The sustainable agricultural mechanization of rice farming and its impact on land productivity and profit in Lampung Tengah Regency

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Abstract. The mechanization of rice farming has been fast developing since implementing the special effort (Upsus) program in 2015. Through this program, many combine harvesters and four-wheel tractors had been distributed to the farmer groups. This study's objectives were to know the practice of sustainable agricultural mechanization, know its impact on land productivity and profit for rice farming, and know whether sustainable agricultural development in Lampung Tengah Regency. This study was conducted at three sub-districts, Central Lampung Regency, in August and September 2020. Respondents were 108 farmers with 359 observations since each respondent was interviewed for 3-4 previous planting seasons, and an observation was a rice farm in a planting season. To know the practice of the mechanization, the data were analyzed descriptively. To know its impact, the data were analyzed using two multiple regression analysis models, each of which the dependent variable is productivity and profit. The independent variables for these two models were the mechanization types, the treatment variables, and the planting seasons and location, which were the control variables. The results revealed that the 4-wheel tractors were more efficient than that of the 2-wheel tractors. Combining harvester (CH) was the most efficient in harvesting than that of manual cutting and thresher and full manual harvesting. The results revealed that statistically, with the level of significance (α) by 1%, the combined harvester's use increased the average productivity by 0.16 tonnes/ha or almost 3%, i.e., from 5.51 tonnes/ha to 5.67 tonnes/ha. They increased the average profit by IDR2.44 million/ha or 40%, i.e., from IDR6.10 million/ha to IDR8.54 million/ha. These findings revealed that the use of a tractor together with a combine harvester was sustainable agricultural development.

1. Introduction

Agricultural mechanization deals with all kinds of equipment, from the simplest to the sophisticated ones with machines and computers. Meanwhile, agricultural modernization needs to be carried out continuously in order to increase the productivity of resources in order to increase production which can ensure an increase in people's food needs. Agricultural modernization is closely related to mechanization. Consequently, mechanization on the one hand supports an increase in productivity of resources; on the other hand, it also conserves existing resources. In this regard, FAO calls it a sustainable agricultural mechanization [1].

As a staple food, rice plays a very strategic role in almost all aspects of Indonesian people's life. Until now, domestic rice production has not been able to meet all the needs of the community. The average rice import in the 2015-2019 was 1.03 million tonnes per year. [2] Various efforts have been

and are being made by the government to increase rice production. One of them is the mechanization of the rice farming. It has been fast developing since the implementation of the Special Effort Program (Upsus) in 2015. Through this program, many combine harvesters and 4-wheel tractors had been distributed to the farmer groups.

Manual rice harvesting requires the most labors. Apart from that, it took quite a long time. To overcome this problem is to use a combine harvester. With the use of CH, cutting, threshing, separating, cleaning and packing are carried out at the same time at rice harvest. Furthermore, the use of CH can minimize the loss of grain at harvest. Therefore, CH is expected to increase productivity. The question is whether CH can increase productivity as well as profit.

The combine harvester is heavy enough that its use can cause the soil to become hard. The next consequence is that the tillage for the next planting season is heavier. In this case, the use of 4-wheel tractor is likely to be more effective than the use of 2-wheel tractor. The question is whether the use of a four-wheeled tractor together with the use of a combine harvester is sustainable. Based on those problems, the objectives of this study are to know the practice of the mechanization, to know its impact on land productivity and profit for rice farming, and to know whether it is a sustainable agricultural development in Lampung Tengah Regency.

