

The Use of Agricultural Technology in Rural Papua: A Rural Sociological Analysis and Global Comparison

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ABSTRACT

This article reviews the literature related to the application of agricultural technology in rural Papua and West Papua using a rural sociology perspective. This study has three main objectives: (1) to examine various national and international literature on agricultural technology in rural Papua, (2) to highlight the social, cultural, and structural factors that influence technology adoption among farmers, and (3) to compare local research findings with international studies to formulate a technology implementation model that is more relevant to local conditions. The analysis shows that technologies such as superior seeds, biotechnology-based fertilizers, simple mechanization, and the digitization of agricultural information can increase productivity by up to 30%. However, these benefits are not evenly distributed due to obstacles such as limited infrastructure, low digital literacy, and dependence on external inputs. Compared with countries such as Vietnam, China, and Kenya, which have recorded 40–45% increases through the use of precision technology and pro-farmer policy support, Papua still lags behind. Social factors such as the leadership of traditional leaders, cultural factors such as local wisdom and resistance to modernisation, and structural factors such as access to extension services and financing are key to successful adoption. Therefore, agricultural development in Papua requires a combination of technological innovation with local knowledge, strengthening social networks, and inclusive, participatory, and sustainable policies.

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1. INTRODUCTION

Agricultural development is a key factor in improving the welfare of rural communities, particularly in areas highly dependent on the agricultural sector, such as Papua. However, the challenges faced by farmers in Papua differ from those in other regions in Indonesia. Complex geographic conditions, limited accessibility, limited

infrastructure, and the dominance of local wisdom are factors that influence the level of acceptance of innovation, including the adoption of agricultural technology. According to [1] theory of innovation diffusion, the rate of technology adoption is influenced by five main factors: relative advantage, compatibility, complexity, trialability, and observability. In the Papuan

context, these five factors are influenced not only by economic aspects but also by social, cultural, and ecological aspects.

Various literature studies show that the use of agricultural technology plays a crucial role in increasing the productivity and efficiency of farming businesses. For example, [1] found that agricultural mechanisation can increase rice production efficiency by up to 25% in rural Java. An international study on Kenya emphasized that the successful adoption of digital agricultural technology depends on the role of extension workers and the availability of communication infrastructure [2]. On the other hand, [3] research on Papua showed that cultural factors and local beliefs often hinder the adoption of new technologies. Therefore, a rural sociological approach is crucial for understanding how social dynamics, traditional values, and community structures influence the adoption of agricultural technology.

Furthermore, international literature confirms that technology adoption in rural areas requires institutional support and inclusive public policies. The reports that developing countries that have successfully improved farmer welfare through agricultural technology generally have strong extension systems, effective market integration, and local community involvement in development planning processes. In the Papuan context, a similar approach could serve as a model, but it must be adapted to local socio-cultural conditions. Agricultural technology is not merely a technical issue but also a social one, as it involves changes in behaviour, relationships among community members, and the distribution of access to resources [4].

Numerous literature studies have been conducted on agricultural technology adoption in Indonesia, particularly in Java, Sumatra, and Sulawesi. However, research specifically focusing on Papua and West Papua remains very limited. This region possesses unique socio-cultural characteristics, such as the dominance of customary systems, ethnic diversity, and a

reliance on subsistence farming practices, which differ from other regions in Indonesia. Furthermore, international studies have focused more on technology adoption in other Southeast Asian, African, and Latin American countries, with little attention paid to the Melanesian context, including Papua. This research gap has led to a lack of understanding of how social, cultural, and structural factors interact to influence the successful adoption of agricultural technology in Papua.

This article aims to: 1) Review the literature on the use of agricultural technology in rural areas, with a particular focus on the context of Papua and West Papua. 2) Analyse the social, cultural, and structural factors that influence the level of technology adoption among Papuan farmers. 3) Compare local research findings with international literature to identify more effective and contextual models for implementing agricultural technology. This article is expected to serve as a reference in understanding the challenges and opportunities of implementing agricultural technology in remote rural areas. It also provides insights for formulating technology-based agricultural development strategies that are appropriate to Papua's socio-cultural characteristics and provide information on the potential use of agricultural technology to increase productivity and welfare.

