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SMART FARMING IN INDONESIA: BEHAVIOURAL STUDY ON ADOPTION OF INTERNET-BASED FERTILISATION SYSTEMS

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Providing precise fertilisation guidance is vital for improving productivity and reducing environmental risks, yet the adoption of precision fertiliser systems remains low. The study investigates farmers' intentions to adopt an Internet-based rice fertiliser information system across three agroecosystems: irrigated (Yogyakarta), rainfed (North Sumatra), and tidal (Central Kalimantan), with 100 farmers from each region. Applying an extended version of the technology acceptance model and using PLS-SEM analysis, the findings showed that perceived usefulness, perceived ease of use, and social norms are key determinants influencing individuals' intention to adopt. Institutional trust also promotes adoption, while experience has no significant effect. These findings highlight the importance of trust and targeted training to boost farmers' digital engagement with precision fertilisation technologies.

Keywords: intention to use; precision fertilisation; structural equation modelling; technology acceptance model

Rice farming plays a vital role in Indonesia's agriculture, contributing to food security, economic development, and sustainability, which requires improvements in ecological, technological, and institutional aspects (Rachman et al., 2022). Fertiliser is a key input, with urea and NPK being the most widely used because they are fertilisers subsidised by the government, and the need for N fertiliser for rice is greater than that for P and K. However, farmers in developing countries often face barriers in accessing timely and reliable agricultural information due to reliance on informal sources and limited access to extension services (Nugroho, 2021). Fertilisation behaviour is influenced by information sources, social networks, and Internet use (Weng et al., 2023).

Fertilisation decisions in Indonesian agriculture rely on peer or farmer perception rather than site-specific data. It leads to over- or under-fertilisation, which raises environmental concerns and lowers potential yield. Increasing input precision requires the implementation of Internet-based fertilisation guidance systems. These systems offer immediate, data-based suggestions specific to the area's agro-ecological circumstances. In order to integrate the smart farming technology into Indonesian smallholder farming systems, the study was carried out as part of a larger project that was backed by national research collaborations and agricultural digital transformation agendas. Precision agriculture offers an effective strategy for enhancing resource efficiency and reducing environmental harm. In this era of information-driven agriculture, equipping farmers with decision-support tools is crucial. Digital platforms like Rice Crop Manager (RCM), proven effective in

Indonesia (Girsang et al., 2025) and the Philippines, provide site-specific fertilisation recommendations (Buresh et al., 2019). Other precision technologies include drone spraying and the Integrated Planting Calendar Information System, which assists in planning crop schedules and fertiliser use (Apriyana et al., 2021).

Farmers are central to innovation adoption and dissemination. Communication effectiveness depends on the integration of mass media and interpersonal interactions (Grözinger et al., 2020), yet adoption is shaped by farmers' attitudes, experiences, and perceptions. The key determinants include perceived usefulness (PU) and ease of use, as well as economic and operational cognition, which influence digital technology acceptance.

The study aims to analyse the determinants of farmers' intentions to adopt an Internet-based fertilisation information system. Using an extended technology acceptance model (TAM), it explores: (1) what factors influence farmers' intention to adopt the Internet-based precision fertiliser information system (IBPFIS); (2) how do perceived usefulness (PU), perceived ease of use (PEOU), and subjective norms (SN) contribute to adoption intention across regions; (3) what is the role of institutional trust and past experience in shaping technology perception and adoption; (4) how do regional differences affect behavioural intention – across three rice agroecosystems in North Sumatra, Yogyakarta, and Central Kalimantan.

The novelty and innovativeness of this research lie in gauging the extent of farmers' willingness to adopt such systems through a psycho-behavioural analytical approach. Also, a comprehensive overview of farmers' behaviour across three district rice field agro-ecosystems: irrigation, rainfed, and tidal, thus enabling the recommendations to enhance farmers' participation. Employing the extended Technology Acceptance Model (TAM), the study incorporates variables deemed influential in shaping farmers' propensity to adopt the technology, most notably institutional trust (IT) and past experience (PE). The inclusion of these variables is considered highly pertinent, as both are anticipated to exert a significant influence on farmers' intentions and, by extension, the successful assimilation of internet-based fertiliser information systems within Indonesia's diverse agricultural landscapes.

