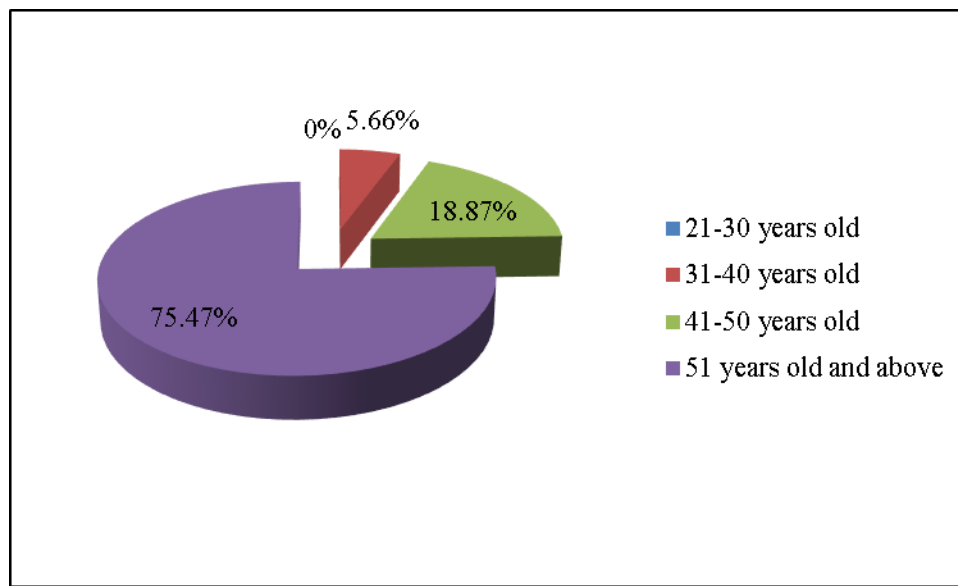


Figure 1. Age distribution of farmer respondents (*n*=53) in Barangay Pongtud, Alegria, Surigao del Norte

Educational attainment showed that 22.64% completed primary and secondary education, and 15.09% held college degrees. This is higher than in Bukidnon, where 53% of older farmers had not finished elementary (Dupa & Cagas, 2021), indicating better access to education in the study area. Still, 18.87% at the elementary level, underscoring education gaps. Household structures were large, with 37.74% having 7–8 members and 33.96% having 5–6 members. This family structure is consistent with extended rural family systems that provide labor and security. Most respondents were married (83.02%), though 13.21% were separated, reflecting migration and economic strain on family stability. Economic vulnerability showed 58.49% earned below Php 10,000 per month, while only 11.32% earned above Php 15,000. These economic constraints of smallholder farming systems limit the capacity for technology adoption. These findings mirror those found in Cawayan, Masbate, where even experienced farmers remain among the poorest (Ibañez Jr et al., 2023). To cope, households pursued other income sources: 37.74% raised livestock, 28.30% engaged in wage labor, and 66.04% participated in non-farm activities (Figure 2). Such diversification aligns with the livelihood complexes described by Rigg et al. (2020) and the survival strategies they employ. No respondents reported fishing despite coastal proximity, indicating limited marine access or agricultural specialization.

Farming experience was 50.94% reporting more than 21 years, and 82.01% than 10 years. However, long experience coexisted with poverty, illustrating the experience–poverty paradox where traditional knowledge does not guarantee economic mobility without market access or institutional support. Land tenure revealed unequal access: 37.74% practiced sharecropping (“suki”), 28.30% were tenants, 18.87% owners, and 15.09% lessees (Figure 3). With a 66.04% sharecropping or tenancy rate, these reflect land concentration (Hirtz, 1998). Moreover, 54.72% farmed less than a hectare, classified as smallholders requiring support to enhance productivity and viability.