2. Methodology

This study was conducted in three sub-districts, Central Lampung Regency. Respondents were 108 farmers who were randomly selected in chosen villages. Each respondent was interviewed for 4 planting seasons, namely MK 2020, MH 2019/2020, MK 2019 and MH 2018/2019. The total samples were 359 observations. According to Cohen *et al.*, the minimum sample size is 30 observations. [3]

To know the practice of the mechanization, the data were analyzed descriptively. To know its impact, the data were analyzed using two multiple regression analysis models, each of which the dependent variable is productivity and profit. The independent variables for these two models were the mechanization types which were the treatment variables, and the planting seasons and location which were the control variables. The two analysis models are as follows:

$$Y_{1i} = \hat{a}_0 + \hat{a}_1 D_{1i} + \hat{a}_2 D_{2i} + \hat{a}_3 D_{3i} + \hat{a}_4 D_{4i} + \hat{a}_5 D_{5i} + \hat{a}_6 D_{6i} + \hat{a}_7 D_{7i} + e_{1i} \quad (1)$$

$$Y_{2i} = \hat{b}_0 + \hat{b}_1 D_{1i} + \hat{b}_2 D_{2i} + \hat{b}_3 D_{3i} + \hat{b}_4 D_{4i} + \hat{b}_5 D_{5i} + \hat{b}_6 D_{6i} + \hat{b}_7 D_{7i} + e_{2i} \quad (2)$$

Where:
Y_1: Productivity (tonnes/ha)
Y_2: Profit (IDR million/ha)
$\hat{a}$, $\hat{b}$: Estimators for the coefficients
D_1, D_2, and D_3: Type of mechanization (treatment variables)
D_1=1; D_2=0; D_3=0: 4-wheel-tractor + 2-wheel-tractor + combine harvester
D_1=0; D_2=1; D_3=0: 2-wheel-tractor + 2-wheel-tractor + combine harvester
D_1=0; D_2=0; D_3=1: 2-wheel-tractor + 2-wheel-tractor + manual cutting & thresher
D_1=0; D_2=0; D_3=0: 2-wheel-tractor + 2-wheel-tractor + all manual in harvesting
D_4, D_5 and D_6: Planting season (control variables)
D_4=1; D_5=0; D_6=0: MK2020
D_4=0; D_5=1; D_6=0: MH2019/2020
D_4=0; D_5=0; D_6=1: MK2019
D_4=0; D_5=0; D_6=0: MH 2018/2019
D_7: Location (control variables)
D_7=1: Trimurjo
D_7=0: The others, i.e. Punggur and Seputih Raman
e_1, e_2: Error terms
i: Observations, 1,2,…, 359

3. Result and Discussion

3.1. Result

The results of the practice for the sustainable agricultural mechanization can be seen in Table 1. This table shows that there are two types of tillage machinery. The first type is that both ploughing and harrowing use 2-wheel tractors, while the second one is that ploughing use a 4-wheel tractor and harrowing use a 2-wheel tractor. The second type is faster and more efficient in terms of man-days and cost than that of the first type. In other word, the 4-wheel tractor is faster and more efficient than that of the 2-wheel tractor.

Table 1. The average/interval for length, labors, man-days and cost per hectare of mechanization

Mechanization	Length		Number of labors	Man-days equivalent	Cost (IDR mill.)
	days	hours/day			
Tillage (plough & harrow) machinery:					
• 2-wheel tractor & 2-wheel tractor	3-4	21	1-2	19	1.27
• 4-wheel tractor & 2-wheel tractor	2-3	17	1-2	16	1.18
Harvesting:					
• All manual	1-2	10-15	25-35	52	3.25
• Manual cutting & Thresher	1	8-12	20-25	42	3.05
• Combine harvester (CH)	1	6	4-6	31	2.14

Table 1 reveals that there are three ways of harvesting rice, i.e. all manual; manual cutting and thresher; and combine harvester (CH). The use of combine harvester is the fastest and the most efficient for harvesting rice.

The results of the estimation model to test the effect of the sustainable agricultural mechanization on productivity can be seen in Table 2. This table shows that there are two estimation models. Model 1 is a preliminary estimate that fits the methodology. Model 1 reveals that all three dummy variables D_1, D_2 and D_3 for distinguishing four types of mechanization are not statistically significant. The four types of mechanization are the following:

1) D_1=1; D_2=0; D_3=0: 4-wheel-tractor + 2-wheel-tractor + combine harvester
2) D_1=0; D_2=1; D_3=0: 2-wheel-tractor + 2-wheel-tractor + combine harvester
3) D_1=0; D_2=0; D_3=1: 2-wheel-tractor + 2-wheel-tractor + manual cutting & thresher
4) D_1=0; D_2=0; D_3=0: 2-wheel-tractor + 2-wheel-tractor + all manual in harvesting