Material and Methods

Sample and data collection

The study used both primary and secondary data. Data were collected via structured and semi-structured interviews with 300 farmers – 100 from each of the three research areas (North Sumatra, Yogyakarta, and Central Kalimantan). These locations were selected purposively to represent the country's major types of rice field ecosystems. Yogyakarta represents technical irrigated rice, North Sumatra represents rainfed rice, and Central Kalimantan represents tidal rice. This classification aligns with the national categorisation of rice ecosystems used in the government's rice self-sufficiency programme. By selecting regions with such agro-ecological diversity, the study aims to capture the varying behavioural dynamics and challenges faced by farmers in adopting Internet-based fertilisation systems across different environmental and infrastructural contexts. Data for this study were collected between June and August 2023 through structured face-to-face interviews with rice farmers in the selected regions. The survey was conducted by researchers involved in the project, assisted by trained agricultural extension officers. Before data collection, all enumerators received detailed training on the questionnaire to ensure consistency in administering the survey and accuracy in recording responses. All respondents participated voluntarily and provided informed consent before the interviews. Additional selection criteria included:

1. technical knowledge of rice cultivation;
2. representation of different agroecosystems (tidal, rainfed, irrigation);
3. access to agricultural information systems through self-learning or extension services.

The recruitment was conducted in coordination with local agricultural extension centres, and key informants included farmer group leaders identified by local extension officers.

Data analysis

To assess model validity and predictive capability, Partial Least Squares-Structural Equation Modelling (PLS-SEM) was conducted using WarpPLS version 8.0, suitable for small samples and non-normal data (Richter et al., 2022). Measurement evaluation followed the criteria outlined by Tenenhaus et al. (2004), including convergent validity, internal consistency, and discriminant validity. Variables tested in the model included PE, PEOU, PU, SN, and IT. A 6-point Likert scale captured farmers' agreement levels. Confirmatory component analysis was used to validate model reliability. Factor loadings exceeded 0.5 (Hair et al., 2019), with average variance extracted (AVE) values >0.5, composite reliability (CR) scores >0.7, and Cronbach's alpha (CA) values >0.6 – acceptable thresholds per George and Mallery (2016). These metrics confirmed the model's robustness and measurement quality.

Results and Discussion

Socio-demographic characteristics of respondents

The age of farmers ranged from 21 to 76 years. In North Sumatra and Central Kalimantan, 66.0–70.0% of farmers were aged 30–50, while in Yogyakarta, 88.0% were over 40. Most farmers were of productive age (30–60), with an overall average of 79.3%. Education levels were dominated by high school graduates (50.7%), with only 4.3% holding bachelor's degrees. Educational attainment positively influences farmers' attitudes toward technology adoption (Santoso et al., 2023). Land ownership varied significantly, with the largest holdings in tidal areas (up to 10 ha). Land size influences adoption decisions, as do education and digital infrastructure support. Eighty-three per cent of respondents used smartphones, suggesting high potential for digital access. Previous studies confirm that socio-demographic factors like age and education affect attitudes toward technology adoption (Pierpaoli et al., 2013).

Likelihood of the adoption level of the IBPFIS based on provinces

Multinomial logit regression identified significant predictors of adoption intention (Table 1). Education was positively correlated with willingness to adopt the IBPFIS, suggesting that better-educated farmers are more open to new technologies. Interestingly, productivity showed a negative correlation, indicating that more productive farmers may feel less need to adopt new systems. Provincial differences were notable. Central Kalimantan farmers showed the highest likelihood of adopting the system in general; Yogyakarta farmers were most likely to adopt without conditions, while those in North Sumatra preferred conditional adoption and were least likely to adopt unconditionally. These findings highlight the need for region-specific strategies, including targeted educational efforts and localised interventions based on specific constraints.