2. LITERATURE REVIEW

2.1. *Agricultural Technology Adoption in Rural Areas*

Agricultural technology adoption has been widely recognized as a fundamental driver of agricultural productivity, food security, and rural economic transformation [4, 5]. Agricultural technology encompasses improved seed varieties, farm mechanization, irrigation systems, biotechnology-based inputs, and digital farming tools [6]. According to Rogers' Diffusion of Innovation Theory, the adoption process is influenced by five key attributes:

relative advantage, compatibility, complexity, trialability, and observability [1]. These characteristics determine farmers' perceptions of innovation and significantly affect adoption rates.

In rural contexts, technology adoption is rarely determined by technical considerations alone. Structural constraints such as limited access to capital, inadequate infrastructure, low education levels, and restricted information flow often hinder farmers' willingness and ability to adopt new technologies [7], [8]. Empirical studies demonstrate that farmers with access to extension services, training programs, and market information exhibit significantly higher adoption rates compared to isolated smallholders [9], [10].

2.2. Socioeconomic Determinants of Technology Adoption

Socioeconomic factors play a decisive role in shaping farmers' technology adoption behavior. Household income and access to agricultural credit strongly influence investment capacity, while education enhances farmers' ability to understand, evaluate, and apply new technologies effectively [11]. Land tenure security further increases farmers' willingness to adopt innovations with long-term benefits [12].

Demographic characteristics also affect adoption patterns. Younger farmers tend to be more open to technological experimentation, whereas older farmers often rely more heavily on traditional knowledge systems [13]. However, farming experience can positively contribute to adoption when combined with adequate information and institutional support.

Social capital represents another critical determinant. Participation in farmer groups, cooperatives, and community organizations facilitates information exchange, collective learning, and risk-sharing mechanisms [14]. In rural and remote areas, these social networks frequently compensate for weak formal institutions and play a central role in accelerating technology diffusion [15].

2.3. Role of Agricultural Extension and Development Communication

Agricultural extension services function as a vital interface between innovation producers and technology users. Extension agents not only disseminate technical knowledge but also influence farmers' perceptions, attitudes, and confidence in adopting innovations [16]. Participatory extension approaches such as farmer field schools, demonstration plots, and on-farm trials have been proven to be more effective than conventional top-down dissemination models [17].

From a development communication perspective, technology adoption is viewed as a social learning process. Dialogical communication, community participation, and culturally sensitive messaging significantly enhance acceptance of innovation [18]. In many rural settings, interpersonal communication channels involving extension workers, lead farmers, and traditional leaders are more influential than mass communication media [19].

2.4. Agricultural Technology Adoption in Papua and Remote Regions

Papua represents one of Indonesia's most complex agricultural development environments due to its geographical

isolation, limited infrastructure, and strong customary institutions [20]. Existing studies indicate that agricultural technology adoption in Papua remains uneven, with higher adoption levels observed among farmers participating in government supported programs, subsidy schemes, and training activities [21].

The introduction of modern agricultural technologies has contributed to the emergence of differentiated farmer groups. A segment of “modern farmers” has developed, characterized by better access to capital, education, information, and institutional networks [22]. Conversely, many smallholders continue to rely on subsistence-oriented practices, constrained by limited resources and strong cultural attachments to traditional farming systems. Without inclusive intervention, this divergence risks intensifying socioeconomic inequality within rural communities [23].

2.5. Global Perspectives on Agricultural Technology Use

International experiences demonstrate that agricultural technology adoption follows diverse trajectories depending on institutional capacity and policy frameworks [24]. In developed economies, innovation systems emphasize automation, precision agriculture, and digital integration. In contrast, developing countries prioritize improved inputs, small-scale mechanization, irrigation efficiency, and climate-smart agriculture [25]. Comparative studies consistently highlight the importance of supportive public policies, investment in rural infrastructure, and strong extension systems [26]. Countries that successfully integrate technological advancement with

farmer empowerment mechanisms tend to achieve higher productivity gains, improved income distribution, and more sustainable rural transformation [27].

