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The evolution of agriculture in the Papua-Papua New Guinea frontier, Keerom District, Indonesia

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Abstract. *Kadir A, Suharno, Iswandi RM, Alwi LO. 2025. The evolution of agriculture in the Papua-Papua New Guinea frontier, Keerom District, Indonesia. Asian J Agric 9: 554-567.* A community's socio-cultural characteristics influence how agricultural systems evolve to support livelihoods. In rural and inland areas, such as in Keerom District, Papua Province, Indonesia, food security is heavily reliant on the availability of natural resources. The local communities in Keerom maintain a hunting-gathering culture and the traditional agricultural systems. This study aims to determine how the agricultural sector in Keerom has developed to meet the needs of people on the border with Papua New Guinea. This includes introducing oil palm and corn as new efforts to develop superior commodities. A survey was conducted using qualitative research techniques and interview methods. The survey analyzed the social, economic, and ecological systems that underlie the evolution of livelihood systems in the region. Data were collected through in-depth interviews with traditional farmers, indigenous community leaders, migrant communities, and other stakeholders, supplemented by field observations. The findings reveal a significant shift in livelihood systems, rooted in evolutionary developments since the time of the ancestors of the Keerom community. This transformation is closely tied to the community's hunting-gathering culture, traditional agricultural practices, the introduction of modern agriculture, the establishment of oil palm plantations, and the implementation of the central government's food estate program. The study highlights that oil palm and corn cultivation present substantial economic opportunities, particularly in terms of income generation and infrastructure development. However, these benefits are accompanied by notable challenges, including shifts in traditional cropping patterns, land tenure conflicts, and adverse impacts on local biodiversity. This research contributes to a deeper understanding of how the integration of new commodities reshapes the agrarian and social landscapes in Keerom District. It also provides insights into the implications for sustainable agricultural development policies in the region, offering a promising path forward for the community and its stakeholders.

Keywords: Evolution of agriculture, food source, Keerom, traditional farmers, traditional knowledge

INTRODUCTION

Human cultural evolution is closely linked to the development of livelihood systems (Stanford 2019). Anthropologically, one of the oldest human livelihood practices is hunting and gathering (Wooten 2016; Raghu 2022). Cultural evolution parallels biological evolution, with language functioning as a cultural replicator, similar to genes in biological evolution. In other words, the principles of cultural evolution can be examined and compared to biological evolution, with a focus on selection in cultural evolution, including the concept of cultural conformity within society (Portin 2015; Zhao 2021).

Agricultural evolution is the process by which agricultural systems change over long periods, driven by community actions. Agro-ecosystem evolution is a complex process involving interactions between plants, disease-causing organisms, and livestock, which influence reciprocal evolutionary changes that are dynamic and unpredictable (Thral et al. 2010). Changes in agricultural evolution involve land ownership systems, shifts in crop types, and technologies used (Dixon et al. 2023). Community changes to agricultural systems influence costs, yields, and farmers' income (Touch et al. 2024; Ongachi and Belinder 2025).

Historically, hunting and gathering were the primary livelihood systems long before the advent of agriculture (Stanford 2019; Natarajan et al. 2022). Modern farming practices, such as field cultivation, fishing, aquaculture, irrigation-based agriculture, and animal husbandry, represent significant advancements from these early systems (Gamage et al. 2024). Initially, hunting and gathering were essential for meeting daily subsistence needs (Balacuit et al. 2018). Evidence suggests that communities in Africa and South-east Asia have hunted wild animals for food for at least 40,000 years, while those in Latin America have done so for approximately 10,000 years (Arobaya et al. 2022). In fact, many communities in tropical regions continue to practice hunting and gathering today (Bennett 2002; Arobaya et al. 2022). Over time, traditional and modern cultivation systems developed. For example, domesticating wild animals signified the shift to livestock farming, while growing plants contributed to the rise of gardening (Manyanga and Pangeti 2017; Pawlik and Fuentes 2023). More recently, integrated aquaculture and fisheries systems have been introduced, reflecting ongoing innovation in livelihood practices (Ndjadi et al. 2021).

Forests serve as a critical resource for fulfilling the needs of rural communities (Iacob 2015; Begazo-Curie and Vranken 2025). In remote areas, where dependence on forests is significantly higher than in urban regions (Yusran and Abdullah 2007; Sullivan 2022), forests often form the backbone of household economies (Iacob 2015). Beyond their economic value, forests also play a vital role in supporting sustainable livelihood systems (Matiwane and Matiwane 2023). The hunting and gathering practices of these communities rely heavily on the availability of suitable habitats for target species, be it plants or animals (Suharno and Kadir 2023). However, disturbances to these habitats, such as deforestation or environmental degradation, often force communities to relocate their hunting grounds to more distant areas (Syamsudin et al. 2023). This displacement frequently requires communities to move closer to new resource-rich locations, prioritizing access to essential resources for survival (Kradin 2002). Since adapting to environmental conditions is essential for survival, communities create strategies to manage resource availability, forming the base of their livelihood systems (Widodo 2005; Adefila et al. 2024). For instance, during resource scarcity or stress, these communities innovate and adapt to maintain resource availability, ensuring their ongoing survival (Widodo 2005).

The border region between Papua (Indonesia) and Papua New Guinea (PNG) has a long history of social development. Communities on both sides of the border share cultural similarities, largely due to their shared dependence on intact tropical forests (Bourke 2009; Bräuchler 2014). Many residents of both Papua and PNG rely on the extraction of forest resources, including plants and animals, for their livelihoods (Arobaya et al. 2022). Despite these cultural parallels, socio-economic conditions in Papua have diverged, influenced by urbanization and government-led transmigration programs targeting low-density areas. Transmigration programs have been implemented in several border regions, including Jayapura City (Muara Tami District), Keerom District (Arso) (Daawia et al. 2024), and Merauke District (Sota District). The arrival of transmigrant farmers from outside the Papuan region — mostly Javanese — significantly affected the livelihood system of local people. Most locals traditionally engaged in hunting and gathering. Over time, the region has also seen the development of oil palm plantations, operated by state-owned enterprises like PTP II Tanjung Morawa and various private companies, which have further altered the area's socio-economic and environmental landscape.