Socio-demographic factors that influence the intention to adopt the IBPFIS

Among the variables examined, only production levels showed a statistically significant, though slightly negative, correlation with a willingness to adopt IBPFIS. This suggests that farmers with higher productivity may see less added value from adopting new technologies. Other variables – land area, experience, education, age, and Internet spending – did not significantly affect intention to adopt (ITA), indicating a weaker influence on adoption decisions. A similar trend was observed with land size, where larger holdings were associated with lower willingness to adopt. This may be due to farmers' satisfaction with existing methods or limited perceived benefits from change. However, contrasting findings exist in the literature. Arrubla-Hoyos et al. (2022) found that larger farms are better suited for precision agriculture implementation. Barnes et al. (2019) similarly observed a positive relationship between land size and adoption rates, though the impact may vary by context. These findings suggest that the influence of landholding and production scale is complex and may be shaped by additional regional or economic factors.

Measurement indicator, factor loading, model fit, and quality indices

All factor loadings presented in Table 2 are statistically significant (p <0.001) and exceed the recommended threshold of 0.5, with the lowest being 0.621 and the highest being 0.951 (Hair et al., 2019). These values confirm that each item reliably measures its respective construct. The model's reliability and validity were evaluated using WarpPLS, applying multiple criteria: Simpson's paradox ratio (SPR), R-squared contribution ratio (RSCR), statistical suppression ratio (SSR), nonlinear bivariate causality direction ratio (NLBCDR), average path coefficient (APC), average R-squared (ARS), average adjusted R-squared (AARS), and Tenenhaus goodness-of-fit (GoF). All criteria were satisfied, demonstrating strong model quality (Table 3). The GoF index

Table 1 Multinomial logit regression of intention to adopt the IBPFIS with provinces and socio-demographic variables

Variables		Coefficient	Standard error
Outcome variable: level of intention to adopt the IBPFIS			
1: No intention			
2: Willing to adopt to conditions	experience	-0.0085	0.0243
	education	0.2980**	0.1144
	land size ownership	0.0001	0.0000
	productivity	-0.0002**	0.0001
	age	0.0221	0.0279
Province:	Yogyakarta		
	North Sumatra	0.4501	0.5524
	Central Kalimantan	-0.7624	0.7175
	Constant	-0.9421	1.6500
3: Willing to adopt	experience	0.0342	0.0243
	education	0.2882**	0.1167
	land size ownership	0.0001	0.0000
	productivity	-0.0002**	0.0001
	age	0.0055	0.0281
Province:	Yogyakarta		
	North Sumatra	-1.1408**	0.5667
	Central Kalimantan	-0.6868	0.6912
	Constant	-0.2178	1.6557
N (total respondents)			300