2.6. Research Gap and Conceptual Contribution

Although extensive literature exists on agricultural technology adoption, relatively few studies integrate rural sociological analysis with international comparative perspectives, particularly within the Melanesian and Papuan context [28]. Most previous research emphasizes technical efficiency and economic outcomes, while giving limited attention to social structure, cultural values, and power relations shaping adoption processes [29]. This study addresses this gap by employing a rural sociological framework to examine agricultural technology use in Papua and by systematically comparing local findings with international experiences. Through this approach, the study contributes to a deeper understanding of how technological innovation interacts with social institutions, cultural norms, and development policy, thereby offering a more comprehensive foundation for inclusive and sustainable agricultural transformation.

3. METHODS

This study employed a systematic literature review with a descriptive qualitative approach. This method was chosen because it aligns with the article's objectives: to examine, analyse, and compare various research findings related to the use of agricultural technology in rural Papua, while also assessing their relevance within the context of international literature. The qualitative approach was chosen to explore the meanings, interpretations, and socio-cultural relationships that influence the

adoption rate of agricultural technology in rural areas.

The data collection process was carried out through searching for relevant scientific articles, books, reports, and official documents from several academic databases, such as Google Scholar, Scopus, ScienceDirect, and ResearchGate. Keywords used in the search included: agricultural technology, rural sociology, Papua, rural agricultural technology, technology adoption in farming, and diffusion of innovation in rural agriculture. Inclusion criteria included articles published between 2015 and 2024, focusing on the adoption or use of agricultural technology, and providing information on social, cultural, and economic factors that influence the success of its implementation. Meanwhile, exclusion criteria included articles that only discussed technical aspects without linking them to the social and rural context.

The initial search yielded 86 relevant articles. After a screening process using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, 34 articles were selected for further analysis. These articles comprised 20 national articles addressing the Indonesian context, including 7 specific studies on Papua, and 14 international articles addressing the application of agricultural technology in developing countries, such as India, Kenya, Vietnam, and the Philippines.

Data analysis was conducted using thematic analysis techniques. Each article was carefully read to identify key themes, such as: (1) the types of agricultural technology used, (2) factors driving and inhibiting technology adoption, (3) the role of extension workers and government institutions, (4) socio-cultural influences on technology acceptance, and (5) the impact of technology use on farmer welfare. Furthermore, to provide a comparative perspective, findings from national literature were compared with international literature to gain a deeper understanding of Papua's position on the global map of agricultural technology adoption. To increase the validity of the

results, this study employed a source triangulation strategy by comparing various types of references, ranging from journal articles, reports from international institutions such as the FAO and the World Bank, to Indonesian government policy documents. This approach enabled researchers to obtain a comprehensive picture of the challenges and opportunities for implementing agricultural technology in rural Papua from various perspectives. With this method design, this study is expected to provide a comprehensive analysis, generating evidence-based recommendations for the government, academics, and other stakeholders involved in technology-based agricultural development in Papua.

4. RESULTS AND DISCUSSION

4.1. *Social and Economic Impacts of Agricultural Technology in Papua*

The use of agricultural technology in rural Papua has had a significant positive impact on productivity, income, and social welfare. Research shows that the application of superior seeds, biotechnology-based fertilizers, agricultural mechanisation, and digitalization of information systems can increase agricultural productivity by 30–40% compared to traditional methods [5], [24]. This increased productivity has a direct impact on household incomes and provides greater access to education, health care, and other social services [30], [31].