In recent years, the Indonesian government has launched the food estate program in Keerom District. This initiative, along with other agricultural developments, has brought about significant cultural and systemic changes in the region's farming practices. Understanding these changes is essential, requiring a detailed study of how community culture has evolved within the agricultural system. Therefore, this study aims to explore the development of the agricultural system in the frontier area of the Indonesia-PNG border, with a specific and engaging focus on Keerom District, Papua. This research emphasizes the roles of government initiatives and agricultural stakeholders in development. By incorporating local wisdom, it provides insights into sustainable farming practices that protect cultural heritage and preserve the environment balance.

MATERIALS AND METHODS

Research area and period

This research was conducted in Keerom District, Papua Province, Indonesia which comprises 11 districts. The study focused on five districts: Arso, West Arso, Skanto, Mannem, and Waris (Figure 1), which was conducted from August to November 2024. Keerom is predominantly a lowland region, with elevations ranging from 40 to 60 meters above sea level. During the observation period, the average temperature ranged from 24 to 34°C. The land use in Keerom is primarily agricultural, with significant areas dedicated to oil palm plantations and forest cover. According to data from Statistics Indonesia (BPS-*Badan Pusat Statistik*), Keerom District (BPS Keerom District 2024) and Suharno et al. (2025), the region experiences an average annual temperature of 27.1 to 28.7°C, with monthly humidity levels ranging from 74.8 to 76.8% and average monthly rainfall of approximately 128.15 mm.

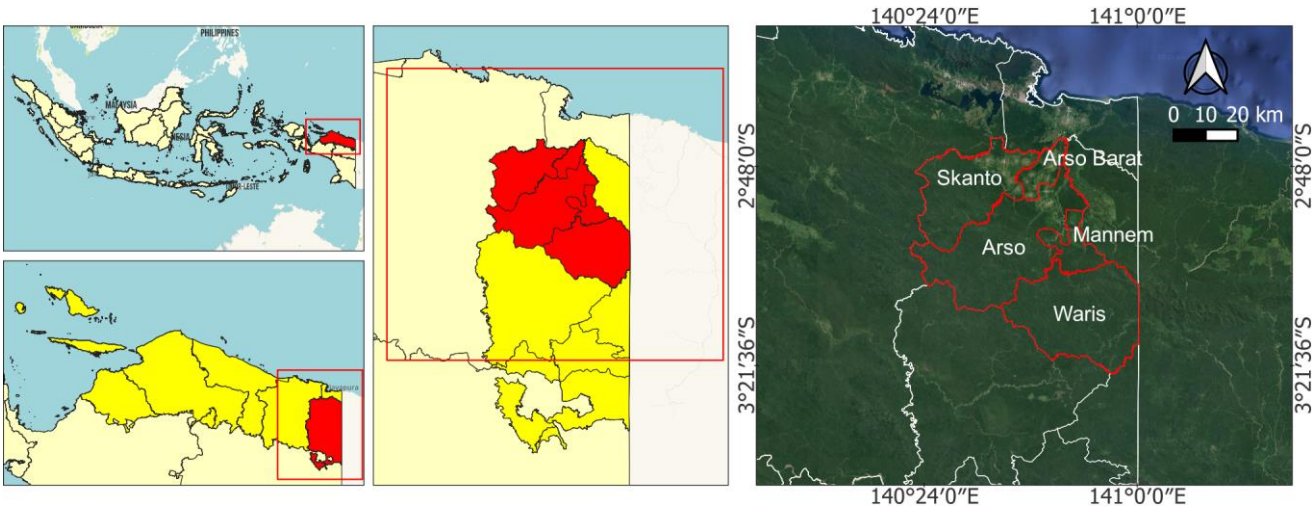

Figure 1. Research area in Arso Barat, Skanto, Arso, Mannem, Waris Sub-districts, Keerom District, Papua Province, Indonesia

Observation method

This study examined the evolution of agricultural systems and their role in supporting community livelihoods in Keerom District through interviews with 63 respondents. The location was selected using purposive sampling to reflect the diversity of agricultural practices. Among respondents, 23 were Indigenous Papuans (OAP). The study identified five stages in the evolution of these systems: hunting and gathering, traditional agricultural practices, modern agriculture, the development of oil palm plantations, the implementation of food security programs. Methodologically, the study employed an ethnographic and ethnobiological approach that analyzed community practices within a larger social and ecological framework. Both qualitative and quantitative data collection focused on the development of community livelihoods, particularly regarding food sources and agricultural practices in Keerom. In-depth, semi-structured interviews were conducted to understand the cultural practices and agricultural income systems of the local communities. Information was collected on the respondents' involvement in livelihood activities, including hunting and gathering, traditional and modern agriculture, oil palm plantations, and food security programs in Keerom, Papua. Additionally, comparative data from the BPS Keerom District (2024) supported the findings.

Data analysis

The observations that encompass a wide range of agricultural practices were analyzed descriptively and qualitatively. Descriptive qualitative analysis was used to examine information on the development of farming systems, hunting and gathering, shifting cultivation (including types of cultivated crops), modern agriculture, and oil palm plantations. Some quantitative maize production data were obtained from secondary sources. The results were presented in the form of tables and figures.

RESULTS AND DISCUSSION

The evolution of the food fulfilment systems

The study identified five distinct stages in the development of cultural systems for fulfilling community needs in Keerom District. These stages include: hunting and gathering, traditional agriculture, modern agriculture, oil palm plantations, and food estate programs (Table 1). Notably, the hunting and gathering culture in Keerom District continues to this day, as documented by Turua (2014).

The results of the study show that fundamental changes have occurred in the plants utilized and cultivated in Keerom's agricultural system in Papua. These changes are influenced by culture and the community's growing needs. The local community fulfills its basic needs through hunting and gathering, depending on the available resources in its habitat (Table 1). This dependence is evident in the continued existence of nomadic communities that naturally live close to natural resources. In traditional agricultural systems, communities focus on obtaining basic necessities by planting crops such as sweet potatoes, bananas, and cassava (Table 3). Meanwhile, oil palm plantations established by companies offer an opportunity to earn wages. Monoculture agricultural systems, such as food estates, are implemented with government support to produce monoculture crops like corn and fulfill community needs. Modern agriculture, on the other hand, emphasizes meeting community needs and generating capital for other purposes through rice farming, vegetable cultivation, and livestock production.

