Shifting cultivation management to increase economic efficiency in potato farms

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Shifting cultivation management to increase economic efficiency in potato farms

Abstract. Farming shifting is one of the cultivation strategies to find the ideal environment. Shifting agriculture is caused by limited knowledge of farmers on environmental conditions for growing plants. This study aims to describe the input variables and shifting cultivation management on the efficiency of potato farming. The research method used is descriptive statistics. The study involved 51 potato farmers in Minyeimemut and Arion villages of Hingk sub-district, Manokwari District, West Papua, Indonesia. Potato commodities cultivated by Arfak farmers are still using a shifting cultivation system. Analysis of the data by quantitative descriptive method with the help of Frontier 4.1 software and the Maximum Likelihood Estimation (MLE) approach to reduce the stochastic frontier cost function. The results showed that the average potato production was 296.08 Kg/Season. The average area of land cultivated by farmers is 0.15 Ha, the average use of seeds is 44.41 kg, and the average workforce is 33.08 Working Days (HOK). The cultivation activities of potato farmers show 4.33 years of shifting. Economic efficiency shows potato farming of 0.08548 which means it has a fairly economical category.

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Змінне управління вирощуванням для підвищення економічної ефективності в картоплярських господарствах

Анотація. Змінне землеробство – одна зі стратегій вирощування, спрямована на пошук ідеального середовища, воно пов'язане з обмеженими знаннями фермерів про умови довкілля для вирощування рослин. Це дослідження спрямоване на опис вхідних змінних та змінного керування вирощуванням, що впливають на ефективність вирощування картоплі. Як метод дослідження використовується описова статистика. У дослідженні взяли участь 51 фермер, який вирощує картоплю в селах Міньєімемут та Аріон у Західному Папуа в Індонезії. Аналіз даних здійснено кількісним описовим методом за допомогою програмного забезпечення Frontier 4.1 та підходу оцінки максимальної правдоподібності (MLE) для зменшення стохастичної граничної функції вартості. Результати показали, що середня врожайність картоплі становила 296,08 кг/сезон. Середня площа землі, що обробляється фермерами, становить 0,15 га, середнє використання насіння – 44,41 кг, а середня робоча сила – 33,08 робочих днів. Вирощування картоплярів показує 4,33 роки змінної роботи. Економічна ефективність показує для картоплярства коефіцієнт 0,08548, а отже, воно належить до досить економічної категорії.
Ключові слова: змінне вирощування; звичайне сільське господарство; економічна ефективність; картопляне господарство; картоплярство.

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Сменное управление выращиванием для повышения экономической эффективности в картофелеводческих хозяйствах

Аннотация. Сменное земледелие – одна из стратегий выращивания, направленная на поиск идеальной среды, оно связано с ограниченными знаниями фермеров об условиях окружающей среды для выращивания растений. Это исследование направлено на описание входных переменных и сменного управления выращиванием, влияющих на эффективность выращивания картофеля. В качестве метода исследования используется описательная статистика. В исследовании приняли участие 51 фермер, выращивающий картофель в деревнях Миньеимемут и Арион в Западном Папуа в Индонезии. Анализ данных осуществлён количественным описательным методом с помощью программного обеспечения Frontier 4.1 и подхода оценки максимального правдоподобия (MLE) для уменьшения стохастической граничной функции стоимости. Результаты показали, что средняя урожайность картофеля составила 296,08 кг/сезон. Средняя площадь земли, обрабатываемой фермерами, составляет 0,15 га, среднее использование семян – 44,41 кг, а средняя рабочая сила – 33,08 рабочих дня. Выращивание картофелеводов показывает 4,33 года сменной работы. Экономическая эффективность показывает для картофелеводства коэффициент 0,08548, а значит, оно относится к достаточно экономичной категории.
Ключевые слова: сменное выращивание; обычное сельское хозяйство; экономическая эффективность; картофельное хозяйство; картофелеводство.