Field studies and technical assessments also show that technology adoption varies across Papua, depending on the local commodity (see Table 1). For example, in Merauke, mechanization of rice fields using Kubota L4508 tractors, Yanmar AP4 rice transplanters, and Kubota DC-70 Plus combine harvesters increased rice productivity by approximately 30% and reduced reliance on manual labour [32]. In Sentani and Jayapura, the use of a 1-ton-per-day sago grater and a hydraulic squeezer tripled the sago starch extraction capacity, making sago not only a subsistence food but also an economically valuable commodity [33]. Post-harvest innovations are also

significant. In Wamena, the implementation of solar dome dryers and optical sorting improved the quality of Arabica coffee, resulting in a dramatic increase in selling prices and export potential. Meanwhile, in Fakfak, innovations in vanilla fermentation and drying using stainless steel ovens increased the selling value of vanilla by up to 200% [34]. The adoption of superior sweet potato varieties and biodegradable mulch-based soil conservation techniques in the Central Highlands helped improve food security for indigenous communities and adaptation to climate change [35]. In Manokwari, the implementation of modern greenhouses, Netafim drip irrigation, and IoT sensors increased the production of high-

value horticultural crops, such as premium peppers and tomatoes, while maintaining consistent product quality [36].

Based on Table 1, it is evident that the implementation of agricultural technologies in Papua has developed significantly and varies according to the characteristics of each commodity and region. For rice cultivation in Merauke, field mechanization plays an important role in increasing productivity and reducing labor demand. Meanwhile, the adoption of modern processing technologies for sago in Sentani and Jayapura has substantially increased production capacity, signaling a shift from traditional methods to semi-industrial practices.

Table 1. Application of Agricultural Technology to Various Main Commodities in Rural Papua

Location	Main Commodities	Types of Technology	Tools / Specifications	Function / Use	Impact / Benefits
Merauke (Kurik District)	Paddy	Mechanization of rice fields	Kubota L4508 Tractor (45 HP), Yanmar AP4 Rice Transplanter, Kubota DC-70 Plus Combine Harvester	Automatic land preparation, planting and harvesting of rice	Productivity increases by $\pm 30\%$, saves labor
Sentani & Jayapura	Sago	Modern processing	Sago Grater Machine Capacity 1 ton/day, Hydraulic Squeezer	Grating sago stems, faster starch extraction	Time efficiency, production capacity increased 3x
Wamena (Jayawijaya)	Arabica Coffee	Coffee post-harvest	Solar Dryer Dome, Optical Sorting, Coffee Huller Cap. 500 kg/hour	Seed drying, premium quality sorting	Coffee quality and prices improve, exports rise
Central Mountains (Jayawijaya-Yahukimo)	Sweet potato	Superior & organic varieties	Sweet Potato Grafting Tool, Biodegradable Mulch, Automatic Compost Fertilizer	Fast seedling propagation, soil conservation	Increased food security, better climate adaptation
Fakfak	Vanilla	Post-harvest & cultivation	Stainless Steel Vanilla Fermentation System, Vanilla Drying Oven Capacity 50 kg	Fermenting and drying export quality vanilla	Vanilla selling price rises by up to 200%
Manokwari	Horticulture	Greenhouse & irrigation	Netafim Drip Irrigation, 500 m ² Modern Greenhouse, IoT Soil Moisture Sensor	Optimal temperature & humidity control	Stable productivity of peppers and vegetables, premium quality

In the highland regions such as Wamena and the Central Highlands, post-harvest technologies for Arabica coffee and

the use of improved sweet potato varieties demonstrate a strong focus on enhancing product quality and strengthening local food

security. These innovations provide direct benefits, including increased market value, improved product quality, and better resilience to climate change. High-value commodities such as vanilla in Fakfak also benefit from modern fermentation and drying technologies, which significantly boost the selling price.