Table 1. The development of the community's food fulfilment systems in Keerom District, Papua Province, Indonesia

Fulfillment system (agriculture)	Location (district)	Year	Description
Hunting and gathering	All districts	~ present	Local communities, particularly Indigenous Papuans, continue to practice traditional hunting and gathering systems. Hunting activities are primarily conducted to obtain game animals, which provide animal protein. Commonly hunted species include wild boar, deer, birds, fish, and other wildlife.
Traditional agriculture	All districts	~ present	Traditional agriculture remains an essential practice for Indigenous Papuans, particularly for obtaining carbohydrate sources such as sago flour (*Metroxylon sagu*).
Modern agriculture	Arso West Arso East Arso Mannem	1984 - present	Modern agriculture is practiced by local communities, including Indigenous Papuans, who cultivate crops on their land, with some still employing traditional shifting cultivation methods.
Oil palm plantations	Arso Mannem West Arso Skanto Waris	1982/1983 (planning) 1984 - present (operational)	Oil palm plantations in the region are predominantly managed by migrant communities, with limited involvement from Indigenous Papuans. These migrant communities primarily originate from Java and East Nusa Tenggara.
Food estate program	Arso Mannem	2023 - present	The food estate program is primarily implemented by migrant communities, with limited participation from Indigenous Papuans.

Indigenous Papuans have long inhabited the customary lands of the Keerom plains, maintaining a cultural heritage of hunting, gathering, and traditional agriculture that has been passed down through generations. The continuity of these practices, despite their undocumented origins, is a testament to the resilience and commitment of Indigenous Papuans communities. This is evidenced by ongoing hunting and gathering activities, as well as traditional agricultural practices. In traditional agriculture, local communities select cultivation sites, which are then managed using simple methods: clearing the land and planting directly without soil cultivation. The year 1984 marked a significant shift with the implementation of modern agricultural systems, including the adoption of land cultivation techniques and basic agricultural technologies. Since then, communities have developed an understanding of water management for irrigation, soil cultivation, herbicide application, and fertilization practices.

Traditional life of local communities: Hunting and gathering traditions

Keerom District, located in the Indonesia-PNG border region, is one of Indonesia's designated transmigration areas. Within Keerom, three districts serve as primary transmigration settlement zones: Arso, Skanto, and Senggi. Keerom District consists of 91 villages (BPS Keerom District 2024; Suharno et al. 2025). Arso and Skanto Districts have the most, with 12 villages each, followed by Towe (ten villages) and East Arso (nine villages). Waris and West Arso each contain eight villages, while Yaffi, Senggi, and Mannem have seven villages each. Web and Kaisenar Districts have six and five villages, respectively. Despite infrastructure and accessibility improvements in some districts, the majority of villages in Keerom (98.90%) remain classified as self-help villages (*desa swadaya* in Indonesian terms). As of 2016, only one village had achieved developing village (*desa swakarsa*) status, indicating a higher level of independence. This highlights the persistent challenges faced by most villages in transitioning to full self-sufficiency (*desa swasembada*). Key contributing factors include limited resources, inadequate access to education and healthcare services, and a reliance on external assistance.

Observational data reveal that Indigenous Papuans in Keerom continue to practice hunting and gathering as a central aspect of their culture (Table 2). According to Arobaya et al. (2021), the majority of Indigenous Papuans communities still engage in these traditional activities. Sultani et al. (2022) further emphasize that hunting and gathering in Papuan society represent prehistoric ways of life, reflecting cultural processes evidenced by artifacts and ideofacts that illustrate the realities of ethnic life. The data indicate that hunting traditions persist today, with communities hunting various wild animals in the forest to meet their subsistence needs. Commonly hunted species include wild boar (*Sus scrofa* Linnaeus, 1758), deer (*Rusa timorensis*), maleo birds (*Macrocephalon maleo* S.Müller, 1846), jungle fowl (*Gallus* sp.), moles (*Rattus* sp.), cassowaries (*Casuarius* sp.), cuscuses (*Spilocuscus* sp.), bats (*Pteropus* spp.), and various fish from local water systems. In addition to hunting, communities gather plants such as sago, bananas, cassava, and papaya as food sources. The proceeds from the hunting and gathering activities are primarily used for consumption, with surplus occasionally sold (Figure 2).

The sale of hunted animals significantly contributes to the economic systems of local families. Observational data indicate that the prices of hunted animals vary widely, ranging from IDR 50,000 to IDR 900,000. For instance, bats (*Pteropus* spp.) and moles (*Rattus* sp.) are sold for IDR 50,000 to IDR 80,000, while cuscuses (*Spilocuscus* spp.) fetch higher prices, ranging from IDR 700,000 to IDR 900,000. According to the local communities, hunting is often more economically advantageous than farming. They perceive farming outcomes as less predictable and potentially less profitable compared to the certain and immediate value of hunted animals.

The practice of tapping sago as a primary carbohydrate source is a longstanding tradition among indigenous Papuans. Sago has been integral to Papuan culture since prehistoric times, as evidenced by artifacts found at ancient residential sites. These artifacts include pottery used for storing sago starch and cooking sago (Suroto 2023). The tradition of cooking sago continues today across various regions in Papua (Suroto 2023; Kadir et al. 2024), including Keerom, which boasts extensive sago-growing areas (Sanggenafa 2020).

The transmigration program in Papua has significantly impacted local community life. This government initiative encouraged some nomadic communities to settle permanently, though not universally. To ensure survival, communities have adapted their livelihood systems through various strategies. In Keerom District, the program was implemented from 1984 through the 2000s (Daawia et al. 2024).

