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Study of Productivity of Smallholder Oil Palm Plantations Based on Region in North Sumatera Province Indonesian

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Abstract
This study aims to determine the differences in productivity and factors influencing the productivity of smallholder oil palm plantations in North Sumatera based on regionalization. Sampling was conducted using a multi-stage approach in three districts known to have the largest area of smallholder oil palm plantations in North Sumatera, representing the West Coast, Highlands and West Coast regions. Each district is represented by one sub-district and two villages. Total of sample was 450 farmers from 75 samples representing each selected village. The analysis conducted involved the One Way ANOVA Test and the Tobit Regression Test. The results of the study indicate significant differences in the productivity of smallholder oil palm plantations in North Sumatera Province based on zoning, with productivity levels categorized as follows West Coast > East Coast > Highlands. Simultaneously, all socio-economic factors have a significant affect on the productivity of smallholder oil palm plantations. Factors that significantly affect the productivity of smallholder oil palm plantations are labor, fertilizer, gender, and type of seed that apply in all three regions. Factors of land area, farming experience, and access to credit apply in two regions (Highlands and West Coast). Farmer education factors apply only in one region (Highlands). Factors that do not affect the three regions are pesticides.

Keywords: Censored Tobit Regression; Productivity; Smallholder Oil Palm Plantations

Introduction

Palm oil is the most prominent plantations commodity and significantly contributes to Indonesian's economic activities. Palm oil commodities are capable of producing vegetable oil, which is in high demand within the industrial sector. Indonesian is the largest producer of palm oil in the world, with an area of palm oil land covering 16.38 million hectares and a production of 46.8 million tons of crude palm oil (CPO). The palm oil sector continues to be a cornerstone of the national trade balance performance. The contribution stands at 13.50% to non-oil and gas exports and 3.50% to Indonesian's total GDP (Kementerian Pertanian, 2022).

Indonesian's palm oil production comes from three business activities, namely large state-owned plantations, coorporate plantations and smallholder plantations. Data from the Direktorat Jenderal Perkebunan (2024) shows that in 2023, the area of oil palm plantations in Indonesian was 15,435,656 hectares consisting of 40.76% smallholder plantations, 3.53% state-owned plantations and 55.71% corporate plantations. In terms of land area, it is estimated that smallholder oil palm plantations will dominate oil palm plantations in Indonesian. Therefore, its existence is also expected to continue to increase its contribution to Indonesian's economic development.

Productivity is the main indicator of the performance of smallholder oil palm plantations because

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it describes the ability of farmers to manage production resources to produce output efficiently. A high level of productivity indicates better technical efficiency, increased farmer income, and successful farm management, so it can be used as a measure of the success and competitiveness of smallholder oil palm plantations. Until now, the performance of smallholder plantations measured by productivity is still below that of large plantations. The low productivity of plants is the main problem in smallholder oil palm plantations in Indonesian. This condition is the impact of the poor management practices applied by farmers. The low level of knowledge, technical, and cultural skills of farming and the limited capital capabilities of farmers cause low management practices. Until now, there is still a relatively high productivity gap between smallholder oil palm plantations and large plantations, namely between 41 - 64% of the national oil palm plantations productivity of around 7 - 20 tons of FFB / ha/year (Suharno et al. 2015).

Based on land area, in 2023, North Sumatera Province will be the third-largest region with oil palm plantations and the fifth-largest region with smallholder oil palm plantations in Indonesian. Smallholder oil plam plantations in North Sumatera Province are spread across 22 districts/cities. Rapid development can be seen in Highlands, which were previously dominated by East Coast and West Coast. In 2023, North Sumatera Province will have 488,414 hectares of smallholder oil palm plantation. To date, it is suspected that there are differences in the progress of smallholder oil palm plantation management based on zoning in North Sumatra Province. These differences in management progress will result in differences in the productivity of smallholder oil palm plantations. (Ditjenbun, 2024).