This result indicates that there is no difference in land productivity between 4-wheel tractor and 2-wheel tractor. Therefore, these four types of mechanization are regrouped into two types by creating a new dummy variable, namely D_8, D_8=1 for using combine harvester (CH) and D_8=0 for non-CH or not using combine harvester. The estimation results are shown by Model 2. In this model, the type mechanization variable (D_8) has a statistically significant effect on productivity. Model 2, therefore, is used for further analysis.

Model 2 (Table 2) shows that R^2 is 0.3427, meaning that 34.27% of the rice productivity can be explained by the use of combine harvester, planting season (MT) and location, while the rest, which is 65.73%, is explained by other variables that are not included into the model. The F-test shows that simultaneously the use of combine harvester; planting season and location have a significant effect (1% significance level) on the rice productivity.

Model 2 in Table 2 shows that statistically with a significant level of 1%, the use of combine harvester on average increases the rice productivity by 0.16 tonnes/ha. Furthermore, by substituting the values of the independent variables in Model 2, the average productivity in each group can be calculated. The results of this calculation can be seen in Table 3. This table shows that the rice productivity increases after using combine harvester, from 5.50 tonnes/ha to 5.67 tonnes/ha, or increase by 0.16 tonnes/ha or almost 3% increase.

Table 2. The impact of the sustainable mechanization on the rice productivity (tonnes/ha)

Independent variables and Description	Model 1			Model 2		
	Coefficients	P-value		Coefficients	P-value	
Intercept	5.74	6.92E-145	*	5.69	1.35E-238	*
Treatment variables:						
D1: Mechanization	0.02	8.80E-01		-	-	
D2: Mechanization	0.18	1.71E-01		-	-	
D3: Mechanization	-0.07	6.04E-01		-	-	
D8:Mechanization-CH	-	-		0.16	6.61E-03	*
Control variables:						
D4: Planting Season	-0.54	6.46E-08	*	-0.57	9.01E-09	*
D5: Planting Season	0.24	8.95E-04	*	0.23	1.01E-03	*
D6: Planting Season	-0.60	4.38E-16	*	-0.60	5.12E-16	*
D7: Location	0.11	5.15E-02	*	0.11	5.42E-02	*
R2	0.3533			0.3427		
Adj. R2	0.3404			0.3333		
Ftest	27.3931	5.76E-30	*	36.8023	2.51E-30	*
Observations	359			359		

Where:
* Significant: P-value < 5%
D8=1: CH dan D8=0: Non-CH

Table 3. The average land productivity of rice (tonnes/ha)

Location	Planting Season	CH	Non-CH	Average
Trimurjo	MK2020	5.39	5.23	5.31
	MH2019/2020	6.19	6.03	6.11
	MK2019	5.36	5.20	5.28
	MH2018/2019	5.96	5.80	5.88
	Average	5.72	5.56	5.64
Lainnya	MK2020	5.28	5.12	5.20
	MH2019/2020	6.08	5.92	6.00
	MK2019	5.25	5.09	5.17
	MH2018/2019	5.85	5.69	5.77
	Average	5.61	5.46	5.54
Average		5.67	5.51	5.60

The results of the estimation model to test the effect of the sustainable agricultural mechanization on profit can be seen in Table 4. This table shows that there are two estimation models. Model 1 is a preliminary estimate that fits the methodology. This result for Model 1 in Table 4 is similar with the result for Model 1 in Table 2, i.e. the three dummy treatment variables for four types of mechanization are not statistically significant. Therefore, these four types of mechanization are regrouped into two types by creating a new dummy variable, namely D_8, D_8=1 for using combine harvester (CH) and D_8=0 for non-CH or not using combine harvester. The estimation results are shown by Model 2. In this

model, the type mechanization variable (D_8) has a statistically significant effect on profit. Therefore, Model 2 is used for further analysis.