Overall, the application of agricultural technologies in Papua shows that appropriate and context-specific innovations can deliver substantial benefits—from increasing productivity and time efficiency to enhancing food security and the competitiveness of local commodities. Differences in the types of technologies used across regions also reflect local needs and the unique potential of each area. From a rural sociological perspective, the adoption of agricultural technology has triggered socio-economic transformations. Agricultural mechanization in Merauke, for example, has changed the division of labour and reduced the need for manual labor, while modernizing sago processing in Sentani has transformed the way communities view sago as a valuable commodity. However, this process also presents challenges, such as limited access to training, business capital, and supporting infrastructure [2]. Therefore, inclusive development communication programs that are sensitive to local cultural contexts are key to ensuring this technological transformation reduces, rather than increases, social inequality in rural Papua.

4.2. Analysis of Social, Cultural, and Structural Factors Influencing the Level of Adoption of Agricultural Technology in Papua

From a rural sociology perspective, the rate of technology adoption in Papua is largely determined by a complex interplay of social, cultural, and structural factors. Socially, Papua's strong kinship-oriented community structure and mutual cooperation practices make adoption decisions more collective: innovations spread more quickly if they have the support of traditional leaders, tribal chiefs, or local farmer groups, as found

in innovation diffusion studies and field research in agrarian communities [1], [37], [14]. This contrasts with the more individualistic agricultural contexts in parts of Southeast Asia, where adoption decisions are often influenced by individual economic calculus and access to credit [6], [11]. Culturally, Papuan customary values emphasising ecological balance, a spiritual connection to the land, and norms of profit-sharing contribute to resistance to technologies perceived as disruptive to traditional practices [11], [38], [28].

Anthropological and agroecological studies show that this kind of resistance is not simply conservatism, but rather a form of protection of local cultural capital and ecosystems, so that technology needs to be designed and communicated in a way that is compatible with local knowledge to be accepted [18], [39], [40]. From a structural perspective, barriers such as poor infrastructure, limited extension services, and minimal access to finance have been empirically proven to hinder technology adoption; cross-country evidence confirms that the availability of roads, markets, electricity, strong extension services, and credit/insurance instruments are key determinants of adoption rates and welfare impacts [41], [5], [7], [8]. Furthermore, digital literacy and technical skills add a dimension to modern barriers—access to mobile phones/smartphones does not automatically lead to effective use of agricultural information without training and institutional support [43], [44], [45]. Comparative studies also show that in successful countries (e.g., China, Vietnam), a combination of pro-farmer policies, infrastructure investment, and intensive extension programs promote more equitable technology adoption, while in infrastructure-poor contexts like Papua, failures are often dual technical and social [24], [25], [27]. Therefore, approaches recommended by the literature include technology co-design with local communities, strengthening social capital through lead farmers and community-based extension workers, and financing schemes that reduce

initial risk (micro-credit, lease-to-own, index insurance). It is this combination of technical engineering and social engineering that increases the chances of inclusive and sustainable adoption in Papua [9], [15], [19], [26].

To deepen the analysis of agricultural technology adoption in Papua, Table 2

provides a comparative overview between the findings from the Papua case study and insights from international literature. This comparison highlights similarities, differences, and contextual factors that influence the outcomes of technology implementation in various regions.

Table 2. Comparison of the Impact of Agricultural Technology Use: Papua Study vs. International Literature