The fact that there are differences in the initial time of the management of oil palm plantations and differences in the growth environment of oil palm based on zoning in North Sumatera Province raises the suspicion that there are differences in the productivity of oil p Differences in the productivity of smallholder oil palm plantations in North Sumatra Province, based on the East Coast, Highlands, and West Coast zoning, can be explained by a combination of agroecological factors, land suitability, climate, infrastructure, and farmer socioeconomic characteristics. This research aims to examine the differences in productivity across smallholder oil palm plantations in North Sumatera Province, with an emphasis on zoning and the factors influencing their productivity. Throughout our investigation, we have found that research on the productivity of smallholder oil palm plantations has never been conducted, particularly in North Sumatera.

Literature Review

The selection of plant cultivars plays a crucial role in the success of cultivation, alongside the environmental and agroecological conditions present, as well as the management practices employed by farmer entrepreneurs (Sasongko, 2010) . Farming production factors are the main factors needed in farming and also become farm inputs. These farming production factors are combined to produce farm production or output through a production process (Arifin, 2015). The farming production process can only run well if the required production factors can be met. Agricultural production factors are classified into four elements: land, labour, capital, and skills or management (Daniel, 2002).

Oil palm plantation productivity is defined as the ability of a plantation to produce fresh fruit bunches (FFB) per hectare within a specific period, usually one year. Several sources explain the low productivity of smallholder oil palm plantations, including technical constraints faced by farmers and institutional issues, including poor seed quality and improper plant care (Ariyanto et al. 2017; Siswati et al. 2018). This condition results in an excessively long harvest cycle, hampering the potential for oil palm harvests. Another problem is suboptimal technology transfer, which contributes to low production and productivity levels in oil palm plantations. Furthermore, the diverse backgrounds of smallholder farmers result in cultural shocks and cultural gaps. Farmers lack adeptness in production technology, which in turn impacts the levels of oil palm production and productivity they achieve (Hidayat, 2017).

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Previous research by Sofyan et al. (2024) showed that differences in productivity are caused by land topography. Research on oil palm productivity by region shows significant variation across regions in Indonesia. Factors determining productivity include land conditions, rainfall, altitude, and the type of fertilizer used by farmers (Abrori, 2023; Hendi et al., 2024).

Research on factors influencing the productivity of farming businesses, including smallholder oil palm plantations, is minimal. The results of previous research Raharjo (2020) show that land area significantly negatively affects palm oil productivity in Indonesian. In the meantime, the findings from the research by Panjaitan et al. (2020) indicate that land area significantly enhances the productivity of independent oil palm farming in Sungai Buluh Village, Kuantan Singingi Hilir District, Kuantan Singingi Regency.

The land area positively influencing coffee farming productivity in Kenya (Wambua et al. 2021). In contrast, the findings of previous research Oluwatusin & Shittu (2014) indicated that land area did not have a significant affect on sweet potato productivity in Nigeria.

The findings of previous research Raharjo (2020) indicated that labor had a significant positive influencing on palm oil productivity in Indonesian. Labor did not significantly affect independent oil palm productivity in Lubuk Tajau Village, Nanga Taman District, Sekadau Regency (Hendi et al. 2024).

Fertilizers did not significantly affect independent oil palm productivity in Lubuk Tajau Village, Nanga Taman District, Sekadau Regency (Raharjo, 2020). In the meantime, the findings of previous research Monita & Zebua (2023) indicated that fertilizer significantly enhanced oil palm productivity at PT. Mustika Agung Sentosa.

The findings of previous research Panjaitan et al. (2020) indicated that pesticides did not have a significant affect on the productivity of independent oil palm farming in Sungai Buluh Village, Kuantan Singing Hilir District, Kuantan Singing Regency. The same thing is true for the result of previous research (Hendi et al. 2024; Raharjo, 2020; Panjaitan et al. 2020; Wambua et al. 2021; Oluwatusin & Shittu, 2014; Monita & Zebua, 2023). Pesticides significantly positively affected rice productivity in Srikaton Village, Buay Madang Timur District (Saputro & Fidayani, 2020).