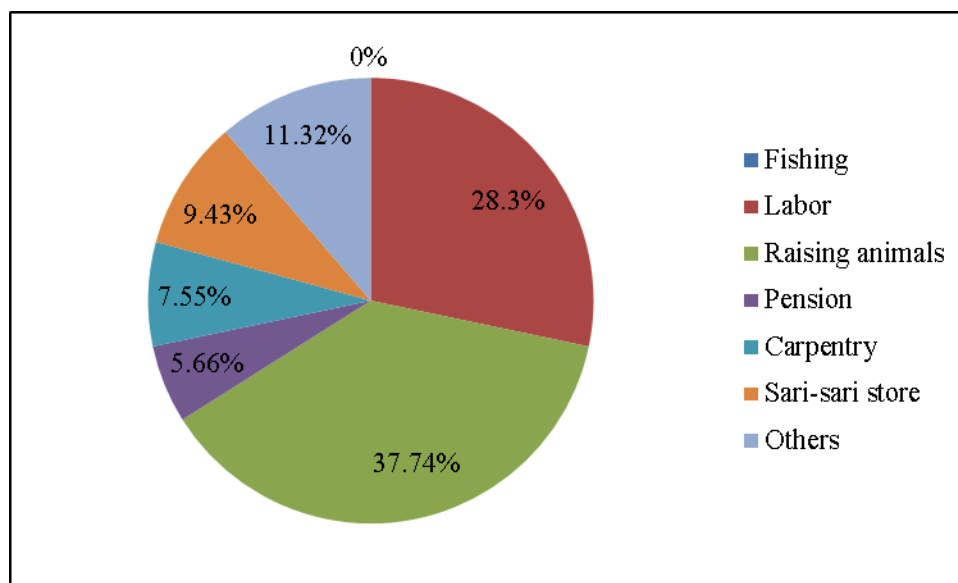


Figure 2. Income diversification strategies among farmer respondents (n=53) in Barangay Pongtud, Alegria, Surigao del Norte

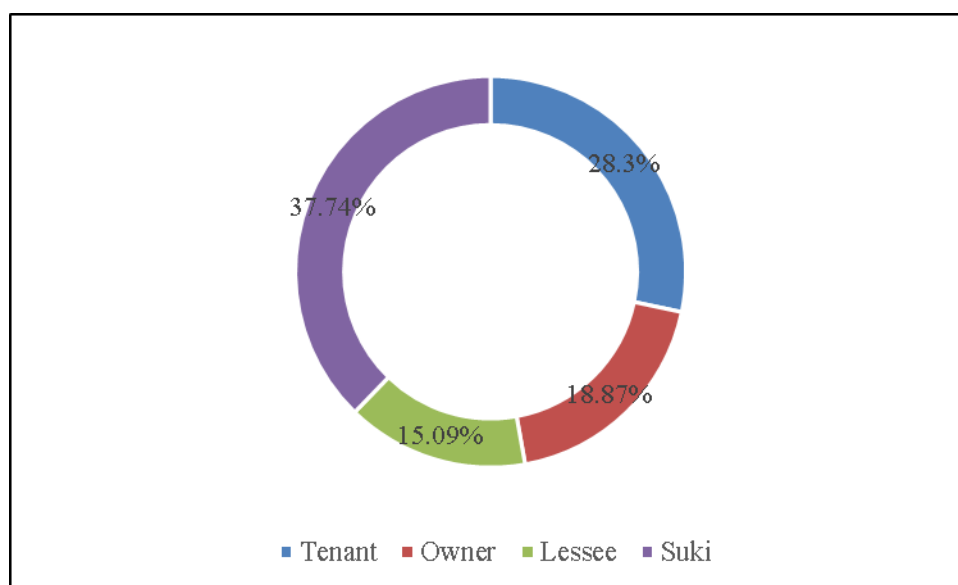


Figure 3. Land tenure distribution among farmer respondents (n=53) in Barangay Pongtud, Alegria, Surigao del Norte

3.2 Farming Characteristics

Most farms (77.36%) were irrigated lowland (Table 2), a proportion that exceeds the national average of 35% (Waibel, 2012). This advantage underpins the community's agricultural productivity and explains its focus on crop cultivation. Rice was the dominant (62.26%), as rice is the national staple providing nearly half of caloric intake (Boquet & Boquet, 2017; Redfern et al., 2012). Corn (28.30%) and mixed rice-corn systems (9.43%) reflect diversification that mitigates risks from climate variability and market fluctuations.