Figure 2. Some types of community game, such as cuscuses (*Spilocuscus* spp.), wild boar (*Sus scrofa*), bats (*Pteropus* spp.), moles (*Rattus* sp.), and others that are traded to meet the daily needs of the people in Keerom, Papua Province, Indonesia

Table 2. The practice of hunting animals and gathering plants by local people in Keerom, Papua Province, Indonesia

Group	Local name	Scientific name	Note
Animal	*Rusa*	*Rusa timorensis* (Blainville, 1822)	Not consistently hunted (currently rare); typically conducted in groups both during the day and at night
	Babi hutan	*Sus scrofa* Linnaeus, 1758	Not daily hunted; usually performed in groups during the day
	Burung maleo	*Macrocephalon maleo* S.Müller, 1846	Often hunted by groups consisting of parents and teenagers
	Ayam hutan	*Gallus* sp.	Often hunted by groups consisting of parents and teenagers
	Kasuari	*Casuarius* sp.	Only when hunters find it in the forest
	Tikus tanah	*Rattus* sp.	Frequently hunted by children.
	Kus-kus	*Spilocuscus* sp.	Often hunted due to the ease of hunting, during the day or at night
	Kelelawar	*Pteropus* spp.	Frequently hunted at night
	Ikan	Various types of fish	Regularly hunted
	Buaya	*Crocodylus* spp.	Sometimes, when hunters find it
	Sowa-sowa	*Varanus* spp.	Often hunted
	Kangguru pohon	*Dendolagus pulcherrimus* Flannery, 1993	Sometimes, when hunters find it
Plant	*Sagu*	*Metroxylon sagu* Rottb.	Gathered when food supplies are limited, based on immediate needs
	Pisang	*Musa* spp.	Often gathered near residential areas
	Ubi kayu	*Manihot esculenta* Crantz	Often gathered near residential areas
	Pepaya	*Carica papaya* L.	Often gathered near residential areas
	Sayur lilin	*Saccharum robustum* E.W. Brandes & Jeswiet ex Grassl.	Typically gathered near residential areas, particularly in areas with water-rich soil
	Nenas	*Ananas comosus* (L.) Merr.	Frequently gathered in open garden lands or uncultivated areas near residential areas

For communities in remote areas, limited access to domestic meat and the availability of wild game from forests remain key reasons for continued hunting practices. Gathering and hunting activities, essential for securing food and ceremonial materials, also help preserve traditional cultural practices (Arobaya et al. 2022; Begazo-Curie and Vranken 2025). These activities reflect the community's deep connection to natural resources, which are central not only to their survival but also to their cultural identity. During the Paleolithic era, humans were deeply connected to nature, often venerating its elements and seeing themselves as indebted to its power. This deep connection underwent a significant shift during the industrial era, altering the way we perceive and interact with nature. Ecological holism, on the other hand, emphasizes the interdependence of all living things within ecosystems. Today, environmental education highlights the need to protect nature, stressing that preserving a single tree is as important as safeguarding an entire forest (Fortier 2014; Yakar 2018).

Wildlife hunting is essential for rural communities, providing a primary source of protein and fat while also generating economic value. Selling hunted meat creates income opportunities (Milner-Gulland et al. 2002), while traditional materials derived from wildlife are used for therapeutic purposes and other cultural practices (Williamson 2002; Mockrin et al. 2005). Additionally, wildlife is hunted for trophies, such as skins, teeth, antlers, and horns, which serve as cultural artifacts or personal adornments (Arobaya et al. 2022).

Beyond protein and carbohydrate sources, these communities exploit various natural resources through hunting, gathering wild plant foods, and fishing (Soriente 2020; Kumar et al. 2021). Unlike agricultural societies, they do not domesticate plants or animals, except for dogs. Instead, they engage in trade with settled groups, exchanging forest products like game, camphor, resin, natural rubber, and rattan for metals, cloth, salt, and tobacco. A key characteristic of hunter-gatherer groups in Borneo is their subsistence economy, which extends beyond sago harvesting. Their livelihood systems are underpinned by a distinct hunter-gatherer ideological core, setting them apart from farming communities (Soriente 2020).

Traditional agriculture

While the hunting and gathering livelihood system has not been entirely abandoned, the cultural practices of the Keerom community have undergone significant development. In response to growing family needs, local communities, particularly Indigenous Papuans, have begun to establish traditional agricultural systems. Simple practices and the absence of modern techniques or management characterize these systems. Initially, the agricultural system adopted was shifting cultivation, a practice deeply rooted in the traditions of several regions in Papua (Suharno 2001). Shifting cultivation is a cyclical process involving the selection of hillside fields, forest clearing, drying, and burning of dry vegetation (Lalnungrenga et al. 2024). Seeds are then sown by digging holes or scattering them before the rainy season. When practiced on a limited scale and guided by local wisdom, shifting cultivation can effectively support local livelihood systems. However, large-scale implementation can lead to environmental degradation, particularly in forested areas.

Shifting cultivation is a highly dynamic and complex socio-ecological system that has developed over centuries through the traditional knowledge of local communities. It remains the most widespread agricultural practice in the hill states of North East Asia (Cairns 2015; Pattiasina et al.

2023; Lalnungrenga et al. 2024). Recent estimates indicate that approximately 280 million hectares of land worldwide are used for shifting cultivation, with the largest areas in Africa, followed by the Americas and Asia. This practice is common in 62% of the mapped regions, each covering about one degree of latitude and longitude, within humid and sub-humid tropical zones. The highest concentrations are in the Americas (41%) and Africa (37%) (Nath et al. 2022). It should be noted that, despite its cultural importance, shifting cultivation can lead to deforestation and a loss of flora and fauna diversity (Lalnungrenga et al. 2024).

The origins of traditional farming practices among local Papuan communities remain undocumented. However, significant changes in agricultural systems in PNG have occurred over an extended period. In the lowlands, these changes began in the early 1870s with the settlement of Europeans, Asians, and other Pacific Islanders. In the highlands, agricultural transformations started several hundred years ago with the introduction of sweet potatoes (*Ipomoea batatas* (L.) Lam.) as a staple food source. Sweet potatoes were brought to the Western Pacific by European travelers after their domestication in South America (Bourke 2001). Today, sweet potatoes remain a vital food source in Papua.

Shifting cultivation remains common in Keerom, as interviews show that most local communities still practice this method. Agricultural land is often rotated to sites that were cultivated more than 5 years ago (Figure 3), since these areas are believed to yield results similar to newly cleared forest land. Traditional farming in Papua is usually small-scale and focused on subsistence (Table 3). However, communities are increasingly realizing the need to diversify their food sources and farming methods to support social, economic, and nutritional needs (Suharno et al. 2016).