Farmer gender did not significantly affect fish and rice farming productivity in Tasikmalaya City (Sujaya et al. 2018). The findings of previous research Wambua et al. (2021) showed that farmer gender had no significant affect on the productivity of coffee farming in Kenya.

The education of farmers does not have a substantial affect on the productivity of independent oil palm farming in Sungai Buluh Village, Kuantan Singing Hilir District, Kuantan Singing Regency (Hendi et al. 2024). The result of previous research Wambua et al. (2021) indicate that education does not have a significant impact on the productivity of coffee farming in Kenya. Education significantly positively affects the productivity of sweet potato farming in Nigeria (Oluwatusin & Shittu, 2014). The results of previous research Ali et al. (2020) showed that education has a significant positive affect on the productivity of wheat farming in Pakistan.

The experience in farming does not have a considerable affect on the productivity of independent oil palm farming in Sungai Buluh Village, Kuantan Singing Hilir District, Kuantan Singing Regency (Hendi et al. 2024). Farming experience significantly positively affects the productivity of sweet potato farming in Nigeria (Oluwatusin & Shittu, 2014). The results of previous research Ali et al. (2020) showed that farming experience has a significant positive affect on the productivity of wheat farming in Pakistan.

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According to the result of previous research Akbar et al. (2023) the use of certified seeds affects the productivity of lowland rice farming in Meureudu District, Pidie Jaya Regency.

Access to credit has a significant positive affect on farming productivity in Ghana (Akudugu, 2016). The results of previous research Abdani et al. (2024) showed that agricultural credit significantly positively affects the productivity of extensive chili farming in Bojonegoro Regency.

Research Method

The research area was determined purposively, namely North Sumatera Province. The population in this study consisted of households of smallholder oil palm plantation farmers in North Sumatera Province. The population in this study was 236,619 heads of families who worked as oil palm farmers (Direktorat Jenderal Perkebunan, 2024). The research sample was obtained through a multistage sampling method. A sampling method was executed in multiple stages. The initial phase was conducted with intention, resulting in the selection of three districts, each representing the East Coast, Highlands, and West Coast regions. The selected districts were Asahan Regency, Simalungun Regency, and Padang Lawas Regency, with the consideration that each district has the largest area of smallholder oil palm plantations for each region in North Sumatera Province. The second stage was conducted with intention by selecting one sub-district from each district. Consequently, Bandar Pulau Sub-district, Hatonduhan Sub-district, and Lubuk Barumun Sub-district were chosen, taking into account that these sub-districts possess the largest area of smallholder oil palm plantations within their respective districts.

The third stage was carried out purposively by selecting 2 villages in each selected sub-district, which are villages with the main smallholder oil palm plantation in each sub-district. The selected villages were Gonting Malaha Village and Padang Pulau Village for Bandar Pulau Sub-district, Buntu Turunan Village and Buntu Bayu Village for Hatonduhan Sub-district, and Aek Lancat Village and Pagaran Mompang Village for Lubuk Barumun Sub-district. The fourth stage was simple random sampling with a sample size of 75 farmers for each village, so the total research sample was 450 smallholder oil palm plantation farmers, as can be seen in the following Table 1. Simple random sampling was carried out, although it tends to produce bias due to the unavailability of secondary data that presents the number of farmers (sub-populations) in villages in each sub-district.

Table 1. Distribution of research samples

No.	Region/District Name	Subdistrict Name	Village Name	Samples
1.	East Coast/Asahan	Bandar Pulau	Gonting Malaha	75
			Padang Pulau	75
2.	Highlands/Simalungun	Hatonduhan	Buntu Turunan	75
			Buntu Bayu	75
3.	West Coast/Padang Lawas	Lubuk Barumun	Aek Lancat	75
			Pagaran Mompang	75
Total				**450**

Source: (BPS Provinsi Sumatera Utara, 2024; BPS Kabupaten Asahan, 2024; BPS Kabupaten Simalungun, 2024; BPS Kabupaten Padang Lawas, 2024; Pre-Survey Data, 2024).

