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Technical efficiency of traditional agriculture based on local knowledge of smallholder farmers

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ABSTRACT

Increasing productivity is a challenge for small farmers in managing their farms. The objectives of this study were to analyze the technical efficiency of potato farming using local knowledge of traditional agriculture and to analyze the variables that contribute to the technical inefficiency of potato farming in the Arfak Mountains. This study was conducted in three districts of the Arfak Mountains Regency of West Papua Province: Anggi, Sururey, and Hingk. This study used cross-sectional data obtained from structured interviews with 140 farmers. The determinants and efficiency levels were estimated using stochastic frontier analysis. The findings of this study indicate that farmers who implement traditional farming systems with local knowledge have an average technical efficiency of 52%, equivalent to the average technical efficiency value of potatoes in other developing countries without local knowledge of 40–70 percent. The variables of extension frequency, total household income, degree of output commercialization, distance between the farmer's house and the farm location, and fallow length are the determining factors for farmers' technical efficiency. The implication is that traditional farmers can improve their technical efficiency through technological improvements, the use of appropriate inputs, infrastructure improvements, intensive counseling, and assistance in correctly managing their farms.

Contribution/Originality: This study supports the development of small-scale agriculture in developing countries. This research provides information on variations in technical efficiency in traditional agriculture and the determinants of increasing efficiency by maintaining the local knowledge of the local community.

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1. INTRODUCTION

Smallholder farmers in developing nations are frequently faced with a variety of difficulties when managing agricultural activities (Alabi, Oladele, & Maharazu, 2022; Madembo, Mhlanga, & Thierfelder, 2020; Meemken & Bellemare, 2020). These difficulties include limited availability of inputs, the use of basic technology and traditional systems, small areas of land owned, a lack of financial resources, inefficient extension services, subsistence farming, and modest profitability. The result is low agricultural productivity due to the inability of farmers to utilize technology, meaning that the use of resources is inappropriate and inefficient, causing a high degree of inefficiency (Lamichhane, Acharya, & Sharma, 2019; Tabe-Ojong & Molua, 2017; Wassihun, Koye, & Koye, 2019). Moreover, the low socioeconomic standing and managerial skills of farmers may contribute to their low output (Abate, Dessie, & Mekie, 2019; Uuld, Magda, & Bilan, 2021).

For smallholder farmers to execute rural development plans, they need to increase their production and efficiency (Abate et al., 2019; Ali & Byerlee, 1991; Andaregie & Astatkie, 2020; Ma, Renwick, Yuan, & Ratna, 2018). The expansion of smallholder farming through greater productivity per land area can be achieved by pursuing sustainable intensification of production through the utilization of resources, according to Baiphethi and Jacobs (2009) and Enwerem and Ohajianya (2013).

From a theoretical perspective, a farmer's technical efficiency is determined by their capacity to manage inputs to achieve the best results (Aigner, Lovell, & Schmidt, 1977; Farrell, 1957; Maryanto, Sukiyono, & Sigit Priyono, 2018). This is based on the notion that efficiency has to do with how resources are combined with current technology to maximize output (Jote, Feleke, Tufa, Manyong, & Lemma, 2018). Additionally, Widanage et al. (2022) asserted that policymakers should prioritize technical efficiency to boost small-scale agriculture's productivity, competitiveness, and resource sustainability. Many studies have identified factors that affect technical efficiency, including farmers' age, education level, amount of land, fertilizer used, number of seeds used, labor, access to credit, counseling frequency, farm experience, farmer group membership, accessibility of and distance from the product market, and off-farm income (Abdul-Rahaman, Issahaku, & Zereyesus, 2021; Abdulai, Nkegbe, & Donkoh, 2018; Abunyuwah, Yenibehit, & Ahiale, 2019; Bozoğlu & Ceyhan, 2007; Esmael, 2017; Malinga, Masuku, & Raufu, 2015; Nyagaka, Obare, Omiti, & Nguyo, 2010; Obayelu, Moncho, & Diai, 2016; Tabe-Ojong & Molua, 2017; Tiruneh, Chindi, & Woldegiorgis, 2017; Wassihun et al., 2019). Technical inefficiencies are estimated and variations in technical efficiency in a farming enterprise are identified using the stochastic frontier Cobb-Douglas production function technique. According to Asfaw (2021), stochastic frontiers used to analyze data at the farmer level have very substantial measurement errors.