1. Introduction

Potato (***Solanum tuberosum* L**) is a horticultural plant that has a high economic value. In addition, potatoes are cultivated in different parts of the world because they contain essential nutrients humans and animals need (Dogbe & Revoredo-Giha, 2021; Timpanaro et al., 2021). In addition, potatoes are also one of the export commodities and sources of foreign exchange. This is because potatoes commodity can be developed to increase the economic productivity of the community (Agussabti et al., 2020; Kovarda, 2021). Indonesia is one of the countries with many potato production centres (Utami & Ambarwati, 2017).

In Indonesia, based on the harvest date, the area of potato business has decreased from year to year. The Central Bureau of Statistics and the Directorate General of Horticulture in 2018, the potato harvested area in Indonesia was 68,683 Ha, then in 2019, it fell to 68,223 Ha. Nevertheless, national potato production and productivity increased by 2.33 tons/ha in 2018 and 3.02 tons/ha in 2019. This fact also occurred in West Papua Province, where potato harvest fell to -98.06 Ha in the same year, and production fell to -84.21 tons. Such a condition should not have happened, considering that West Papua still has agricultural areas and land potential that have not been used optimally.

Gunung Arfak Regency is a fertile area with biodiversity (Kowalski et al., 2020; Manik et al., 2018). Geographically this region can produce various types of highland vegetables. Potato commodities cultivated by Arfak farmers are still using a shifting cultivation system (Szalka & Tamándl, 2019). Hingk District is one of the areas where most of the farmers cultivate potato plants traditionally. The resulting potatoes can meet market demand in the city of Manokwari.

The Arfak Farmers Group succeeded in changing the cultivation system by opening small forest plots (Stachowicz et al., 2021). Diversion of cultivation affects economic efficiency in potato cultivation. Economic efficiency focuses on producing achievement targets with the lowest process costs (Su & Jiang, 2021; Szalka & Tamándl, 2019). Economic efficiency is the inverse of cost-efficiency (Kuzmenko et al., 2020). The knowledge of Arfak farmers about shifting cultivation system management is still low. Lack of knowledge impacts the economic efficiency of the Arfak community, especially potato farmers (Seal et al., 2017). Economic efficiency analysis needs to be considered to assist farmers in managing the economy in traditional cultivation (Pavlenko et al., 2018). Different methods of technology quality affect costs and then affect economic performance (Kowalski et al., 2020). Farmers must manage sustainably with a good shifting cultivation system.

2. Research Methods

The research method used is descriptive statistics. The study involved 51 potato farmers in Minyeimemut and Arion villages, sub-district, Hingk, Manokwari District, West Papua, Indonesia.

The analysis method is a quantitative descriptive analysis to explain the management of the farming system. Furthermore, economic efficiency (EE) is measured by deriving ***stochastic frontier*** costs using ***Frontier software 4.1***. Common functions of ***stochastic cost frontier*** are:

$$Ci = C\,(Yi,\ Wi) + (Vi - Ui)\ . \tag{1}$$

The ***stochastic frontier*** of the cost function for shifting cultivation system in this study can be formulated as follows:

$$ln\ Bprod\ LP/NP = \beta 0 + \beta 1\ lnProd + \beta 2\ lnHBbt + \beta 3 lnHTk + (vi\text{-}ui)\ , \tag{2}$$

where:
$BProdLP$ is Potatoes' total cost of production in shifting cultivation system (Rp/Season);
$BProdNP$ is Potatoes' total cost of production in settled agricultural system (Rp/Season);
$Prod$ is Amount of production or output of potatoes (Kg);
$HBbt$ is seed price (Rp);
HTk is Labor Cost (Rp/Season);
$\beta 0$ is Intercept;
$\beta 1$-$\beta 3$ is Coefficient;
vi - ui is Error term;