To test the differences in productivity of smallholder oil palm plantations between the West Coast, Highlands, and West Coast regions, a One Way ANOVA Test was conducted by as follows:

H_0: $\mu_1 = \mu_2 = \mu_3$
H_1: At least one μ_i different

Where:

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μ_1 = Average productivity in the East Coast region

μ_2 = Average productivity in the Highlands region

μ_3 = Average productivity in the West Coast region

The differences between groups can be identified using the Fratio calculation as follows:

$$F_{ratio} = \frac{MSR}{MSE} \qquad (1)$$

Where:

MSR = mean square regression

MSE = mean square error

Using $\alpha = 0.05$, the hypothesis testing criteria are if the probability Frasio ≥ 0.05, then H_0 is accepted, and H_1 is rejected. If the probability Frasio < 0.05, then H_0 is rejected, and H_1 is accepted. If what happens is accepting H_1, it will be continued with the Bonferroni Test to see if there is a difference between each group (1 vs. 2, 1 vs. 3, and 2 vs. 3) by comparing the significance of the ratio with a value of $\alpha = 0.05/3 = 0.0167$. The testing criteria are if the probability ratio ≥ 0.0167, then H_0 is accepted, and H_1 is rejected (there is no difference between the two groups that are distinguished). If the probability ratio < 0.0167, then H_0 is rejected, and H_1 is accepted (there is a difference between the two groups that are distinguished).

To determine the factors influencing the productivity of oil palm plantations, a Tobit Regression Test was conducted. The Tobit Regression Test was conducted for the East Coast, Highlands, West Coast, and Pooled Sample. The reason for using the Tobit Regression Test is because some of the independent variables are discrete variables, making it impossible to use Ordinary Least Squares. The formula used is the formula according to Amemiya (1984) as follows:

$$\mathbf{Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \ldots + \ldots + b_9X_9 + e}$$

Where,

Y = Productivity of smallholder oil palm plantation (kg FFB/ha)

b_0 = Intercept

b_1-b_9 = Regression Coefficient

X_1 = Land area (ha)

X_2 = Labor (ME)

X_3 = Fertilizer (kg)

X_4 = Pesticide (liter)

X_5 = Farmer Gender (0 = Female; 1 = Male)

X_6 = Farmer Education (years)

X_7 = Farmer Farming Experience (years)

X_8 = Category of Seeds Used by Farmers (0 = not certified; 1 = certified)

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X_9 = Access to Credit Implemented by Farmers (0 = none; 1 = yes)

To determine the affect of the independent variable (X_i) partially on the dependent variable (Y), a Z Test is carried out with the following test criteria:

1. If the probability value Z ≥ 0.05, then the independent variable Xi partially has no significant effect on Y.
2. If the probability value Z <0.05, then the independent variable Xi partially has a significant effect on Y.

To determine the affect of the independent variable (X_i) simultaneously on the dependent variable (Y), a Likelihood Ratio Test or G Test is carried out with the following test criteria according to:

1. If the probability ratio likelihood value ≥ 0.05, all independent variables simultaneously have no significant affect on Y.
2. If the probability ratio likelihood value is <0.05, then all independent variables simultaneously significantly affect Y.

Results and Discussion

1. Descriptive statistics

The following will present descriptive statistics detailing the average productivity of smallholder oil palm plantations according to region, as well as research variables in the form of factors influencing the productivity of smallholder oil palm plantations in North Sumatra Province in 2023. The following descriptions provide relevant information.

a. Productivity Of Smallholder Oil Plam Plantation

Table 2 presents the productivity of smallholder oil palm plantations in North Sumatera Province over the course of one year of production.