Aspect	Papua (Eastern Indonesia)	International Literature
Agricultural Productivity	Productivity has increased by around 30% through the use of superior seeds, biotechnology-based fertilizers, and simple mechanization. However, this increase is uneven across regions due to limited infrastructure and capital.	In India, Vietnam, and Kenya, modern technologies such as precision farming and IoT-based agriculture have increased productivity by 40–45% and reduced crop losses by 15%.
Farmer Welfare	Household incomes of farmers increased by 10–15% among technology users. However, the gap with traditional farmers widened, triggering social stratification.	In developing countries like Kenya and Nigeria, the adoption of mechanization and digital technologies has increased smallholder farmers' incomes by 25–30% and opened up access to global markets.
Food security	Crop diversification is increasing, but dependence on specific commodities (rice and corn) remains high. A shortage of imported fertilizer and seeds makes Papua vulnerable to market shocks.	In China, a smart agriculture program increased fertilizer efficiency by 20% and reduced post-harvest losses by 15%, thereby strengthening national food security.
Socio-Cultural Challenges	Technology adoption often clashes with local wisdom and customary systems. Mutual cooperation and traditional profit-sharing are difficult to reconcile with capitalist production models.	Studies in Southeast Asia and Latin America show similar cultural resistance if technology is not integrated with local knowledge.
Dependence on Input	The high level of dependence on imported seeds, chemical fertilizers, and agricultural equipment from outside Papua makes it vulnerable to global price fluctuations.	In Sub-Saharan Africa, a similar phenomenon is occurring. Farmers are becoming heavily dependent on external inputs, increasing economic risk if global prices rise.
Policy & Infrastructure	Fertilizer subsidy policies and mechanization support are suboptimal. Transportation and input distribution infrastructure remains limited, hampering the equitable distribution of technology.	In Vietnam and China, successful technology integration was supported by large investments in infrastructure, agricultural research, and pro-farmer policies.

The comparison presented in Table 2 reveals that the impact of agricultural technology adoption in Papua shares several similarities with global patterns, yet also reflects unique regional constraints. In terms of productivity, Papua has shown a notable increase of around 30%, although the progress

remains uneven due to infrastructural and capital limitations. This contrasts with countries such as India, Vietnam, and Kenya, where more advanced technologies—such as precision agriculture and IoT-based systems have produced higher gains and reduced crop losses more effectively. The use of agricultural

technology in Papua shows a different trend compared to international literature. In Papua, the adoption of technologies such as superior seeds, biotechnology-based fertilizers, and agricultural mechanization tools can increase productivity by an average of 30% [5]. This increase is relatively lower compared to countries that are more advanced in the application of agricultural technology, such as Vietnam, which saw a productivity increase of up to 42% thanks to the integration of precision farming technology and strong government support [25]. Similarly, a study in Kenya showed a 40% increase in productivity through digital extension programs and equitable access to fertilizer subsidies [46]. In China, the use of smart farming systems and the Internet of Things (IoT) has even driven productivity increases of up to 45% [47].

This difference impacts not only productivity but also farmer welfare. In Papua, the increase in household income for farmers is around 15%, lower than Vietnam (28%) and Kenya (30%), and far below China (32%). The low impact on welfare in Papua is due to limited infrastructure, access to capital, and low digital literacy. While countries like Vietnam and China have successfully utilized inclusive policies and institutional support, Papua still faces challenges such as cultural resistance and dependence on external inputs such as imported seeds and fertilizers. Therefore, this comparison confirms that the successful implementation of agricultural technology is highly dependent on policy support, access to information, and socio-cultural integration. For Papua, community-based approaches and rural sociology are crucial for technology adoption to not only increase productivity but also reduce social disparities and sustainably improve farmer welfare.

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5. CONCLUSION

This study confirms that the use of agricultural technology in rural Papua has significant potential to increase productivity, farmer welfare, and local food security. However, its adoption remains hampered by social, cultural, and structural factors. First, national and international literature shows that technologies such as superior seeds, biotechnology-based fertilizers, simple mechanization, and information digitization can increase productivity by up to 30%, although this achievement lags behind those achieved in Vietnam, China, and Kenya, which achieved 40–45% through policy support and the integration of precision technology. Second, socio-cultural factors, including the role of traditional leaders, farmer groups, and local wisdom, are crucial for successful adoption; resistance arises when technology is perceived as threatening cultural and ecological identity. Third, from a structural perspective, limited infrastructure, extension services, digital literacy, and access to financing remain major obstacles. Comparison with international studies shows that Papua's success will depend heavily on strategies that combine modern innovation with local knowledge, strengthen community-based social capital, and implement inclusive and participatory development policies. Therefore, the model for implementing agricultural technology in Papua needs to be contextual, equitable, and sustainable to benefit all levels of rural society.

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