Obstacles to boosting production include small-scale farming's ineffectiveness and low productivity (Adhikari, Timsina, Brown, Ghimire, & Lamichhane, 2018). These obstacles also apply to potato farming in the Arfak Mountains. In the Arfak Mountains, the yearly productivity of potatoes was only 1.48 tons/ha from 2017 to 2020. According to the Minister of Forestry's Decree No. 783/Kpts-11/1992, dated August 11, 1992, the area has an altitude range of 155-2950 m above sea level, and 80 percent of the land is characterized by steep slopes with a slope level of > 40-75 percent; moreover, land area expansion is not possible because a significant portion of the Arfak Mountains is a conservation area (68 325 hectares) (UNIPA Team, 2015).

Compared to potato cultivation in other areas, low production is caused by farmers maintaining traditional practices. The Arfak Mountains' restricted land area, extensive farming methods, limited post-harvest handling, and difficult access to input and output markets are the realities of farming there. In addition, farmers' local knowledge about cultivation is determined by hereditary farming experience (Indrawati, Sumarno, Kusuma, & Raharjo, 2022; Toansiba, Katmo, Krisnawati, & Wambrauw, 2021). Traditional farming has been practiced for generations and is based on firsthand knowledge and experience (Hamadani et al., 2021). Additionally, Kirt, Catherine, and Philip (2022) and Senanayake (2006) claimed that local knowledge is the information that is rooted in place, tied to humans, and developed by individuals and faith groups so that it directly influences the thinking of farmers and cannot be used elsewhere.

An illustration of a local knowledge system in the context of food production is the requirement that local community features be taken into account when applying technology (Sultana, Muhammad, & Zakaria, 2018). Farmers in the Arfak Mountains have a unique set of cultivation techniques that they use based on knowledge acquired from their parents. For instance, they cultivate potatoes without fertilizer and use a shifting cultivation system, which is their community's indigenous knowledge for achieving food security and conserving the environment (Indrawati et al., 2022; Mulyadi, 2012; Toansiba et al., 2021; Yuminarti, Darwanto, Jamhari, & Subejo, 2018). As is the case in many developing countries, it is difficult for regions to boost production, productivity, and efficiency (Tenaye, 2020). So, it is essential to study the technical efficiency of smallholder farmers.

Although traditional farming meets the food needs of farmers, their families, and the general public, Arfak farmers are semi-commercial farmers. Therefore, the degree of commercialization becomes an important part of determining their farms' productivity and efficiency (Toansiba et al., 2021; Yuminarti et al., 2018). Based on the community's local knowledge, the distance from the house, the placement of the field, the location of the market, the slope planting system, the planting pattern, and the length of the fallow period were all determined (Indrawati et al., 2022; Mulyadi, 2012; Toansiba et al., 2021; Yuminarti et al., 2018). There have been numerous studies on the technical efficiency of potatoes, and these studies have produced a range of technical efficiency values. As reported by Ahmed, Burhan, Amanuel, Diriba, and Ahmed (2018), Al-Hachami, AL-Bahadely, and Jbara (2020), Andaregie and Astatkie (2020), Kadakoğlu and Karlı (2022), Kamau, Gathungu, and Mwirigi (2020), Lamichhane et al. (2019), Mardani and Salarpour (2015), Martínez, Tarazona-Velásquez, Martínez-Pachón, and Ramos-Zambrano (2022), Mengui, Oh, and Lee (2019), Uche, Umar, Girei, and Ibrahim (2021), Wassihun et al. (2019), and Widanage et al. (2022), technical efficiency ranges from 44% to 90%. Because they have the smallest amount of land (0.1 hectares), high input costs, and deal with intense insect infestations, the current study examined the appropriate management of smallholders' potato farms. The gap in this previous research is that there is little information on the efficiency of potato farming in the traditional agricultural system, which is based on local knowledge and an average land area of 0.07 hectares. This research tries to close this gap. The research question asks to what degree local knowledge-based traditional agricultural practices in the Arfak Mountains hinder farming productivity. Thus, the purpose of this study is to examine the differences in the technical efficiency of potato farming among traditional local farmers as well as the variables contributing to the technical inefficiency of potato farming in the Arfak Mountains. Policymakers in developing nations with similar characteristics can use the study's findings to create traditional farming enterprises based on local knowledge.