Table 2. Productivity of smallholder oil palm plantations (kg FFB/ha)

No.	Region	Mean	Min.	Max.	S. Deviation
1.	East Coast	21.073,03	19.071,43	23.285,71	716,45
2.	Highlands	19.228,72	17.083,33	20.714,29	576,74
3.	West Coast	24.013,80	22.300,88	25.781,25	521,97
4.	Pooled Sample	21.438,51	17.083,33	25.781,25	2.064,64

Source: Processed Primary Data

b. Research Variables Affecting The Productivity Of Smallholder Oil Palm Plantations

This study examines the research variables influencing the productivity of plantations of oil palm. The dependent variable is the productivity of smallholder oil palm plantations, measured in kg FFB/ha. The independent variables include land area (X_1), labour (X_2), fertiliser (X_3), pesticide usage in litres (X_4), farmer gender (X_5), farmer education (X_6), farming experience (X_7), seed category used by farmers (X_8), and access to credit utilised by farmers (X_9). The details are presented in Table 3.

Table 3. Average Research Variables Of Factors Affecting The Productivity Of Smallholder Oil Palm Plantations

No.	Variable	East Coast Region	Highlands Region	West Coast Region	Pooled Sample
1.	Y	21,073.03	19,228.72	24,013.80	21,438.51

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2.	X_1	2.78	2.64	2.31	2.57
3.	X_2	117.15	96.98	78.69	97.61
4.	X_3	997.82	623.85	469.90	697.19
5.	X_4	14.19	12.75	10.48	12.47
6.	X_5	0.63	0.62	0.57	0.61
7.	X_6	12.21	12.45	12.59	12.42
8.	X_7	21.37	19.66	19.16	20.06
9.	X_8	0.62	0.55	0.61	0.59
10.	X_9	0.44	0.41	0.37	0.41

Source: Processed Primary Data

Based on Table 3, a simple explanation can be provided as follows:

1) The average productivity of smallholder oil palm plantations in North Sumatera is 21,438.51 kg of Fresh Fruit Bunches (FFB)/ha. There is a tend of productivity on the West Coast > East Coast> Highlands regions.

2) The average area of land cultivated by farmers is 2.57 ha. There is a tend of land cultivated by smaalholder farmers on East Coast> Highlands > West Coast regions.

3) The average labour by smaalholder farmers is 97.61 ME. There is a tend of labor on the East Coast > Highlands > West Coast regions.

4) The average fertilizer use by smaalholder farmers is 697.19 kg. There is tend of fertilizer use on the East Coast > Highlands > West Coast regions.

5) The average pesticide use by smallholder farmers is 12.47 liters. There is a tend of pesticide use on the West Coast > East Coast > Highlands regions.

6) The average smallholder farmer gender is 0.61, meaning that 61% of smallholder farmers are male and 39% are female. There is a tend af male farmers in the East Coast > Highlands > West Coast regions.

7) The average smallholder farmer education level is 12.42 years. There is atend that education level of smallholder farmers in the Psntsi Barat > Highlands > East Coast regions.

8) The average smallholder farmer farming experience is 20.06 years. This shows a tendency for farming experience in East Coast > Highlands > West Coast regions.

9) The average category of seeds used by smallholder farmers is 0.59, meaning that 59% of farmers use certified seeds and 41% of farmers use uncertified seeds. There is a tend for certified seed use in the West Coast > East Coast > Highlands regions.

10) The average access to credit used by smallholder farmers is 0.41, meaning that 41% of farmers have access credit and 59% of farmers do not access credit. There is a tend for access credit on the East Coast > Highlands > West Coast regions.

2. Differences In Productivity Of Smallholder Oil Palm Plantations In North Sumatera Province Based On Regions

The One-Way Anova Test was used to analyze differences in the productivity of smallholder oil palm plantations on the East Coast (group 1), Highlands (group 2), and West Coast (group 3) of North Sumatera Province. The results of the analysis are shown in Table 4.