Economic Efficiency (EE) is the ratio between the minimum observed total production cost (C^*) and the total overall actual production cost (C), as in the following equation:

$$EE = \frac{C^*}{C} = \frac{E(C_i|u_i = O_i, Y_i, P_i)}{E(C_i|u_i, Y_i, P_i)} = E[u_i|\varepsilon]\ . \tag{3}$$

The value of economic efficiency ranges from 0 to 1. By using frontier 4.1 program application, it will be obtained cost efficiency value or Cost Efficiency (CE), which was originally calculated as an equation inverse;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|U_i X_i)}{E(Y_i|U_i=0, X_i)} = E[\exp(-U_i|\varepsilon) ,$$

hence, the economic efficiency (EE) of farming is the inverse of Cost Efficiency (CE) with the following formula:

$$EE = \frac{1}{CostEfficiency\,(CE)} \,. \qquad (4)$$

The criteria for determining the level of efficiency are:

- Very efficient: $EE \geqslant 0.90$;
- Quite efficient: $0.70 \leqslant EE < 0.90$;
- Not efficient: $EE < 0.70$.

3. Results and Discussion

3.1. Cultivation Characteristics

Farmer Arfak is working on potato cultivation with a semi-commercial pattern. Farmers use conventional methods in potato cultivation. Conventional farming produces higher yields and is easier than non-conventional methods (Heinrichs et al., 2021; Musyoka et al., 2017; Schrama et al., 2018). Farm the Arfak community, if the land area is limited, will be consumed by itself and will not be sold. This pattern of behavior is very common for farmers using conventional farming methods (Papadopoulos & Kalivas, 2021).

Potato is a commodity that has been planted for generations by the Arfak community in the Hingk sub-district. Potatoes are a staple food for the Arfak community in addition to tubers. Farmers in the Arfak community never use chemical fertilizers and herbicides in the process of plant growth (Anh et al., 2017). Instead, plant cultivation is influenced by the seeds used (Virmond et al., 2017). The cultivation results are organic vegetables that are good for the body compared to non-organic vegetables (Pacifico et al., 2017). Production costs in potato cultivation are very low because they do not use chemical fertilizers and herbicides. Low production costs result in higher economic profits (Seal et al., 2017).

Farmers provide potato seeds independently from previous harvests. To increase productivity, farmers need seeds of superior quality (Zhang et al., 2018). The local government has provided a tractor used as a land management tool, but Farmers Arfak has never used it for potato cultivation activities. Arfak farmers do not use tractors due to low knowledge, skills, or gaps in technology (Khanal et al., 2018; Ngango & Hong, 2021). Land located separately and topography difficult to access is another obstacle in transporting and using tractors (Sumadi et al., 2020).

In general, Arfak farmers manage farming with the shifting cultivation system collectively with the clan members. With an average number of family members of as many as four people, farmers can do land clearing activities until planting farmland areas (Golovin et al., 2021). Furthermore, the land area will be used to plant potatoes and other horticultural crops (Seheda et al., 2019). Therefore, the planting is adjusted with the contribution of each family member in land clearing activities.

3.2. Description of Farm System Management and Potato Farming Input

Potato's Production factors in shifting cultivation systems are still limited to the main production factors: land, seedlings, and labor. The description of the production factors and the output obtained can be seen in Table 1.

The average potato production in shifting cultivation system is 296.08 Kg/Season, with a standard deviation of 121.62 Kg/Season. The distribution of potato farmer production per season between farmers is quite large. Land productivity for potato plants is relatively low because farmers do not use production inputs. The growth of potato plants is only supported by soil fertility due to shifting cultivation systems. Farmers use agricultural land collectively, known as ulayat land, by some Arfak communities who have clans. According to the clan agreement, the

Table 1:
Statistics Description of Input and Variable for Management of Shifting Cultivation System in Hingk District