2. MATERIALS AND METHODS

This study was carried out in the three districts of Anggi, Hingk, and Sururey in the Arfak Mountains Regency of West Papua. The study area was chosen purposively because it is a center for potato production and has the potential for further development (Sagrim, Sumule, Iya, & Baransano, 2017). The three-month data collection period ran from December 2021 to February 2022. The snowball sampling approach was used to identify the sample farmers. This method was chosen because the Department of Agriculture's list of farmers in the region is outdated and incomplete, making the selection of samples from the list prone to bias (DiGaetano, 2013). The three chosen districts provided a total of 140 samples. The data used in this study were cross-sectional at the level of households engaged in potato growing. The results were then collated and subjected to both quantitative and qualitative analysis. Similar to Andaregie and Astatkie (2020), Battese and Coelli (1995), Najjuma, Kavoi, and Mbeche (2016), and Wassihun et al. (2019), technical efficiency was calculated using the stochastic frontier Cobb-Douglas production function. The selection of the functional form was affected by the application of stochastic frontier analysis. The following equation was used to mathematically estimate the production function of the stochastic frontier in potato farming:

$$LnY_i = \beta_0 + \beta_1\, lnX_1 + \beta_2\, lnX_2 + \beta_3\, lnX_3 + \beta_4\, lnX_4 + e_{(vi-ui)} \qquad (1)$$

Where Y_i represents potato production, measured in units (kg). X_{1-4} is a factor of input such as potato-growing area (ha), number of seeds (kg), number of male workers (working days), and number of female workers (working days). β_i represents the vector of the parameter to be observed, and v_i-u_i is the error term (inefficiency effect in the model). Expected coefficient values: $\beta_1, \beta_2, \beta_3, \beta_4 > 0$

The technical efficiency was estimated using the following formula:

$$Technical\ Efficiency\ (TE) = \frac{E(y|_{x,z,u})}{E(y|_{x,z,u}=0)} = 1 - \frac{u\,.\,g(x,z)}{f(x,z)} \leq 1 \qquad (2)$$

Where the value of technical efficiency is $0 \leq TE \leq 1$.

The technical inefficiency technique utilized in this study is an adaptation of the technical inefficiency effect model created by Battese and Coelli (1995) and Coelli, Rao, and Battese (1998). Assuming that the u_i variable is free, its distribution is half-normal, with N $(u_{i,}\sigma^2)$, and it is used to quantify the impact of technical inefficiency. This study's distribution parameter *(ui)*, which measures the impact of technical inefficiency, is calculated using the formula below:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} Z_{13} + wi \qquad (3)$$

Where U_i represents the technical inefficiency effect, Z_{1-13} represents a factor of age, formal education, farmer's experience, frequency of counseling, total household income, degree of commercialization of inputs, degree of commercialization of output, distance between house and farming location, distance between house and market, slope, planting system (directional slope, unidirectional contour, bench terrace), planting pattern (intercropping, monoculture), and fallow length. δ_i represents the vector of the parameter to be observed.