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Table 4. Results Of One Way Anova Test Of Productivity Differences

Source	SS	Df	MS	F	Prob. F
Between groups	1,7473E+09	2	873664672	2343.56	0,000
Within groups	166638876	447	372793.91		
Total	1,9140E+09	449	426735.46		

Source: Processed Primary Data

Table 4 indicates that the Probability F is less than 0.05. In conclusion, H_0 is rejected and H_1 is accepted, indicating that the productivity of smallholder oil palm plantations in North Sumatera Province shows a significant difference at $\alpha = 0.05$. Additionally, the Bonferroni Test was conducted to assess any differences among the groups, with the results presented in Table 5.

Tabel 5. Results Of The Bonferroni Test For Productivity Differences Between Groups

Group	1	2
2	-1844.31	
Probability t	0,000	
3	2940.77	4785.08
Probability t	0,000	0,000

Source: Processed Primary Data

The data presented in the table indicates that for the three tests assessing productivity differences among the three groups (1 vs. 2, 1 vs. 3, and 2 vs. 3), the probability t is less than 0.000/3. This outcome leads to the rejection of H_0 and the acceptance of H_1. Thus, among all existing groups, there are significant differences in productivity. When connected with Table 1, it can be concluded that there are fundamental differences in the productivity of smallholder oil palm plantations based on regionalization, where the productivity of small-scale farmers plantations on the West Coast > East Coast > Highlands. When connected with BPS Data (2024), where the productivity of smallholder oil palm plantations in Asahan Regency in 2022 was 4,800 kg CPO/ha (equivalent to 24,000 kg fresh fruit bundles (FFB)/ha), Simalungun Regency was 4,482 kg CPO/ha (equivalent to 22,410 kg fresh fruit bundles FFB/ha). Padang Lawas Regency was 5,518 kg CPO/ha (equivalent to 27,590 kg fresh fruit bundles FFB/ha), and the data was based on the research results obtained. Research on the differences in productivity of smallholder oil palm plantations in North Sumatra Province, as far as we have searched, does not exist or cannot be found.

Factors Affecting The Productivity Of Smallholder Oil Palm Plantations

In this study, the productivity of smallholder oil palm plantations of oil affected by X_1 = land area, X_2 = labor, X_3 = fertilizer, X_4 = pesticides, X_5 = farmer gender, X_6 = farmer education, X_7 = farmer farming experience, X_8 = category of seeds used by farmers, X_9 = access to credit implemented by farmers. The findings of the Tobit Regression Test are presented in Table 6.

Table 6. Outcomes Of The Tobit Regression Analysis On Factors Influencing The Productivity Of Smallholder Oil Palm Plantations

No.	Variable	East Coast Region		Highlands Region		West Coast Region	
		Coeficient	Prob. Z	Coeficient	Prob. Z	Coeficient	Prob. Z
1	X_1	-455.572	0.397	-796.672	0.000*	-1,239.686	0.000*
2	X_2	22.649	0.000*	15.708	0.000*	29.709	0.000*
3	X_3	0.382	0.000*	0.381	0.000*	0.580	0.000*

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4	X_4	-119.232	0.244	5.338	0.867	1.493	0.961
5	X_5	-286.106	0.001*	-259.778	0.001*	-177.035	0.000*
6	X_6	-9.662	0.603	-31.816	0.015*	-1.095	0.903
7	X_7	8.618	0.239	21.794	0.003*	38.656	0.000*
8	X_8	308.647	0.000*	278.518	0.000*	101.820	0.015*
9	X_9	34.753	0.647	-126.167	0.023*	-146.695	0.000*
Prob. Likelihood		0.000*		0.000*		0.000*	

Source: Processed Primary Data

Note: * = significant at α = 0.05

Partial Influence of Factors Affecting the Productivity of Smallholder Oil Palm Plantations

Table 6 presents the findings from the Tobit Regression analysis regarding the factors affecting the productivity of smallholder oil palm plantations in North Sumatra Province. The subsequent interpretations may be provided.