Table 2. Farming system characteristics of respondents in Barangay Pongtud, Alegria, Surigao del Norte.

Farming System	Categories	Quantity	Percentage
Land Topography	Upland	12	22.64
	Lowland	41	77.36
Irrigation System	Rain fed	12	22.64
	Irrigated	41	77.36
Crops planted	Rice	33	62.26
	Corn	15	28.3
	Both	5	9.43

The coexistence of irrigated (77.36%) and rainfed systems (22.64%) illustrates adaptive strategies. While irrigation provides production stability, rainfed serves as a fallback during infrastructure repairs or water shortages. This mirrors that rainfed farming is important despite irrigation expansion (de la Torre et al., 2021). Mixed cropping supports resilience during irrigation reconstruction when shifts from rice to corn were observed. This cropping shift demonstrates farmer adaptability to infrastructure challenges and market opportunities (Quion & Cagasan, 2021). The favorable infrastructure and diversified production position the community for agricultural development. However, 58.49% of households earn below Php 10,000, highlighting that infrastructure cannot ensure livelihood improvement without access to technology, markets, and financial support.

3.3 Demographic Associations

Gender was significantly associated with civil status and education, but not with age (Table 3). These relationships reflect traditional marriages, gendered migration, and differential access to education, where men remain in agriculture while women pursue alternative opportunities (McKay, 2005). Age was strongly associated with farming experience, as older farmers possess greater agricultural knowledge (Chaudhary et al., 2020; Rizki & Andini, 2024).

Table 3. Statistical associations among socio-demographic variables of respondents (Chi-square test)

Variable 1	Variable 2	χ^2	p-value
Sex	Age	4.00	0.135
Sex	Civil Status	40.52	< .001
Sex	Education	45.16	< .001
Age	Farming Experience	74.05	< .001
Education	Family Income	76.48	< .001
Farming Experience	Tenurial Status	82.80	< .001

However, the absence of younger farmers highlights risks to intergenerational transfer of farming expertise. Education was strongly linked to income, underscoring its role in socioeconomic improvement practices (Khurana, 2014), market access, and the cultivation of higher-value crops (Bagamba, 2007). Farming experience also correlated with land tenure, as experienced farmers either secure favorable tenure over time or stay in stable systems of sharecropping (Caulfield et al., 2020). These associations reveal that demographic factors shape and reinforce livelihood outcomes. Education is a pathway for poverty reduction (Panduwinata et al., 2025), while tenure security is tied to farming experience. Agricultural policies should prioritize education and land access, recognizing that interventions in one demographic domain can generate cascading effects across others.

3.4 Perception of Farm Mechanization

Machinery performance and reliability received the highest rating of 4.23 (Table 4), with 100% favorable responses and a large effect size (Cohen's $d = 2.90$), $p < .001$ (Table 5). This finding aligns with Bacalso et al. (2023), who noted that Philippine farmers value mechanization over manual labor.

Table 4. Farmers' perceptions of farm mechanization impact in Barangay Pongtud, Alegria, Surigao del Norte

Indicators	Weighted Mean	Verbal Interpretation	Descriptive Rating
How would you rate the effectiveness of farm mechanization in increasing your farm's overall productivity?	4.19	Extremely	Very High
To what extent has farm mechanization simplified your farming tasks and operations?	4.11	Extremely	Very High
How satisfied are you with the performance and reliability of the machinery and equipment you use on your farm?	4.23	Extremely	Very High
How would you rate the impact of farm mechanization on reducing your workload and labor requirements?	4.15	Extremely	Very High
How effective do you believe farm mechanization has reduced postharvest losses and increased efficiency?	3.87	Significantly	High
How confident are you in your ability to effectively utilize and maintain farm machinery and equipment?	3.87	Significantly	High

Similarly, productivity effectiveness and labor reduction benefits both support with huge effect sizes (Cohen's $d = 3.01$ and 3.18 , respectively) (Table 5). This confirms mechanization's role in enhancing and alleviating labor shortages (Declaro-Ruedas, 2019). Operational simplification also scored high, with 92.5% favorable responses. This supports Lak and Almassi's (2011) observation that technology adoption is linked to ease of use. However,

lower ratings were observed for post-harvest loss reduction (77.40%) and confidence in machinery utilization/maintenance (81.10%). These results suggest that farmers recognize mechanization's benefits, but technical gaps in maintenance remain. Similar challenges have been documented in the Philippines (Munar et al., 2021) and elsewhere (Sigdel et al., 2022).