Table 4. The impact of the sustainable mechanization on the profit of rice farming (IDR million/ha)

Indipendent variables and Description	Model 1			Model 2		
	Coefficients	P-value		Coefficients	P-value	
Intercept	5.57	2.68E-13	*	6.59	5.00E-51	*
Treatment variables:						
D1: Mechanization	3.61	8.92E-07	*	-	-	
D2: Mechanization	3.31	5.59E-06	*	-	-	
D3: Mechanization	1.21	1.00E-01		-	-	
D8:Mechanization-CH	-	-		2.44	6.18E-13	*
Control variables:						
D4: Planting Season	-1.66	2.45E-03	*	-1.56	4.01E-03	*
D5: Planting Season	1.00	1.16E-02	*	1.00	1.17E-02	*
D6: Planting Season	-3.42	1.42E-16	*	-3.41	1.65E-16	*
D7: Location	1.08	9.98E-04	*	1.00	1.94E-03	*
R2	0.3738			0.3678		
Adj. R2	0.3614			0.3588		
Ftest	29.9381	2.29E-32	*	41.0734	2.86E-33	*
Observations	359			359		

Where:
* Significant: P-value < 5%
D8=1: CH dan D8=0: Non-CH

Model 2 (Table 4) reveals that R^2 is 0.3678, meaning that 36.78% of the profit of rice farming can be explained by the use of combine harvester, planting season (MT) and location, while the rest, which is 63.22%, is explained by other variables that are not included into the model. The F-test shows that simultaneously the use of combine harvester, planting season and location have a significant effect (1% significance level) on the profit.

Model 2 in Table 4 reveals that statistically with a significant level of 1%, the use of combine harvester on average increases the profit by IDR2.44 million/ha. Furthermore, by substituting the values of the independent variables in Model 2, the average profit in each group can be calculated. The results of this calculation can be seen in Table 5. This table shows that the profit of rice farming increases after using combine harvester, from IDR6.10 million/ha to IDR8.54 million/ha, or increase by IDR2.44 million/ha or 40% increase.

This study reveals that the use of tractor and combine harvester for a rice farm increases the land productivity without ruining the rice field. In addition, it creates more profit. Therefore, it implies that the mechanization by using tractor and combine harvester is a sustainable agricultural development.

Table 5. The average profit of rice farming (IDR million/ha)

Location	Planting Season	CH	Non-CH	Average
Trimurjo	MK2020	8.47	6.03	7.25
	MH2019/2020	11.03	8.59	9.81
	MK2019	6.62	4.18	5.40
	MH2018/2019	10.03	7.59	8.81

	Average	9.04	6.60	7.82
The others	MK2020	7.47	5.03	6.25
	MH2019/2020	10.03	7.60	8.81
	MK2019	5.62	3.18	4.40
	MH2018/2019	9.03	6.59	7.81
	Average	8.04	5.60	6.82
Average		8.54	6.10	7.32

3.2. Discussion

The result of this study indicates that the rice productivity increases with the use of combine harvester (Table 2). This finding is in line with the results of previous studies. [4]–[6] This increase in the rice productivity is due to the reduction in grain loss. [7]–[11] This is because the CH is equipped with cutting tools, thresher and winches. In addition, at harvest time, CH operators also carry out packing activities.

This study indicates that the profits of rice farming using combine harvester have increased (Table 5). This finding is in line with the results of the previous studies. [12][13] In addition to increasing productivity and lowering cost, the use of combine harvester increases the price of grain because it is cleaner. Therefore, the benefits of rice farming using combine harvester can increase profit.

The results of this study conclude that the mechanization in a rice farm is a sustainable agricultural development since it preserves the land, increases the land productivity and the profit. According to FAO, sustainable agriculture must preserve the natural resources such as land and water, while ensuring food security and profitability. [14]

4. Conclusion

The results revealed that the 4-wheel tractors were more efficient than that of the 2-wheel tractors. The use of combine harvester was the most efficient in harvesting than that of manual cutting and thresher as well as full manual harvesting. There was no difference in land productivity between a 4-wheel tractor and a 2-wheel tractor. The results revealed that statistically, with the level of significance (α) by 1%, the combine harvester's use increased the average productivity by 0.16 tonnes/ha (almost 3%), i.e., from 5.51 tonnes/ha to 5.67 tonnes/ha. They increased the average profit by IDR2.44 million/ha (40%), i.e., from IDR6.10 million/ha to IDR8.54 million/ha. These findings revealed that the use of tractor together with combine harvester in rice farming was a sustainable agricultural development.