1) Land area (X_1) negatively affects on the productivity of smallholder oil palm plantations. A significant effect occurs in Highlands and West Coast (where probability Z < 0.05). However, for East Coast, land area has no significant effect on the productivity of smallholder oil palm plantations (where probability Z > 0.05). In all three regions, there is an inverse relationship between the size of the land area managed by farmers and the productivity of smallholder oil palm plantations. This is due to the fact that as the area of land being cultivated increases, the ability of smallholder farmers to manage their farming business decreases, especially the availability of capital for fertilizer, so that productivity decreases. The results of the study in Highlands and West Coast are consistent with previous research findings in Indonesian Raharjo (2020), while for East Coast, it is consistent with previous research findings in Nigeria (Oluwatusin & Shittu, 2014).

2) Labor (X_2) positively affects on the productivity of smallholder oil palm plantations. A significant effect occurs for the entire region, namely East Coast, Highlands, and West Coast (where probability Z < 0.05). For all three regions, the more labor employed by farmers, the higher the productivity of smallholder oil palm plantations. This is possible because with the increasing use of labor, the management of smallholder farmers will also improve, so that farming productivity will increase. The results of the study are consistent with previous research findings in Indonesian (Raharjo, 2020).

3) Fertilizers used by farmers (X_3) positively affects on the productivity of smallholder oil palm plantations. A significant effect occurs for the entire region, namely East Coast, Highlands, and West Coast (where probability Z < 0.05). For all three regions, the more fertilizer used by farmers, the higher the productivity of smallholder oil palm plantations. This is possible because by increasing the use of fertilizer, the availability of nutrients for the growth of oil palm plants will be better so that farming productivity will also increase. The results of study are consistent with previous research findings at Mustika Agung Sentosa (Monita & Zebua, 2023).

4) Pesticides used by farmers (X_4) negatively affects on the productivity of smallholder oil palm plantations on East Coast but positively affect on Highlands and West Coast. An insignificant effect occurs for the entire region, namely East Coast, Highlands, and West Coast (where probability Z > 0.05). This shows that the use of pesticides does not affect the productivity of oil palm plants, because the pesticides used are for weed control which does not really interfere with the growth of plants which have quite wide canopies. However, for the East Coast there is a tendency for increased use of pesticides to tend to reduce productivity, while for the Highlands and West Coast, increased use

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of pesticides will increase the productivity of smallholder oil palm plantations. The results of this study are consistent with previous research findings at Desa Sungai Buluh Kecamatan Kuantan Singingihilir, Kabupatenkuantan Singingi Panjaitan et al. (2020), Desa Lubuk Tajau Kecamatan Nanga Taman Kabupaten Sekadau Hendi et al. (2024), and Mustika Agung Sentosa (Monita & Zebua, 2023).

5) Farmer gender (X_5) negatively affects to the productivity of smallholder oil palm plantations. A significant effect occurs for all regions, namely East Coast, Highlands, and West Coast (where probability $Z < 0.05$). Female farmers produce higher productivity of smallholder oil palm plantation compared to male farmers. This is possible because, in reality, female farmers are more focused on managing oil palm farming as the primary source of family income. Male farmers are often busy with non-farm work as a source of additional family income. Consequently, the productivity of farms managed by female farmers is higher than that male farmers. The results of previous studies that are based on the results of this study cannot be traced. The results of this study are not consistent with previous research findings in Kota Tasikmalaya Sujaya et al. (2018) and Kenya (Wambua et al. 2021).

6) Farmer education (X_6) negatively affects to the productivity of smallholder oil palm plantations. A significant effect occurs in Highlands (where probability $Z < 0.05$). However, for East Coast and West Coast, farmer education has no significant effect on the productivity of smallholder oil palm plantations (where probability $Z > 0.05$). This is possible because the farmers' education is formal and not directly related to oil palm farming management. Therefore, the education needed for oil palm farming management is not obtained through formal education but through training or field extension workers from relevant agencies. This results of study are consistent with previous research findings at Desa Lubuk Tajau Kecamatan Nanga Taman Kabupaten Sekadau Hendi et al. (2024) and Kenya (Wambua et al. 2021).