Initially, local communities in Papua cultivated only a limited variety of plants to meet daily subsistence needs, such as sweet potatoes (*I. batatas*), cassava (*Manihot esculenta*), papaya (*Carica papaya*), sugarcane, bananas, and several types of vegetables (Suharno 2001). Over time, the range of traditionally cultivated plants in Keerom has expanded significantly. Most of these plants are grown to fulfill staple food requirements and support the family economy. For example, besides sweet potato (*I. batatas*), cassava (*M. esculenta*), taro (*Colocasia* spp.), papaya (*C. papaya*), sugar cane, imperial taro (*C. esculenta*), there are at least 20 types of plants cultivated by local communities (Table 3). Other economically valuable plants, such as areca nut (*Areca catechu* L.), coconut (*Cocos nucifera* L.), and matoa (*Pometia pinnata* J.R.Forst. & G.Forst.), also contribute to household income (Sanggenafa 2020).

Despite these developments, many communities have yet to capitalize on the economic potential of their garden produce fully. Similar to broader Papuan society, Keerom communities, though more connected to the outside world, continue to practice communal gardening within extended family units. This has led to the gradual development of larger-scale agricultural systems, enabling surplus harvests to serve as a source of income. This condition can be seen in the harvest, which is consumed not only by the farmers themselves but also marketed.

The traditional farming system of the Keerom indigenous people begins with clearing forest floors, cutting down trees, and collecting and burning branches and twigs. The soil and grass are then cleared, followed by planting. This farming system is intertwined with their worldview and respect for nature. Land is central to their identity, serving as a benchmark for meeting daily needs and symbolizing the character of each group, clan, "*fam"*, or "*keret"*. For the Keerom people, land is revered as "*mama*" (mother). This analogy reflects non-material culture, emphasizing that the earth—like a mother's lap—is where humans are born, live their lives, and are ultimately laid to rest (Turua et al. 2014). This perception is embedded in their social structure, obligating every community member to adhere to customary rules that prohibit encroaching on or damaging land (forest) without cause. To harm the land is to harm "*mama*." For the indigenous Papuan communities, sustainable land and forest use is a cultural consensus that must be understood and upheld. This obligation to adhere to customary rules is a significant responsibility in the indigenous Papuan communities, ensuring sustainable land and forest use.

Keerom's local communities view land and forests through deeply rooted wisdom focused on preservation and sustainability. This perspective shapes their practice of shifting cultivation. The system relies on abundant land and the careful selection of high-quality seeds, chosen based on traditional knowledge of optimal growing conditions. In addition, social relationship capital plays a critical role in the life systems of Keerom's communities. Customary rules governing interactions between families or *fam* are strictly upheld. The concept of "*tamne yisan kefase*" embodies the spirit of cooperation, particularly in addressing social and economic challenges, such as during the process of clearing agricultural land. This concept has been adopted by the local government as an official motto, emphasizing the importance of traditional values in regional development. Cooperation is also an integral component of the community's social capital, serving as a foundation for building stronger and more self-reliant communities. In the context of Keerom's development, reviving and strengthening this spirit of cooperation could be pivotal in addressing the challenges of modernization and social change. By grounding progress in local values that have historically promoted social harmony, the community can sustainably develop its agricultural systems while preserving its cultural identity.

Figure 3. Clearing of new land or reforested former plantations (>5 years) for traditional cultivation's "new land" in Keerom District, Papua Province, Indonesia

Table 3. Types of plants cultivated by local Papuan people in Keerom District, Papua Province, Indonesia

Local name	Scientific name	Note
Ubi jalar	*Ipomoea batatas* (L.) Lam.	The main plants used as a source of staple food for the community, both for personal consumption and for animal feed, and often cultivated as a source of family income.
Ubi kayu	*Manihot esculenta* Crantz	The main plants used as staple food for the community, both for personal consumption and for animal feed. Often cultivated as a source of family income.
Bete	*Colocasia* sp.	Local people cultivate some for personal consumption and are currently often marketed as a source of community income.
Keladi	*Colocasia esculenta* (L.) Schoff	Local people cultivate some for personal consumption and are currently often marketed as a source of community income.
Pepaya	*Carica papaya* L.	Often planted in between the main plants, but are currently being cultivated due to increasing market demand along with population growth.
Tebu	*Saccharum officinarum* L.	Often planted in between the main plants, but not yet widely cultivated.
Sayur lilin	*Saccharum robustum* E.W. Brandes & Jeswiet ex Grassl.	Often planted in between the main plants, and have been widely cultivated due to market demand.
Sayur gedi	*Abelmoschus manihot* (L.) Medik.	Planted in between the main plants and not yet widely cultivated.
Labu Siam	*Sicyos edulis* Jacq. [Syn: *Sechium edule* (Jacq.) Sw.]	Widely cultivated by the indigenous people of Waris district, in addition to being consumed by themselves, they are also a source of family income.
Labu	*Cucurbita* sp.	The main plants used as staple food for the community, both for personal consumption and for animal feed. Often cultivated as a source of family income.
Pinang	*Areca catechu* L.	Often planted in between the main plants, and has been widely cultivated due to increasing market demand.
Pisang	*Musa* spp.	The main plant used as a staple food ingredient for the community, both for personal consumption and for animal feed. Often cultivated as a source of family income.
Buah merah	*Pandanus conoideus* Lam.	Often planted in between the main plants, and has been widely cultivated due to increasing market demand.
Cabai rawit	*Capsicum annuum* L.	Cultivated and is a source of income for the local community because it has a fairly high selling value compared to other plants.
Sagu	*Metroxylon sagu* Rottb.	Cultivated and is a source of income for the community, and already has a sago flour factory that can be processed into cookies, in addition to being a staple food for the indigenous Keerom community.
Durian	*Durio zibethinus* Murray	Cultivated and is a source of income for the local community because it has a fairly high selling value.
Duku	*Lansium domesticum* Corrêa	Cultivated and is a source of income for the local community because it has a fairly high selling value.
Vanili	*Vanilla planifolia* Andrews	Cultivated by local communities in East Arso and Mannem Districts, and is a source of income for the community because it has a fairly high selling value of around IDR 300,000/kg.
Cokelat	*Theobroma cacao* L.	Cultivated and a source of income for local communities because it has a fairly high selling value of ± IDR 120,000/kg.
Jagung	*Zea mays* subsp. *mays*	Cultivated by the community, and is a source of income for them.