Expected coefficient values:

$$\delta_0 > 0; \delta_1 > 0;$$
$$\delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7, \delta_8, \delta_9, \delta_{10}, \delta_{11}, \delta_{12}, \delta_{13} < 0$$

All parameters for both the stochastic frontier function and the inefficiency effect were simultaneously obtained through the Frontier 4.1 software program.

3. RESULTS AND DISCUSSION

3.1. Stochastic Frontier Model Estimation Results

Table 1 shows the results of the estimation of stochastic frontier models of potato farming in the Arfak Mountains, specifically a log-likelihood value of 138.1, which is significant at the 5% level and denotes that the null hypothesis is rejected. Therefore, this indicates that the technical inefficiency of potato growing varies among farmers in the study area. According to the variance associated with inefficiency, which accounts for 99% of the overall variance, inefficiency substantially predominates the total variance. This suggests that the level of potato output fluctuation is greatly influenced by the impact of inefficiency.

Table 1. Results of estimation of stochastic frontier models of potato farming in the Arfak Mountains, 2022.

Variable	Estimation parameters	Standard error	T-ratio
Constant	3.472	0.306	11.361
Land area (X1)	0.138**	0.021	6.558
Seeds (X2)	0.827**	0.051	16.342
Male labor (X3)	-0.043	0.057	-0.758
Female labor (X4)	0.049*	0.021	2.326
Variance and gamma value			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.042	0.002	23.713
$\gamma = \sigma_v^2 / \sigma_u^2$	0.999	0.002	462.089
LR-test	138.1		

Note: * significant at α = 5% (0.05); ** significant at α = 1% (0.01).

The size of each input's coefficient implies a partial elasticity greater than 1. This indicates that the output is responsive to changes in the input, i.e., if the input of potatoes increases by 1%, the output will also increase by 1%. Land area, seeds, and women's labor were positively marked, according to the results of the maximum likelihood estimates of the stochastic frontier model's parameters, and the statistical significance indicates they have a major impact on changes in potato output. Male labor shows a decreasing trend but has little impact on changes in potato output.

3.2. Spread of Technical Efficiency

Using the estimation parameters for the Cobb-Douglas stochastic frontier production function, the technical efficiency in this study was calculated from the results of estimating Equation 1 (error $e_i = v_i, u_i$). The variation in potato growers' technical efficiency levels is shown in Table 2.

Table 2. Frequency distribution of technical efficiency of potato farmers in the Arfak Mountains, 2022.

Technical efficiency level (%)	Number of respondents	Percentage (%)
0 – 10	0	0.00
11 – 20	4	2.86
21 – 30	7	5.00
31 – 40	28	20.00
41 – 50	33	23.57
51 – 60	27	19.29
61 – 70	24	17.14
71 – 80	10	7.14
81 – 90	4	2.86
91 – 100	3	2.14
Total	140	100.00
Maximum technical efficiency	98.95	
Minimum technical efficiency	16.39	
Average technical efficiency	51.56	

The findings indicate that traditional potato farmers in the research area had an average technical efficiency of 52%, which is comparable to the average technical efficiency of potatoes in other developing nations without a local knowledge base. The average technical efficiency of potatoes in Ethiopia, according to research by Wassihun et al. (2019), Al-Hachami et al. (2020), and Uche et al. (2021) was found to be 46%, 50%, and 68%, respectively. According to Widanage et al. (2022), the use of high-quality inputs produced an average technical efficiency of 57%. This indicates that when local knowledge is used effectively and combined with scientific knowledge in farm business management, it increases productivity (Baye & Teshome, 2020; Hambati, 2021). Local knowledge plays a significant role in the adoption of new technologies and the development of agricultural practices (Kirt et al., 2022). However, in emerging nations with intensive farming methods, the technical efficiency value of agricultural products and horticulture ranges from 47% to 90% (Alabi et al., 2022; Asfaw, 2021; Hong, Heerink, Zhao, & van der Werf, 2019; Muzeza, Taruvinga, & Mukarumbwa, 2023; Oumer, Mugera, Burton, & Hailu, 2022; Tasila Konja, Mabe, & Alhassan, 2019; Tenaye, 2020).