7) Farmer farming experience (X_7) positively affects on the productivity of smallholder oil palm plantations. A significant effect occurs in Highlands and West Coast (where probability $Z < 0.05$). However, for East Coast, farmer farming experience has no significant effect on the productivity of smallholder oil palm plantations (where probability $Z > 0.05$). This is because the more experience farmers have in managing oil palm plantations, the more capable they are of taking steps to increase production, such as through better plant care and harvesting. These efforts will increase crop productivity. The study results in Highlands and West Coast are consistent with previous research findings in Nigeria Oluwatusin dan Shittu (2014) and District Peshawar, Pakistan (Ali et al. 2020). The result of study on East Coast is consistent with previous research findings at Desa Lubuk Tajau Kecamatan Nanga Taman Kabupaten Sekadau (Hendi et al. 2024).

8) The category of seeds used by farmers (X_8) positively affects the productivity of smallholder oil palm plantations. A significant effect occurs for all regions, namely East Coast, Highlands, and West Coast (where probability $Z < 0.05$). For the three regions, smallholder oil palm plantations that use certified seeds have more productivity than farmers who use uncertified seeds. This situation confirms that using certified seeds results in higher yields, especially when combined with proper plant care. Using certified seeds will result in higher productivity compared to using uncertified seeds. This result of study are consistent with previous research findings at Kecamatan Meureudu, Kabupaten Pidie Jaya (Akbar et al. 2023).

9) Access to credit implemented by farmers (X_9) positively affects on the productivity of smallholder oil palm plantations on East Coast. However, it negatively affects to productivity smallholder oil palm plantations in Highlands and West Coast. A significant effect occurs in Highlands and West Coast (where probability $Z < 0.05$), but an insignificant effect occurs on East Coast (where

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probability Z > 0.05). This fact indicates that smallholder farmers who access credit have lower farm productivity (especially smallholder farmers in the Highlands and West Coast). The opposite is true for smallholder farmers on the East Coast. In-depth observations indicate that smallholder farmers who do not access credit have better farm capital than those who do. Smallholder farmers who do access credit often use the borrowed credit for other needs, thus not increasing oil palm farm productivity. The previous study findings that consintent with the results of this study cannot be traced. The results of this study not consisitent with previous research findings in Ghana Akudugu (2016) and Kabupaten Bojonegoro (Abdani et al. 2024).

Simultaneous Influence of Factors Affecting the Productivity Of Smallholder Oil Palm Plantations

Factors of land area, labor, fertilizer, pesticide, farmer gender, farmer education, farmer farming experience, category of seeds used by farmers, and access to credit implemented by farmers simultaneously have a significant affect on the productivity of smallholder oil palm plantations as indicated by the probability Likelihood value < 0.05. That applies to all areas in North Sumatra Province, including the East Coast, Highlands, and West Coast.

Conclusion

The study findings show significant variations in the productivity of smallholder oil palm plantations in North Sumatra, which are caused by zoning factors. The productivity of smallholder oil palm plantations in the Pantai Barat > Pantai Timur > Dataran Tinggi. Several factors that significantly affect the productivity of smallholder oil palm plantations in North Sumatra are labor, fertilizer, gender, and seed category. A factor that does not affect the productivity of smallholder oil palm plantations in North Sumatra is pesticide. Furthermore, factors that significantly or insignificantly affect the productivity of oil palm plantations for one or two regions are land area, education, farming experience, and access to credit. This research is expected to contribute to the literature on smallholder oil palm plantations in North Sumatra Province. Based on the research results obtained, the factors that can increase the productivity of smallholder oil palm plantations in North Sumatra Province are the use of fertilizer and seeds used by farmers. Therefore, government support is needed through the provision of sufficient fertilizer at affordable prices for farmers and providing counseling for farmers, especially on the use of certified seeds, proper plant care, and correct harvesting. Another area requiring government intervention is the development of farmer groups as a forum for farmers to learn and exchange experiences. A limitation of the study is the simple random sampling method, which ignored farmers' status, whether they were independent or assisted br large plantations. By considering farmers' status, it is hoped that a more representative sample will be selected.

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