Table 5. Item-level descriptive statistics and tests for farm mechanization perceptions.

Item	Mean	SD	Favorable	Cohen d vs 3	p-value (two-sided)
Productivity	4.19	0.39	100.00%	3.01	< .001
Tasks simplified	4.11	0.51	92.50%	2.20	< .001
Performance/reliability	4.23	0.42	100.00%	2.90	< .001
Reduced workload	4.15	0.36	100.00%	3.18	< .001
post-harvest losses	3.87	0.56	77.40%	1.56	< .001
Confidence using/ maintaining	3.87	0.48	81.10%	1.80	< .001

SD = Standard Deviation; Cohen d vs 3 = Cohen's d effect size comparing item mean against neutral point (3.0); p-value = Statistical significance level (two-sided test)

The strong acceptance of mechanization in this study contrasts with reports from Bunawan, Agusan del Sur, where costs and spare parts limited adoption (Garcines, 2019), as well as financial barriers faced by Nigerian smallholders (Adekanye, 2014). For smallholder farmers facing labor shortages and an aging population, mechanization is essential to achieve productivity gains within their limited landholdings. The favorable perceptions here reflect supportive conditions such as higher irrigation access and organized farmer associations. Mechanization was perceived as reliable, productive, and labor-saving, but technical skills and maintenance support remain critical gaps. Policy should convince farmers of the value of mechanization to strengthen extension services, provide training, and develop local networks. When combined with infrastructure and farmer organizations, such support can maximize the contribution of mechanization to agricultural development.

3.5 Perceptions of GMO

Farmers expressed negative views on GMOs due to food safety concerns. Confidence in safety received the lowest score of 1.77 (Table 6), with 88.7% unfavorable responses and no favorable ratings (Table 7). This perception was significantly below neutrality (Cohen's $d = -1.92$), indicating strong practical significance. Similar safety apprehensions have been reported in Zimbabwe (Chagwena et al., 2019), suggesting these concerns transcend geographic boundaries.

Table 6. Farmers' perceptions and attitudes toward genetically modified organisms (GMOs) in Barangay Pongtud, Alegria, Surigao del Norte

INDICATORS	Weighted Mean	Verbal Interpretation	Descriptive Rating
How familiar are you with the concept of genetically modified (GMO) crops and their planting methods?	2.83	Moderately	Moderate
To what extent do you believe GMO crops can contribute to addressing food security and reducing hunger?	2.02	Slightly	Low
How likely are you to accept the planting of GMO crops on your farm in the near future?	1.79	Slightly	Low
How confident are you in the safety of consuming GMO crops for human health?	1.43	Not at All	Very Low
To what extent do you believe GMO crops can help reduce the use of chemical pesticides and herbicides in agriculture?	1.77	Slightly	Low
How receptive are you to adopting new GMO varieties that offer improved traits such as drought resistance or higher nutritional value?	2.04	Slightly	Low

Willingness to adopt GMO crops scored 1.94, with 90.6% of responses unfavorable. The largest negative effect size (Cohen's $d = -2.13$) confirmed resistance and rejection (Table 7). Farmers doubted GMO environmental benefits, with skepticism about reductions in pesticide use (2.02, $p < .001$) and contributions to food security (2.11, $p < .001$). These views counter the evidence on GMO yield and pest-resistance benefits (Karau et al., 2020).