Customary rules governing interactions between families or *fam* are strictly upheld. The concept of "*tamne yisan kefase*" embodies the spirit of cooperation, particularly in addressing social and economic challenges, such as during the process of clearing agricultural land. This concept has been adopted by the local government as an official motto, emphasizing the importance of traditional values in regional development. Cooperation is also an integral component of the community's social capital, serving as a foundation for building stronger and more self-reliant communities. In the context of Keerom's development, reviving and strengthening this spirit of cooperation could be pivotal in addressing the challenges of modernization and social change. By grounding progress in local values that have historically promoted social harmony, the community can sustainably develop its agricultural systems while preserving its cultural identity.

Shifting cultivation systems are often discussed because some people worldwide still depend on them. In India, for example, 68% of the population practices shifting cultivation alongside other agricultural activities. Traditional methods damage the land and cause environmental changes (Longkumer et al. 2019). From 2011 to 2015, shifting cultivation severely impacted the environment, leading to deforestation and landscape degradation. It also played a significant role in the global decline of biodiversity, including endangered species (Sati 2019). An estimated 14 to 34 million people in tropical Asia depend on shifting cultivation. In the tropics, shifting cultivation is accounts for at least 60% of total deforestation and is considered a source of greenhouse gas emissions (Mukul and Herbohn 2016). The top five drivers of forest disturbance on a global scale are commodity-driven deforestation, shifting cultivation, forestry, forest fires, and urbanization (Kadoya et al. 2022).

Clearing new forest land for sporadic shifting cultivation impacts the reduction of flora and fauna populations (Kadoya et al. 2022). It takes up to 50 years for the land to recover to its primary forest state (Mukul and Herbohn 2016). Therefore, a community assistance solution is needed to minimize the prolonged negative impact of land changes and avoid environmental damage, land use, and permanent forest loss (Kadoya et al. 2022). Severe challenges to life's necessities have led to a more resilient, sustainable modern agricultural model that minimizes environmental risks (Elouattassi et al. 2023).

Modern agriculture

Migrant communities predominantly practice modern agriculture in Keerom District. According to Manida and Ganeshan (2021), this shift is driven by advancements in science, technology, and innovation. Modern agricultural practices are characterized by the use of improved equipment, advanced land management systems, and the application of agricultural technologies. In Keerom, modern agriculture began in 1984, marked by the adoption of basic agricultural technologies and land management techniques (Table 1; Figure 4). Communities have since developed an understanding of water management for irrigation, soil cultivation, herbicide application, and fertilization practices. Significant changes were catalyzed by the transmigration program, which aimed to enhance agricultural productivity across Indonesia.

Globally, modern agriculture developed in the 1800s and 1900s, using gas and oil-powered machinery, chemical fertilizers, and pesticides. Scientists also helped create new plant and animal varieties (Spiertz 2014; Federico 2015). In Keerom, modern farming practices include better land management techniques and the use of irrigation systems to control water supply and drainage, showing a shift toward more efficient and sustainable agriculture.

The transmigration program has played a key role in agricultural development by relocating populations to reduce the isolation of inland communities, promote social integration, and strengthen national security. Transmigrants are granted rights to manage land for agriculture, including home gardens, farmland, and plantations; initially, the policy of issuing land certificates aimed to enhance economic and agricultural stability.

Today, Keerom District serves as a key agricultural hub, supplying produce to Jayapura City, Jayapura District, and mountainous regions. It is also a major producer of rice and corn in Papua Province. With its vast land area, Keerom has substantial potential for further agricultural development. Local villagers primarily sustain themselves through sago gathering, farming, hunting, and occasionally fishing and shrimp harvesting in nearby rivers. Sago gathering is a central activity, with sago forests appearing limitless in size (Sanggenafa 2020). These forests are divided among clans, with strict boundaries enforced to respect customary land rights. Natural markers such as mountains, rivers, large trees, and roads delineate the customary rights of each clan, ensuring careful adherence to tribal boundaries.

This lifestyle has led to variations in the community's diet. While sago remains a staple, tubers have also become an integral part of their consumption pattern (Kadir et al. 2024). The shift from gathering to farming, and from consumers to producers, has significantly impacted their social and economic lives. The Keerom community began engaging in trade, in a testament to their self-sufficiency, selling their garden produce. However, this shift has not triggered a major economic boom, as their trade remains small-scale, primarily limited to fruits, corn, and vegetables. This condition can occur for various reasons, such as a reliance on natural resources for daily needs, limited financial resources, or a limited ability to use technology.

Figure 4. Modern agricultural systems have integrated several types of plants to optimize needs and better management systems in Keerom District, Papua Province, Indonesia. A. Planting animal feed, B. Planting various types of vegetables

Keerom District grows various productive fruit plants, including citrus (*Citrus* spp.), dragon fruit (*Hylocereus* sp.), and bananas (*Musa* spp.). With its agricultural potential, Keerom is set to become a major agricultural hub in the Papua region. Currently, there is an increasing trend in adopting advanced agricultural technologies to boost productivity and fulfill community food needs. The involvement of indigenous peoples and the government in promoting income-generating activities has driven this change. According to Manida and Ganeshan (2021), these technologies include indoor vertical farming, agricultural automation, livestock technology, modern greenhouses, precision agriculture, blockchain, artificial intelligence, soil and water sensors, weather tracking, satellite imaging, pervasive automation, microsomal technology, and Radio Frequency Identification (RFID) systems.

Development of oil palm plantations

The transmigration program also aimed to boost plantation productivity. During the New Order era, the Indonesian government sought to increase foreign exchange earnings through the plantation sector, particularly by expanding oil palm plantations (Widyatmoko and Devi 2019). This expansion followed two main strategies: rehabilitating existing state-owned plantations and establishing new plantations under the community core plantation (PIR) model. The PIR model was introduced to promote equitable development, improving farmers' livelihoods by increasing agricultural production and income.

Transmigration is a government initiative aimed at accelerating development. The relocation of populations has brought positive impacts to target areas, including Keerom District, where some transmigrant communities were specifically designated to manage oil palm plantations (Figure 5). Initially, transmigrants were granted three land ownership certificates: one for their house, one for a garden, and one for a one-hectare oil palm plantation. Many of these transmigrants came from Java and Flores.