significance level * p <0.05; ** p <0.01

Table 2 Dimensions of model constructs, item measurement, factor loading

Variable	Description/indicator (measurement item)	Factor loading		
		YK	NS	CK
Perceived usefulness (PU)	farmers' subjective belief that using precision fertiliser information management systems will enhance their job performance			
	– internet-based precision fertilisation management information (IBPFMI) makes fertiliser management easier for farmers	0.893	0.877	0.869
	– IBPFMI has an impact on increasing rice yields	0.937	0.858	0.806
	– IBPFMI makes it easier to implement balanced fertilisation	0.866	0.816	0.933
	– implementing IBPFMI increases the efficiency of my farming business	0.930	0.859	0.911
	– implementing IBPFMI is a solution for balanced and appropriate fertilisation	0.942	0.896	0.867
Perceived ease of use (PEOU)	the term pertains to the level of ease or difficulty experienced by farmers in adopting a precision fertilisation information management system, as well as the barriers that may hinder their adoption of IBPFMI			
	– I possess the necessary proficiency and expertise to utilise IBPFMI	0.866	0.935	0.864
	– I possess the capability to utilise Internet-based data for precise fertilisation management	0.869	0.942	0.899
	– I am used to researching agriculture-related topics via gadgets, including cell phones	0.847	0.879	0.838
	– I find the implementation of IBPFMI to be straightforward	0.892	0.881	0.799
Subjective norms (SN)	the farmer's perception is that most people who are important to him (extension workers, researchers, heads of farmer groups, or farmer colleagues) think that they should or should not use IBPFMI			
	– my decision to adopt IBPFMI followed advice from agricultural extension workers	0.846	0.886	0.791
	– my decision to adopt IBPFMI follows the decision of the farmer group leader	0.943	0.912	0.899
	– my decision to adopt IBPFMI follows the decision of my fellow farmers	0.919	0.757	0.867
Intention to adopt (ITA)	farmers' intention or willingness to implement IBPFMI			
	I plan to adopt IBPFMI next year	0.860	0.913	0.809
	I plan to use IBPFMI to get the right fertiliser recommendations	0.933	0.884	0.824
	I am willing to take part in training on the use of IBPFMI	0.951	0.901	0.859
	I am willing to promote and invite my colleagues to use IBPFMI	0.878	0.862	0.845
Institutional trust (IT)	farmers' trust in government institutions in the agricultural sector such as extension offices, agricultural services, and research institutions			
	– I still trust the research institutions that designed IBPFMI	0.851	0.726	0.862
	– I still put my trust in the local government	0.939	0.911	0.920
	– I still put my trust in the central government	0.921	0.912	0.924
Past experience (PE)	PE experienced by farmers related to the use of technology or information systems that use the Internet			
	– I have been using gadgets for a long time	0.843	0.621	0.822
	– I have used a mobile phone to implement an Internet-based agricultural information system	0.942	0.910	0.912
	– I have often accessed Internet-based agricultural information systems	0.918	0.932	0.861

YK – Yogyakarta; NS – North Sumatra; CK – Central Kalimantan

Table 3 Model fit and quality indices of the structural model

Model fit index	Measure recommended	Actual value		
		YK	NS	CK
Average block VIF (AVIF)	≤3.3 (ideal), ≤5 accepted	3.884	2.117	1.864
Average full collinearity VIF (AFVIF)	≤3.3 (ideal), ≤5 accepted	3.206	2.172	2.767
Tenenhaus goodness-of-fit (GoF)	small ≥0.1, medium ≥0.25, large ≥0.36	0.698	0.598	0.627
Sympson's paradox ratio (SPR)	acceptable if ≥0.7, ideally = 1	1	1	0.778
R-squared contribution ratio (RSCR)	acceptable if ≥0.9, ideally = 1	1	1	0.966
Statistical suppression ratio (SSR)	acceptable if ≥0.7	1	1	1
Nonlinear bivariate causality direction ratio (NLBCDR)	acceptable if ≥0.7	1	1	1
Average path coefficient (APC)	$p = 0.001$	0.275	0.262	0.272
Average R-squared (ARS)	$p < 0.001$	0.601	0.475	0.526
Average adjusted R-squared (AARS)	$p < 0.001$	0.591	0.461	0.514

YK – Yogyakarta; NS – North Sumatra; CK – Central Kalimantan

Table 4 Convergent reliability and validity analysis

Variable	CA			CR			AVE		
	YK	NS	CK	YK	NS	CK	YK	NS	CK
PU	0.951	0.913	0.925	0.962	0.935	0.944	0.836	0.742	0.772
PEOU	0.891	0.930	0.872	0.925	0.951	0.913	0.754	0.828	0.724
IT	0.887	0.809	0.886	0.931	0.889	0.930	0.817	0.730	0.815
ITA	0.927	0.912	0.855	0.948	0.938	0.902	0.821	0.792	0.697
PE	0.884	0.766	0.832	0.929	0.868	0.900	0.814	0.694	0.750
SN	0.887	0.812	0.813	0.930	0.890	0.890	0.817	0.730	0.729

CA – Cronbach's alpha; CR – composite reliability; AVE – average; YK – Yogyakarta; NS – North Sumatra; CK – Central Kalimantan; PU – perceived usefulness; PEOU – perceived ease of use; IT – institution trust; ITA – intention to adopt; PE – past experience; and SN – subjective norms

values, ranging from 0.598 to 0.698, exceed the threshold of 0.36, indicating that the model is both stable and well-suited for hypothesis testing.