Based on the technical efficiency findings, 12.14% of potato farmers had technical efficiency levels better than 70%, meaning that up to 87.86% were still operating inefficiently. According to the efficiency analysis, potato farmers' technical efficiency ranges from a low of 16% to a high of 99%, with an average value of 51.66%. This demonstrates that the typical potato farmer could increase their productivity by utilizing available resources and technology (Al-Hachami et al., 2020; Wassihun et al., 2019). Effective agricultural practices could have an impact on improving potato productivity (Nahraeni, 2012). The wide range of technical efficiency scores is a sign that farmers did not use resources wisely during the production process (Andaregie & Astatkie, 2020). Also, it was noted by Nahraeni (2012) and Wassihun et al. (2019) that if farmers are at average efficiency and aim for maximum efficiency, their chances of increasing production are 47.89% (1-51.56/98.95). Production increases by 83.44% (1-16.39/98.99) if inefficient farmers try to become as efficient as possible.

The typical potato farmer in the research area has not yet attained a high level of technical efficiency. Farmers who practice traditional farming without fertilizer and grow potatoes based on knowledge passed down from their parents (local knowledge) as well as those who use seeds from prior planting cycles for more than four cycles contribute to this inefficiency (except in Anggi District where some farmers are members of farmer groups and obtain seed assistance). Nevertheless, production can still be maximized. Using technology based on farmers' local knowledge, assisting with farming practices, particularly the utilization of inputs, attempting to use organic fertilizers, and eradicating pests and illnesses are some ways to do this. Similarly, Mengui et al. (2019) showed that low efficiency was brought on by ineffective farm management, intense pest infestations, and deficient soil fertility.

3.3. Potential Production and Loss of Potato Farming Production

The following formula can be used to determine the potential production (frontier) based on the outcomes of stochastic frontier analysis (Alabi et al., 2022; Wassihun et al., 2019):

Potential Production = 100/Technical Efficiency * Actual Production

Table 3 demonstrates that farmers with a technical efficiency achievement of 17.9%, for instance, can increase their actual production from 31 kg/ha to 173 kg/ha if they operate their farming business with 100% efficiency.

Table 3. Potential production and production losses of potato farming at various levels of efficiency in the Arfak Mountains, 2022.

Efficiency spread (%)	Number of farms	Average efficiency (%)	Actual production (kg/ha)	Potential production (kg/ha)	Loss		
					Production (kg/ha)	Percentage (%)	Value (million Rp)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0-10	0	0	0	0	0	0	0
11-20	4	17.9	31	173	142	458.66	2.22
21-30	7	26.60	70	263	193	275.94	3.01
31-40	28	35.53	94	265	171	181.45	2.66
41-50	33	46.24	144	311	167	116.26	2.61
51-60	27	55.16	196	355	159	81.29	2.49
61-70	24	65.69	178	271	93	52.23	1.45
71-80	10	74.82	187	250	63	33.65	0.98
81-90	4	85.29	259	304	45	17.25	0.70
91-100	3	95.61	175	183	8	4.59	0.13
Sum	140	502.84	1334	2375	1041	1221.33	16.25

The least efficient farmers currently lose 142 kg/ha of their potential yield. Farmers must boost productivity by 458.66% if they wish to handle potato cultivation as efficiently as possible. In contrast, farmers who have attained a high level of technical efficiency (95.61%) only require a 4.59 percent increase in production to reach maximum efficiency of 100%. Regarding economic value, farmers with the lowest efficiency lose 2.22 million rupiahs per acre in revenue. The factors that lead to production loss are associated with the ways that local farmers cultivate potatoes using traditional methods based on inherited knowledge, including improper land management, lack of fertilization, vulnerability to intense pest attacks, and inaccuracy in the use of seeds and planting techniques.

Table 4. Results of the estimation of parameters model of technical inefficiency based on the stochastic frontier production function of potato farming in the Arfak Mountains, 2022.