Table 7. Item-level descriptive statistics and tests for GMO perceptions

Item	Mean	SD	Favorable	Unfavorable	p-value (two-sided)
Familiarity	2.83	0.80	24.50%	41.50%	0.1219
Contributes to food security	2.11	0.61	3.80%	83.00%	<0.001
Likely to accept soon	1.94	0.50	0.00%	90.60%	<0.001
Confident in human safety	1.77	0.64	0.00%	88.70%	<0.001
Pesticide/herbicide use	2.02	0.72	0.00%	73.60%	<0.001
Receptive to improved traits	2.19	0.68	0.00%	66.00%	<0.001

SD = Standard Deviation; Cohen d vs 3 = Cohen's d effect size comparing item mean against neutral point (3.0), p-value = Statistical significance level (two-sided test)

Drought tolerance or enhanced nutrition of GMO failed to attract support, scoring 2.19, $p < .001$, indicating that perceived risks outweigh benefits. Familiarity with GMOs approached neutrality, with a mean score of 2.83 ($p = .122$), implying moderate awareness but little trust. This gap between knowledge and acceptance reflects misinformation and the weak credibility of information (Olomy et al., 2023). The contrast between the rejection of GMOs and the strong acceptance of mechanization indicates that resistance is not to innovation, but to specific technologies perceived as unsafe. Smallholder aversion to GMOs reflects their vulnerability to food security threats, as crop failure has immediate household consequences, unlike in larger commercial operations. Local cultural and contextual factors in the Philippines and elsewhere (Aerni, 2002) play a role. Addressing safety concerns, improving trust through credible communication, and establishing regulatory frameworks are conditions for GMO adoption (Autade et al., 2015).

3.6 Demographic-Perception Relationships

Independent t-test results showed no significant difference in mechanization perceptions between male and female farmers ($t = 0.731$, $p = .476$) (Table 8), indicating gender does not shape mechanization attitudes. This contrasts with gender-based barriers to adoption (Abad et al., 2023). Both men and women in this community value mechanization equally, consistent with Bacalso et al. (2023), who found that Philippine farmers acknowledge mechanization's advantages. One-way ANOVA revealed no significant variation in GMO perceptions across education levels ($F = 0.705$, $p = .623$) (Table 8). These negative attitudes despite education are notable given the strong education-income association ($\chi^2 = 76.481$, $p < .001$) in Table 3. The results suggest skepticism toward GMOs is shaped less by formal schooling than by factors such as misinformation or distrust (Zakaria et al., 2022; Karau et al., 2020).

Spearman correlation indicated no significant relationship between farming experience and mechanization perceptions ($\rho = -0.176$, $p = .208$) (Table 8). Both beginner and long-tenured farmers expressed positive attitudes toward the benefits of mechanization, recognizing them regardless of experience. While the weak negative trend hints that older farmers may be slightly more hesitant, the lack of statistical significance rules out meaningful differences.

Table 8. Relationships between socio-demographic variables and technology perceptions

Test	Variables Compared	Test Statistic	p-value
Independent t-test	Mechanization perception: Male vs Female	$t = 0.731$	0.476
One-way ANOVA	GMO perception by Education Level	$F = 0.705$	0.623
Spearman Correlation	Farming Experience vs Mechanization perception	$\rho = -0.176$	0.208

Across gender, education, and experience, perceptions of mechanization and GMO showed no significant demographic variation, emphasizing community-wide consistency in technology attitudes. This uniformity reflects farming challenges, community exposure to mechanization, and persistent skepticism toward GMOs regardless of personal background. These results align with Aerni (2002) on context-driven perceptions and with Olomy et al. (2023), who highlight the role of weak communication in sustaining farmer mistrust.

4.0 Conclusion

Smallholder rice farmers in Surigao del Norte show strong acceptance of mechanization but clear rejection of GMO, reflecting technology-specific concerns rather than demographic factors. Mechanization adoption can be supported through training and maintenance assistance, while GMO acceptance requires transparent safety information and strong regulatory oversight. Policies should also address constraints faced by smallholders, such as limited capital, small farm sizes, and subsistence needs. Overall, agricultural modernization in rural Philippine communities depends on tailored and sensitive approaches to technology adoption.

5.0 Contribution of Authors

Author 1- designed the study, performed the statistical analysis, and corresponded. Author 2- data gathering, managed the literature search, and approved the final manuscript.

6.0 Funding

No funding agency for this research.

7.0 Conflict of Interest

The authors declared no conflict of interest.

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