Table 4 displays the values of Cronbach's alpha (CA), average variance extracted (AVE), and composite reliability (CR) across the three provinces. All the AVE values exceed 0.5 (range: 0.694–0.836), confirming that the constructs adequately capture variance among observed variables. The CR values are all above 0.8, indicating strong internal consistency. Similarly, CA values surpass the minimum threshold of 0.7, confirming excellent measurement reliability (Tama et al., 2021). These results affirm that the indicators are valid and reliable for assessing the latent constructs in the model.

Structural model and hypothesis testing results

The study applied an extended TAM by integrating SN, IT, and PE with core constructs – PU, PEOU, and ITA. The results

Table 5 The hypothesis test result

Hypothesis group	Relationship	Path coefficient		
		Yogyakarta	Nort Sumatra	Central Kalimantan
H1	PU-- > ITA	0.498***	0.136ns	0.672***
H2	PEOU-- > ITA	0.309***	0.211*	0.008ns
H3	SN-- > ITA	0.165*	0.389***	-0.068ns
H4	SN-- > PU	0.227**	0.131ns	0.242**
H5	SN-- > PEOU	0.624***	0.460***	0.430***
H6	IT-- > ITA	0.058ns	0.120ns	0.185*
H7	PE-- > ITA	0.000n	0.113ns	-0.051
H8	IT-- > PU	0.326***	0.542***	0.630***
H9	PE-- > PU	0.266**	0.256**	0.166*

PU – perceived usefulness; PEOU – perceived ease of use; SN – subjective norms; ITA – intention to adopt; IT – institution trust; and PE – past experience; *** significant at $p < 0.001$; ** significant at $p < 0.01$; *significant at $p < 0.05$; ns insignificant revealed variation across provinces (Table 5), emphasising how local infrastructure, culture, and institutional dynamics shape adoption behaviour. The regional insight is critical for tailoring interventions that promote the IBPFIS.

The role of perceived usefulness and perceived ease of use as a key driver of adoption

Perceived usefulness significantly influences ITA in Yogyakarta and Central Kalimantan (β = 0.498, *p* <0.001; β = 0.672, *p* <0.001), but not in North Sumatra. Central Kalimantan showed the strongest PU effect, reinforcing that favourable perceptions enhance motivation and reduce resistance to adoption (Mishra et al., 2024). This finding is supported by Salimi et al. (2020), who emphasised that PU exerts a positive and significant impact on adoption intention, particularly in agricultural automation systems. Their findings, based on Davis's TAM, confirm that when users perceive a technology as improving their performance, their likelihood of adoption increases accordingly. Perceived ease of use significantly influenced ITA in Yogyakarta (β = 0.309, *p* <0.001) and North Sumatra (β = 0.211, *p* <0.05), but not in Central Kalimantan (β = 0.008, insignificance). These results validate that ease of use fosters confidence and encourages adoption (Wang et al., 2024), particularly in areas with greater Internet access. As most respondents used smartphones (83%) and social media (82%), digital literacy can be leveraged with training to enhance the ease of use. Perceived ease of use is the second most influential factor in farmers' intention to adopt the IBPFIS. Consistent with Tan et al. (2023), the findings confirm that when farmers perceive a technology as easy to use or with minimal barriers, their adoption intention increases. Bagheri et al. (2024) also emphasised that both PEOU and PU have a direct positive impact on user attitudes, underlining their importance in shaping favourable behavioural responses toward the use of precision agricultural technologies.