Variable	Estimation parameters	Standard error	t-ratio
Constant	1.326	0.795	1.667
Age	-0.001	0.005	-0.148
Formal education	0.011****	0.001	9.164
Farming experience	0.001	0.005	0.255
Frequency of counseling	-0.051***	0.023	-2.195
Total household income	-0.017****	0.005	-3.479
Degree of commercialization of inputs	0.007****	0.001	6.212
Degree of commercialization of output	-0.022****	0.002	-9.475
Distance between residence and location of farm	-0.064**	0.033	-1.947
Residential distance from market location	0.009*	0.006	1.555
Slope	0.001	0.003	0.186
Planting system	0.023	0.144	0.162
Cropping pattern	0.048	0.123	0.392
Fallow length	-0.005**	0.003	-1.777

Note: * significant at α = 15% (0.15); ** significant at α = 10% (0.1); *** significant at α = 5% (0.05); **** significant at α = 1% (0.01).

3.4. Factors Affecting Potato Farming Inefficiency

The socioeconomic factors of farmers that related to their activities in potato farming were the variables used in the model. As shown in Table 4, the findings provide an estimate of the stochastic frontier production function's technical inefficiency. The frequency of counseling, total household income, the degree of commercialization of outputs, the distance between residence and farm, and the length of the fallow period are the five factors that have a significant positive impact on technical efficiency. Technical efficiency is negatively impacted by the factors of formal education, the extent of input commercialization, and the distance between home and market. Technical efficiency is unaffected by the variables of age, experience, slope, planting system, and cropping pattern.

Age has a statistically insignificant negative effect on technical efficiency. The farmer's performance in making decisions about his farming enterprise is influenced by his age. Farmers' technical inefficiencies decrease as they get older, and their technical efficiency rises. Age, however, does not have a significant impact, since as farmers get older, they do not become more likely to accept technologies that would help them become more productive and thus more efficient farmers.

Farmers' number of years in formal education is represented by the education variable. Education has a significant negative effect on technical efficiency. This suggests that a farmer is technically less efficient at growing potatoes the higher their level of formal education. This indicates that education does not make farmers more likely to adopt new technologies for their farming operations or enhance their management skills. These findings contradict those of Linn and Maenhout (2019) and Wamuyu, Bett, Kariuki, and Cadot (2022), who claimed that a lack of education had a negative impact on technical efficiency. By enhancing farmers' managerial abilities and their capacity to learn, comprehend, and use new inputs, education can boost agricultural productivity.

Technical efficiency is unaffected by farming experience, yet the value is positive. Because they do not dare to risk crop failure, it is believed that farmers continue to operate their farms based on the inherited knowledge of their parents. This finding aligns with the research of Andaregie and Astatkie (2020), but it contrasts with the conclusions of other studies (Maryanto et al., 2018; Wamuyu et al., 2022), which found that experience had a negative impact on inefficiency. This suggests that farmers who specialize in growing potatoes will be more technically proficient. High levels of experience among farmers can boost agricultural productivity and entrepreneurial skills.

The number of times the farmers had attended counseling was used to gauge the counseling frequency. In essence, farmer extension programs in the Arfak Mountains are failing. Several issues emerged as barriers, including 1) the farming community's resistance to extension workers' presence and 2) the absence of extensive extension activity in the Arfak Mountains. Only farmers who belong to farmer groups receive the highest level of counseling. The findings indicate that technical efficiency can rise with counseling frequency. Continuous counseling and mentoring can alter farmers' attitudes regarding the use of production inputs, production practices, and willingness to accept innovations, reducing technical inefficiencies (Asfaw, 2021). According to Wamuyu et al. (2022), inefficiency is negatively impacted by counseling frequency. This suggests that extension boosts potato farmers' technical efficiency. The diffusion of technologies to aid farming activities depends on access to extension activities.