Variable	Data Statistics of Input and Variable			
	Average	St.Dev.	Min	Max
Production (Kg/Season)	296.08	121.62	80.00	550.00
Productivity (Kg/ha)	2.42	1.37	0.72	6.67
Land (ha)	0.15	0.07	0.02	0.30
Amount of seedlings (Kg)	44.41	15.89	20.00	80.00
Labor (WD)	33.08	10.27	18.18	68.27
Period (year)	4.33	1.11	3.00	7.00
Planting Period (time)	3.33	1.15	1.00	8.00
Age of farmer (year)	30.39	11.90	18.00	65.00
Experience (Years)	13.14	7.81	5.00	40.00
Family member of farmer (person)	3.86	1.37	2.00	7.00

Source: Compiled by the authors

head of the family in a clan group can use their ulayat land. The average land area for potato plants (0.15 ha) by households is relatively small based on the production land area. This is because farmers cultivate other crops such as sweet potatoes, carrots, and cabbage in the same land area.

The number of seeds used as planting material for one planting period on average was 44.41 kg. The average labor used for potato farming is 33.08 working days (WD) or 304.18 WD per hectare. Labor in cultivation comes from workers from family groups, both men and women. Most of the work in the production process is done by women, while men work to clear land and help with harvesting. The period of shifting cultivation system has a mean of 4.33 years. This system's limited land use period allows the soil to recover from planting (Teegalapalli et al., 2018; Wood et al., 2017). The time spent by the Arfak tribe is relatively lower than the shifting cultivation of the Dayak tribe, which ranges from 5 to 15 years. The short period of land rest may explain why land productivity for potato crops in the Hingk District is low. The short soil rest period results in a very short time to return to the fertile soil.

The average age of potato farmers in the Hingk Regency ranges from 30 to 39 years. The age of the farmer is in line with the experience of the farmer. Farming experience affects their ability to adapt to natural changes (Atube et al., 2021; Nel & Mabhena, 2021; Yan et al., 2021). Arfak Tribe Farming Experience is 13 to 14 years. The Arfak tribe has quite a lot of experienced farmers in potato cultivation. In addition to the experience of productive age, farmers are one of the determining factors in shifting cultivation (Suresh et al., 2021). The land management system is still practiced by local indigenous peoples (Baffour-Ata et al., 2021). In addition, the time used in the process is quite long, namely three months from land clearing to planting potatoes.

3.3. Economic Efficiency of Potato Farming

Economic efficiency is analyzed in terms of production inputs based on prices applicable at the farmer level. Cost efficiency analysis using stochastic frontier cost function model with frontier 4.1 program. The results of the estimation of the stochastic frontier cost function of potato farming in the migrated fields in Arfak Mountain District are presented in Table 2.

Table 2:
Estimated Model of Production Cost of Stochastic Frontier Potato Farm in shifting cultivation system in Hingk District

Variable	Parameter	Sign of Hope	Shifting Cultivation System	
			Coefficient	T-Ratio
Constant	α_0	+/-	1.0516	0.6134
Seed Price	α_1	+	0.1898**	2.1231
Labor Cost	α_2	+	0.8896***	5.4822
Potato Production	α_3	+	0.3579***	4.6846
Sigma-squared	σ^2		0.0574**	2.0533
Gamma	γ		0.6651*	1.8323

Notes:
***: Significant α = 1%; $t_{table\ 0,01;47}$ = 2.6845, $t_{table\ 0,01;49}$ = 2.6799;
** : Significant α = 5%; $t_{table\ 0,05;47}$ = 2.0117, $t_{table\ 0,05;49}$ = 2.0095;
*: Significant α = 10%; $t_{table\ 0,1;47}$ = 1.6779, $t_{table\ 0,1;49}$ = 1.6765.

Source: Compiled by the authors

The estimated results of the stochastic frontier cost model show that the coefficient sigma square ($\sigma 2$) of 0.0574 is significant at a 5% error rate. This means a 0.0574 or 0.06% variation of the cost of potato farming on the shifting cultivation contributed by the influence of cost inefficiency (UI) and external influence (VI). The gamma value ($\acute{\upsilon}$) of the cost of production is 0.6651 significantly at a 10% error rate, significant at a 5% error rate, meaning that 66.51% of errors in the cost of production due to cost inefficiencies and the remaining 33.49% due to external influences.