The placement of transmigrants, especially from Flores in 1991 in Arso VII, greatly improved the oil palm farming system in Keerom. The government supported these transmigrant communities by providing housing, agricultural land, and oil palm plantations to help manage the plantations. However, the program faced many challenges because most of the land was forested, needing lots of clearing and preparation. During this time, the local economy heavily depended on oil palm plantations in the Tami area. Transmigrants mainly did oil palm maintenance work, including grass spraying, fertilization, and weed control, earning a daily wage of IDR 3,000 from the company (Sumardi 2024). After three to four years of guidance from the state-owned company, the oil palm land was handed over to the community for independent management. Gradually, farmers' incomes began to increase compared to their previous incomes.

The first oil palm plantation in Keerom was established by the Nusantara Plantation Limited Company (PTPN II), Tanjung Morawa, Medan, in 1985 in Arso District. Initially, the company employed transmigrants, who settled in transmigrant settlement units (UPT-*Unit Pemukiman Transmigran*) in Arso. These transmigrants managed a 7,000-hectare oil palm plantation, which also employed 10,522 local families as oil palm farmers (Dekenat Keerom 2008). While the plantation was expected to boost the local economy, many promises made by the company remained unfulfilled. Farmers faced challenges such as inadequate wages, limited access to healthcare, and insufficient educational opportunities, issues that also affected the local Keerom community.

Figure 5. Oil palm plantations remain operational today in Keerom District, Papua Province, Indonesia: A. Condition of oil palm plantations, B. Harvesting of oil palm fruit

Regional development has significantly influenced community activities, including oil palm plantation operations. Communities have demonstrated foresight in shaping their future, with many plantation workers transitioning to other occupations, such as agricultural activities and small businesses, as urban areas expand (Rustiadi et al. 2023; Supriatna et al. 2024). While oil palm plantation companies have not significantly expanded their operations, the entry of several private companies has contributed to local economic growth. Over time, some oil palm plantation areas have become idle or repurposed for vegetable farming and other agricultural activities. However, several oil palm farmers continue to maintain their plantations. Workers report monthly incomes ranging from IDR 2-3 million from oil palm-related activities. Companies that have endured to the present have effectively managed oil palm land processing (Figure 5). These companies employ workers from diverse regions, including Flores, Kupang, Java, Manado, Sulawesi, and the local Keerom population.

The establishment of oil palm plantations has significantly impacted the lives of the Keerom people. Positive effects include more job opportunities, better access to healthcare, steady monthly incomes, and improved infrastructure like roads and electricity. However, the presence of oil palm plantations also brings negative consequences. Clearing land for plantations has caused deforestation, habitat destruction, loss of biodiversity, and the displacement of traditional lands. These changes have disrupted the traditional ways of life for communities that rely on hunting, gathering, and traditional farming. Hunting areas are now farther from homes, and sago forests have shrunk. Around 18,000 hectares of forest land have been converted into oil palm plantations, leading some community members to switch to plantation work. This shift has changed the social and economic structure of local communities, as many now depend on fixed salaries from plantation companies. Despite these changes, oil palm plantations in Keerom mainly produce crude palm oil (CPO), which is exported to other regions for processing into cooking oil and other products.

The food estate program: Corn as a flagship commodity

The food estate program is a key agricultural initiative aimed at meeting national food needs. Since 2023, Keerom District has been designated as a corn-producing area (Table 1; Figure 6) and a center for agricultural development in Papua Province. Despite being categorized as an underdeveloped border region, Keerom possesses abundant natural resources that have yet to be fully utilized. This program reflects the government's commitment to sustainable community empowerment, promoting equitable and inclusive prosperity. One of the strategies to accelerate development in border areas is the establishment of export-oriented food barns (Beding et al. 2023). The program focuses on cultivating strategic food commodities, including rice, corn, soybeans, tubers, horticultural crops, fruits, plantation crops, and livestock (Lewaherilla et al. 2019).

The food estate program is being developed in Arso and Mannem Districts, with a primary focus on corn cultivation. Corn serves multiple purposes, functioning as food, feed, and fuel (Panikkai 2017). As a national strategic agricultural commodity, the development of corn in Keerom District is expected to contribute significantly to national corn self-sufficiency. The availability of underutilized idle land, institutional backing, and agricultural infrastructure supports this initiative. The area dedicated to corn cultivation has expanded considerably. Among the 11 districts in Keerom, 6 serve as the primary bases for corn development: Web, West Arso, Yaffi, Arso, East Arso, and Towe (Table 4) (Lewaherilla 2023; BPS Keerom District 2024). Under the food estate program, the target is to add approximately 10,000 hectares of corn farmland. In 2023, the development of 500 hectares of corn land began, utilizing unused oil palm plantation areas. Given this development, it is estimated that the total area of corn farms in Keerom will reach 819 hectares by 2024.

Figure 6. The food estate program develops superior maize commodities in Keerom District, Papua Province, Indonesia

Table 4. Average corn production in seven districts in Keerom District, Papua Province, Indonesia, before the food estate program

Dictrict	Harvest area (hectare)	Production (ton/hectare)	Average production (ton)
Web	5.0	14.0	2.8
Towe	6.0	22.4	3.7
Senggi	24.0	67.2	2.8
Waris	69.0	193.2	2.8
Arso	85.0	238.0	2.8
East Arso	32.0	89.6	2.8
Skanto	98.0	274.4	2.8
Total	319.0	898.8	2.9

Source: BPS Keerom District (2024)

In Wambes Village, Mannem District, a significant shift in land use has occurred, bringing about economic benefits. The community, in collaboration with the government, has developed 500 hectares of corn fields, utilizing idle land, particularly unproductive oil palm plantation areas. The initial corn harvest, which yielded 6-7 tons per hectare, has surpassed the national average of 5.6 tons per hectare. With corn prices in Keerom ranging from IDR 5,000 to 6,000 per kilogram, farmers earned approximately IDR 42 million per hectare, a substantial increase in income. This success has not only influenced community activities in transmigration areas but also sparked a renewed interest in agriculture. Many farmers have converted oil palm land to cultivate crops such as corn and vegetables, a shift in land use that reflects a growing trend among local communities.