References

[1] FAO, 2020, Sustainable Agricultural Mechanization. [Online]. Available: http://www.fao.org/sustainable-agricultural-mechanization/overview/what-is-sustainable-mechanization/en/. [Accessed: 18-Sep-2020].
[2] Statistics Indonesia, 2020, Imports of Rice by Major Countries of Origin, 2000-2019. [Online]. Available: https://www.bps.go.id/statictable/2014/09/08/1043/impor-beras-menurut-negara-asal-utama-2000-2019.html. [Accessed: 12-Aug-2020].
[3] Cohen L Manion L and Morrison K, 2007 *Reseacrh Methods in Education* 6th ed. New York: Routledge.
[4] Amrullah E R and Pullaila A, 2020 Dampak Penggunaan Combine Harvester terhadap Kehilangan Hasil Panen Padi di Provinsi Banten *J. Agro Ekon.* **37**, 2 p. 113.
[5] Murtadha Ismayani and Safrida, 2019 Analisis Produksi dan Pendapatan Sebelum dan Sesudah Penggunaan Combine Harvester di Kabupaten Pidie Jaya *J. AGRIFO* **4**, 1 p. 33–40.
[6] Rusida, 2019 Dampak Penggunaan Teknologi Combine Harvester terhadap Perubahan Sosial Ekonomi Petani Padi Desa Padang Kalua Kecamatan Lamasi Kabupaten Luwu *J. Ecosyst.* **19**, April p. 109–116.
[7] Hasan M K Ali M R Saha C K Alam M M and Haque M E, 2019 Combine Harvester: Impact on paddy production in Bangladesh *J. Bangladesh Agric. Univ.* **17**, 4 p. 583–591.

[8] Hasan M K Ali M R Saha C K and Alam M M, 2020 Sustainable paddy harvesting solution for the southern delta of Bangladesh in *ASABE 2020 Annual International Meeting* 2000785 p. 1–9.
[9] Iqbal Supratomo and Azis A, 2020 Combine rice harvester performance test in Takalar Regency in *IOP Conference Series: Earth and Environmental Science* **486**, 1.
[10] Mokhtor S A Pebrian D El and Johari N A A, 2020 Actual field speed of rice combine harvester and its influence on grain loss in Malaysian paddy field *J. Saudi Soc. Agric. Sci.* **19**, 6 p. 422–425.
[11] Rusdin Witjaksono J Indrasti R and Rawung J B M, 2020 Study of harvesting losses for sustainable agricultural production in Southeast Sulawesi (a case study in Konawe district) Study of harvesting losses for sustainable agricultural production in Southeast Sulawesi (a case study in Konawe district) in *International Conference: Improving Tropical Animal Production for Food Security*.
[12] Abubakar A A and Rafsanjani A, 2018 Analisis Perbandingan Pendapatan Petani Padi Sawah Menggunakan Mesin Combinehervester dengan Cara Tradisional di Gampong Blang Meurah Dua Pidie Jaya *J. Agroristek* **1**, 2 p. 53–57.
[13] Muharram and Masbar R, 2018 Dampak Penggunaan Mesin Panen Padi (Combine Harvester) terhadap Pendapatan Petani di Kecamatan Glumpang Tiga Kabupaten Pidie *J. Ilm. Mhs.* **3**, 3 p. 350–358.
[14] FAO, 2020, Sustainable agriculture. [Online]. Available: http://www.fao.org/sustainable-development-goals/overview/fao-and-the-post-2015-development-agenda/sustainable-agriculture/en/. [Accessed: 12-Sep-2020].