Table 2 shows that all independent variable coefficients (seed prices, labor wages, and production amounts) are positive. This means that all of these factors increase the total cost of production of ***catering paribus***. In the shifting cultivation system t-ratio, seed prices are statistically significant at 5%, while labor and production costs were high at 1%. Thus, the variable price of production inputs determines potato production in shifting cultivation systems (Das et al., 2021; Pichler et al., 2021). The effect of seed price on the increase in total cost is due to farmers not producing their seeds. Rather they buy the seeds from other farmers, either by bartering or replacing them with labor to other farmers who have seedlings. The more seedlings needed by farmers in the study area, the rarer the potato seedlings. Thus, the greater the production cost for the procurement of seeds can be obtained from other villages in Hingk District or surrounding districts.

Labor is important in traditional farming. Every activity in potato farming requires labor, both from within the family and from outside the family. It also requires labor costs that are the amount of the cost of farming activities related to the work done by the workforce. Production costs are greater for activities that require more work time (Komariah & Razzaq, 2020). The costs include costs for consumption and other costs such as cigarettes.

Potato production has a positive and significant effect at a 1% of error rate. The coefficient of production on shifting cultivation system is 0.3579, meaning that a 1% increase in farm potato production could cause production costs to increase by 0.36%. This suggests that increased production as a result of increased production factors caused the increase in production costs.

Economic efficiency is achieved if the marginal product value equals the production factor's price or the allocation of production factors has reached efficiently. The distribution of farmers based on the value of economic efficiency is presented in table 3. The table shows that the average economic efficiency (EE) in shifting cultivation system is 0.8548. This means that the economic efficiency of the farm is classified as fairly efficient criteria, which are achieved (70.59%) by most shifting cultivation system farmers. Determination of the product price does not depend on the number of production costs incurred. The price of production must be determined by the price of potatoes in the market. This happens even though there is no difference between the selling price of potatoes at the production site and in the market. The efficiency value of potato cultivation of the Arfak tribe can be seen in Table 3.

The ability of farmers to use production inputs at minimal cost is relatively good, meaning that potato farmers can use minimal production costs. The minimum cost can be achieved because potatoes are grown as a staple food (Seheda et al., 2019; Závadský & Hiadlovský, 2020). In addition to yams, production input costs can be reduced since farmers can obtain production factors such as seed and labor from the family in one clan. However, agricultural systems must be improved not to cause environmental damage (Morton et al., 2020; Thong et al., 2020).

Table 3:
Value of economic efficiency for shifting cultivation system in Hingk District

Efficiency Level	Economic Efficiency	
	Number of Farmers	Percent (%)
< 0.70	2	3.92
0.70≤ Eff<0,90	36	70.59
≥ 0.90	13	25.49
Total	51	100.00
Average	0.8548	
Deviation Standard.	0.0659	
Minimum	0.6652	
Maximum	0.9435	

Source: Compiled by the authors

4. Conclusions

The results showed that the average potato production was 296.08 Kg/Season. The average area of land cultivated by farmers is 0.15 Ha, the average use of seeds is 44.41 kg, and the average workforce is 33.08 WD. The cultivation activities of potato farmers show 4.33 years of shifting. Economic efficiency shows potato farming of 0.08548 which means it has a fairly economical category. b. Due to the mixed shifting cultivation system, farmers' land productivity is 2.42 Kg/ha in the very low category. Farmers with shifting cultivation systems are expected to add more agricultural land to increase production. The economic efficiency of potato farming is, on average 0.8548 quite efficient. b Farmers' productivity is low but relatively efficient for the economy. Farmers can continue the farming system and better management of the farming system so that there is no environmental damage

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