The agricultural sector plays a pivotal role in the national economy, particularly in rural employment and ensuring food security. Agriculture in Indonesia must be supported by robust institutions rooted in traditional values. Traditional agriculture, therefore, represents a vital activity for rural communities, sustaining livelihoods while preserving the natural environment (Timisela et al. 2020). In Keerom District, the evolution of agricultural systems and community income has been gradual. Initially, local communities relied on hunting and gathering to meet their subsistence needs. Over time, advancements in science and technology have introduced traditional and modern agricultural practices, culminating in the establishment of oil palm plantations and the food estate program focused on corn as a flagship commodity. The agricultural development in Keerom is expected to become a flagship program, contributing to food security at both local and national levels.

Although monoculture farming systems such as oil palm and maize are highly profitable, they can have negative environmental impacts. Experts reveal that monoculture can lead to a decline in soil quality. In the long term, changes in soil pH, organic matter content, and soil salinity can affect crop yields (Zhao et al. 2018). Fungal and bacterial communities and populations decline as well, as does enzyme activity in the plant rhizosphere. Under different conditions, environmental nutrients can decline, requiring fertilization, while disease-causing fungi may increase (Elouattassi et al. 2023).

The increased reliance of farmers on pesticides and fertilizers can affect water quality, human health, and wildlife populations (Rahman 2023). Compared to monocultures, intercropping retains more water and biomass, has larger root systems and more litter, and offers habitat for a greater variety of organisms. Intercropping can also help reduce flooding, conserve soil, improve habitat quality, and increase carbon storage (Ma et al. 2022). Climate change is expected to raise the frequency and intensity of future droughts in many regions around the world (Elouattassi et al. 2023). Under these conditions, governments must intervene in agricultural systems based on the needs of local communities and promote sustainable farming practices.

The dynamics of the PNG-Indonesia border

Remote and frontier areas in Indonesia, including border regions, are a priority for community development. Similar conditions exist in the Indonesia-PNG border region, where development of physical and human resources is an ongoing commitment. This continuous effort, coupled with Indonesia's well-established cooperation with PNG, provides positive opportunities for both countries, especially for improving the welfare of people in the border region. This change is evident in the construction of market facilities on the Indonesian side of the border, which provide Indonesia with various benefits and the people of PNG with basic necessities.

Cultural changes are occurring quite rapidly in Indonesian border communities, while in PNG, they are relatively slow. One contributing factor is infrastructure; PNG communities often take advantage of the opportunity to shop in Indonesia. Conversely, Indonesian communities often take advantage of recreational opportunities in PNG. This situation impacts the economic system in the border region. According to Lanati and Venturini (2021), migration flows are based on wage differences between the country of origin and the destination country, as well as related travel costs. However, migration patterns must also be considered. Relatively small migration flows, both within and between countries, have shifted the focus of discussion away from economic factors despite the presence of strong economic drivers, such as unemployment and wage differences. Currently, more attention is given to non-economic factors influencing migration decisions, such as cultural ties.

Evolution and changes in environmental conditions

The evolution of the agricultural system strongly impacts both local communities and migrants in border areas. Based on observations, transmigrants from other regions of Indonesia have the chance to access productive agricultural land. Of course, they can only use the land for agricultural purposes. Meanwhile, local communities typically follow shifting cultivation or traditional agricultural practices. However, clearing shifting cultivation fields and opening large areas of land for development, such as oil palm plantations, can harm the environment. The main change is the loss of the original landscape, which is transformed into agricultural land. Large-scale deforestation can lead to negative consequences, such as the loss of biodiversity and other environmental damage.

The massive and excessive hunting of animals and plants can lead to a decline in the population of flora and fauna, and even the loss of endemic species (Tilker et al. 2019). Meanwhile, shifting cultivation systems that occur throughout the year can contribute to environmental damage. Changes in the ecological status of forests, from primary to secondary, affect forest structure and composition, which naturally affects the life of the entire region (Rodríguez-León et al. 2025). This condition can also occur in monoculture systems, such as oil palm or corn plantations. This means that the structure and composition of forests and land will shift, and the flora and fauna must readjust to the existing habitat.

Meanwhile, modern agricultural systems involve improved land cultivation processes, which align with the current mindset of sustainable agriculture. However, the use of chemicals, such as herbicides and insecticides, must also be reduced. The community often uses these chemicals. According to Parven et al. (2025), this will impact environmental damage, soil quality, and changes in the structure and composition of the flora and fauna that support agricultural systems based on an ecological approach. Therefore, any change in the agricultural system will cause environmental damage. The most important thing is minimizing the impact of each stage of change to avoid environmental damage.

The process of evolution and improvement in the quality of life of the community

The evolution of agricultural systems in border areas has positively impacted the well-being of border communities. Communities that still practice traditional activities, such as hunting and gathering, continue these practices to this day. For example, they hunt deer, cuscus, wild boar, and other animals. They earn a good income from these activities. For instance, a mature cuscus (*Spilocuscus* sp.) can fetch between Rp. 750,000 and Rp. 850,000. Meanwhile, the community can hunt an average of four animals at a time. Thus, hunting and selling the prey can generate an income of around 3.2 million Indonesian rupiah. Moreover, they can hunt at least four times a month. This is unlike shifting cultivation and traditional farming systems, where communities must wait until harvest time, when the yield is intended solely for subsistence needs.

This situation shows that people's income from traditional agriculture is often only enough to buy food for one day. Meanwhile, the oil palm plantation system provides a relatively better income because workers receive a monthly salary. This differs from the food estate system, in which workers must wait until harvest time. On average, income from oil palm plantations and food estates is higher than income from shifting cultivation or traditional agriculture. Although modern agricultural systems require more effort and capital, they offer better conditions. However, modern agricultural systems, such as intercropping and land intensification, increase production. This increased production can be used to meet the community's needs and provide food reserves for the future. According to Ahmed and Ahmed (2023), modern agricultural systems will have a positive impact on increasing community income, thereby affecting the welfare of the community and the country.

In general, it can be concluded that as the global population grows, human needs increase and resources become increasingly limited, we must carefully consider every step in the development process. The development of the cultural system for meeting the needs of the community in Keerom was carried out in several stages, namely: hunting and gathering, traditional agriculture, modern agriculture, oil palm plantations, and food estate programs. The evolution of agriculture brings benefits as well as impacts on humans. Based on these experiences, establishing a healthy and sustainable agricultural management system should be a top priority. The findings of this study provide a foundation for community understanding of the advantages and disadvantages of the current agricultural system. It is hoped that implementing healthy, sustainable agricultural technologies and systems will help reduce agriculture's negative impacts.

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