The role of subjective norms on adoption intention across region

Subjective norms significantly impacted ITA in North Sumatra (β = 0.389, *p* <0.001) and Yogyakarta (β = 0.165, *p* <0.05), reflecting the influence of peers and community leaders in shaping adoption decisions. Subjective norms also influenced PU in Yogyakarta and Central Kalimantan, and strongly affected PEOU across all provinces, most notably in Yogyakarta (β = 0.624, *p* <0.01). These findings highlight that social support not only shapes perception but also boosts confidence in technology use (Mishra et al., 2024).

The role of trust level in institutions and past experience in adopting the IBPFIS

Institutional trust significantly influenced ITA only in Central Kalimantan (β = 0.185, *p* <0.05), suggesting trust is crucial for reducing perceived risk in regions with limited digital infrastructure. Institutional trust also strongly influenced PU across provinces, particularly in Central Kalimantan (β = 0.630, *p* <0.001), affirming that trust enhances technology credibility. In contrast, PE did not directly impact ITA in any region, but it significantly influenced PU in Yogyakarta and North Sumatra. This implies that while past behaviours may not drive intention directly, they shape the perceptions of usefulness (Mishra et al., 2024), suggesting a mediating effect through attitude and familiarity.

Policy implications

The study offers adopting the IBPFIS across different agro-ecological zones in Indonesia. First, the significant influence of PU in Yogyakarta and Central Kalimantan underscores the need for awareness campaigns, field demonstrations, and pilot programmes to illustrate the IBPFIS benefits. Tailored training can further enhance farmers' understanding and appreciation of its value. Second, PEOU, particularly relevant in Yogyakarta and North Sumatra, emphasises the importance of user-friendly design. Systems should include intuitive interfaces, local language options, and step-by-step guides. Complementary training and technical support are essential for building digital literacy and encouraging adoption. Third, SN plays a critical role in North Sumatra, suggesting the need to engage trusted social actors such as farmer group leaders, extension agents, and community influencers. Promoting peer learning and group decision-making can boost acceptance and build momentum for adoption. Fourth, IT found to be influential in Central Kalimantan, should be strengthened through transparent communication and credible extension services. Government and research institutions must engage farmers directly to reduce scepticism and foster confidence in the system. Lastly, while PE does not directly impact ITA, it positively shapes PU. This highlights the importance of facilitating continuous learning, enabling farmers to leverage prior exposure to digital tools to shape more favourable attitudes toward adopting the IBPFIS.

Conclusion

The study investigated the behavioural factors influencing farmers' intention to adopt the IBPFIS in three distinct agro-ecological zones in Indonesia, using an extended TAM. The results reveal regional differences that reflect the varying socio-technical environments. The most significant determinant of adoption was perceived usefulness (PU), particularly in Central Kalimantan (β = 0.672, *p* <0.001) and Yogyakarta (β = 0.498, *p* <0.001), highlighting that when farmers perceive the technology as beneficial, their adoption intention increases significantly. Perceived ease of use (PEOU) also played a crucial role, especially in Yogyakarta (β = 0.309, *p* <0.001) and North Sumatra (β = 0.211, *p* <0.05), reinforcing that user-friendly technologies encourage uptake, especially in digitally literate communities. Subjective norms (SN) were particularly influential in North Sumatra (β = 0.389, *p* <0.001) and Yogyakarta (β = 0.165, *p* <0.05), emphasising the role of peer influence and community leaders in shaping farmer decisions. Additionally, institutional trust (IT) significantly affected adoption in Central Kalimantan (β = 0.185, *p* <0.05), suggesting that in areas with weaker infrastructure, building trust is essential to reducing perceived risks. While past experience (PE) did not directly influence intention, it notably impacted perceived usefulness in Yogyakarta and North Sumatra, indicating its indirect role in shaping attitudes. These findings underscore the need for regionally tailored strategies to promote smart farming adoption, considering technological readiness, social dynamics, and institutional trust in different farming ecosystems.

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