The total household income was calculated using the income that farmers receive from their on-farm, off-farm, and non-farm enterprises. In addition to farming, several farmers earn a living as civil servants in occupations such as teaching, nursing, honorary positions, district employees, and regional employees. Technical efficiency is positively correlated with total household income. The technical inefficiency of potato farming decreases and potato farming technical efficiency rises in direct proportion to total household income. Farmers who have supplementary jobs can make money to fund their farming business. This is consistent with studies showing that off-farm/non-farm revenue has an impact on technical efficiency (Andaregie & Astatkie, 2020; Wamuyu et al., 2022). The capital difficulties that rural households have in many developing nations can be addressed in part by providing off-farm income options.

The variable degree of commercialization of inputs was measured as the ratio of the cost of using inputs acquired on the market to the cost of their creation. Only the wages of labor performed outside the household were used as the input value. This was due to the lack of usage of fertilizers and pharmaceutical inputs by farmers. The findings indicate that the level of input commercialization is significant and influences the decline in technical efficiency. Because the land area is small and many farmers carry out their farming activities with their families, this finding suggests that farmers do not frequently use labor inputs from outside the family.

The degree of output commercialization has a favorable impact on enhancing technical efficiency, in contrast to the degree of input commercialization, which has a negative impact. The results show that the commercialization index coefficient is negative, which suggests that as the commercialization of the potato farming industry increases the technical efficiency rises and the inefficiency decreases. The ratio of potato sales revenue to total revenue from production was used to determine the degree of commercialization of the output. In terms of output, all farmers sell their potatoes to the market, and only a small number are eaten or utilized for seeds. Commercial farmers work harder to boost their output. This study supports the finding of Tirkaso and Hess (2018) that commercialization can boost smallholder farmers' productivity by raising their revenues.

The distance between the home and the potato field has a beneficial impact on technical efficiency. Farmers are more motivated to actively manage their farms when they have easier access to their land. Technical inefficiency declines as a result, while technical efficiency rises.

Technical efficiency is negatively impacted by the distance between the home and the marketplace. The longer it takes farmers to travel to the market, the harder it is for them to gather market data on prices, demand, and supply of products (Asfaw, 2021), leading to an increase in technical inefficiency and a decrease in technical efficiency. This finding is consistent with studies by Khanal, Wilson, Shankar, Hoang, and Lee (2018) and Tolno, Kobayashi, Ichizen, Esham, and Balde (2016), which found that the farther a farmer lives from the market, the less productive they are. Due to their lack of market knowledge, the expense of transport, and poor access to transportation, farmers only play a minor role in the market. Farmers from the Arfak Mountains sell their potatoes at the Manokwari District Market, which is 90–120 km away and has limited transportation options. As a result, farmers are forced to pay high prices to rent automobiles. The level of efficiency is unaffected by the slope, planting method, or cropping pattern despite their overall favorable effects. This shows that farmers' ability to manage inputs is not influenced by whether they plant on a moderate slope, without bench terraces, following the contour, or by their choice of monoculture cropping patterns.

The fallow period is the time it takes for farmers to grow potatoes on the same ground again. According to local wisdom, the land is left for 1-4 years, and farmers move their fields after 2 or 3 harvests. The longer the land is left fallow, the more fertile it will be. According to research by Siahaya, Hutauruk, Aponno, Hatulesila, and Mardhanie (2016), a long fallow period of 9 to 20 years is a predictor of land fertility. As a result, technical inefficiency is reduced and technical efficiency increases.

4. CONCLUSION AND RECOMMENDATION

In the research area, farmers who use traditional agricultural practices and local knowledge had an average technical efficiency of 52%, with a range of 16 to 99%. The factors that determine a farmer's technical efficiency include the frequency of extension counseling, the total household income, the degree of commercialization of outputs, the distance between the farmer's residence and the farm, and the length of the fallow period.

Technological advances based on farmers' local knowledge, the use of suitable inputs, infrastructural upgrades, intense counseling, and aid for farmers so they can improve their farm management are all necessary to increase the efficiency of potato cultivation by traditional farmers.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
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