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THE EFFECT OF FERTILIZER AND AGRICULTURAL MACHINERY SUBSIDIES ON PADDY PRODUCTIVITY: A FEASIBLE GENERALIZED LEAST SQUARES APPROACH

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Abstrak: *Padi merupakan komoditas yang banyak dibudidayakan oleh petani di Indonesia. Petani padi saat ini menghadapi ancaman penurunan produktivitas usahatani akibat aktivitas konversi lahan, akses input yang sulit dijangkau, dan perubahan iklim. Namun, produktivitas dapat ditingkatkan melalui penggunaan input pupuk dan mesin pertanian. Dukungan pemerintah untuk petani padi diberikan melalui subsidi input dan mesin pertanian. Oleh karena itu, penelitian ini mengeksplorasi pengaruh subsidi input dan mesin pertanian terhadap produktivitas padi. Kami memilih 20 provinsi dengan proporsi lahan sawah tertinggi terhadap total luas. Analisis Feasible Generalized Least Squares (FGLS) digunakan untuk mengetahui pengaruh subsidi pupuk dan mesin pertanian terhadap produktivitas padi di Indonesia. Hasil penelitian menunjukkan bahwa subsidi input lebih banyak dialokasikan di pulau Jawa, Sumatera, dan Sulawesi, sedangkan mesin pertanian lebih banyak dialokasikan di pulau Sulawesi dan Nusa Tenggara. Analisis FGLS menunjukkan bahwa luas lahan irigasi, subsidi pupuk urea, subsidi pupuk NPK, subsidi pupuk ZA, dan hibah traktor roda 2 berpengaruh terhadap peningkatan produktivitas padi. Sedangkan pengaruh kenaikan suhu menyebabkan penurunan produktivitas padi.*

Kata kunci*: feasible generalized least squares; produktivitas padi; subsidi mesin pertanian; subsidi pupuk*

Abstract: Paddy is a commodity that is widely cultivated by farmers in Indonesia. Paddy farmers are currently facing the threat of declining farm productivity due to land conversion activities, access to inputs that are difficult to reach, and climate change. However, productivity can be increased through the use of fertilizer inputs and agricultural machinery. Government support for paddy farmers is provided through input subsidies and agricultural machinery. Therefore, this study explores the effect of input subsidies and agricultural machinery on paddy productivity. We selected 20 provinces with the highest proportion of paddy fields to the total area. Feasible Generalized Least Squares (FGLS) analysis is used to determine the effect of subsidies on fertilizers and agricultural machinery on paddy productivity in Indonesia. The results showed that input subsidies were mostly allocated to Java, Sumatra, and Sulawesi islands, while agricultural machinery was allocated more to Sulawesi and Nusa Tenggara islands. FGLS analysis shows that the area of irrigated land, subsidies for urea fertilizer, subsidies for NPK fertilizers, subsidies for ZA fertilizers, and grants for 2-wheel tractors affect increasing paddy productivity. Meanwhile, the effect of increasing temperature causes a decrease in paddy productivity.

Keywords : agricultural machinery subsidies, feasible generalized least squares, fertilizer subsidies, paddy productivity

INTRODUCTION

The agricultural sector is the main source of livelihood for 90% of the population in developing countries. Its role is very crucial as a source of income, providing employment, providing food for the community, and raw materials for industry (De Marinis and Sali, 2020). Paddy fields are still the main focus of the economy of most small farmers in Indonesia with their role as a source of income as well as the main source of food for the Indonesian people (Warr and Yusuf, 2014). Although it has great potential to cultivate other agricultural commodities, the fact is that paddy remains the main choice for cultivation. This can be seen from the behaviour of farmers who allocate all their land resources to plant paddy when entering the paddy planting season (Agussabti et al., 2020). This is different from what farmers in Nepal do, where they use their land by doing crop rotation. Not only to adapt to climate change but also as a strategy to increase farm income (Chalise and Naranpanawa, 2016).

The availability of domestic paddy is very influential on economic, social, and political stability, which requires price stability and supply is available at any time and is evenly distributed (Anggraeni et al., 2017). This is reinforced by the results of research by Hafizah et al. (2020) which states that households in Indonesia still make rice as a priority food compared to other commodities so that it is very influential on the high value of income elasticity of rice commodities. Intensification of the agricultural sector is a strategy that needs to be realized to maintain the existence of diminishing agricultural land and ensure food security, especially in developing countries that require a larger scale approach (Wang et al., 2021). The threat of productive agricultural land conversion is also currently an important issue, where there are many activities of changing the function of people's agricultural land for the needs of corporations or large companies with the support of the local government. The provision of incentives or compensation to farmers is not following the actual value of the land owned so that many farmers are disadvantaged in this situation (Daulay et al., 2016).

The main determinants of the productivity level of paddy cultivation are strongly influenced by the availability of quality inputs from agricultural products and superior agricultural technology. The availability of all these inputs can trigger the achievement of increased productivity and food security. However, what often becomes a problem is that access to quality inputs is difficult for farmers to achieve, both because they are relatively expensive and their availability is limited (Hemming et al., 2018). The results of a study in Sri Lanka show that input subsidies such as fertilizers can maintain and increase paddy productivity which is further strengthened by the existence of intensive assistance to farmers or workers in their application methods (Ranathi8laka and Arachchi, 2019).

The latest data obtained from the Indonesian Central Statistics Agency shows that the national paddy harvested area reached more than 11 million hectares in 2018 and decreased to 10 million hectares in 2019 (BPS, 2020). Of course, these advantages are very potential if the right approach strategy is carried out in their development. But on the other hand, it becomes a challenge in terms of meeting the input needs to boost national paddy productivity, one of which is to reduce rice imports. The high volume of rice imports indicates a weak agricultural system and domestic food security (Frimawaty et al., 2013).

Data from the Indonesian Ministry of Agriculture shows that in the last five years the rate of rice consumption per capita of the Indonesian population has decreased. At least in the last five years since 2016 which reached 100.57 kg/capita/year then it gradually decreased to 97.64 kg/capita/year in 2017 and the latest data in 2020 showed that the consumption of rice per capita of the Indonesian population fell at 94,02 kg/capita/year (Pusdatin-Kementan, 2020). Nevertheless, Indonesia has continued to import rice in the last five years. Indonesia's rice imports since 2015 have continued to fluctuate and tend to rise. The highest import figure was recorded in 2018 which reached 2.25 million tons with the main exporting countries being Thailand and Vietnam (BPS, 2020).

Adeniyi and Dinbabo (2020) stated that increasing productivity can be achieved by implementing efficiency. The main principle of efficiency is the use of limited resources to achieve productivity without having to exploit new resources and a minimal touch of technology, which is the end goal with increasing productivity will have an impact on the availability of sufficient food for all levels of society. In its development, the Indonesian government continues to strive to boost domestic paddy productivity with various aid and subsidy programs. Several factors that greatly determine the level of efficiency and success of paddy production in Indonesia are the use of certified seeds, methods of controlling pests and diseases in paddy plants, farmer education in the form of assistance, and irrigation or irrigation (Haryanto et al., 2015). Koirala et al. (2016) concluded that land ownership has a significant effect on the level of efficiency. This statement is further strengthened by Hakim et al. (2021) which state that government assistance in the form of making irrigation channels and extension programs has a significant influence or impact on the level of efficiency of paddy farming.

No less important thing that needs to be watched out for from agricultural production is the impact on the environment by global warming through greenhouse gas emissions. Referring to the research of Laborde et al. (2021) which states that government subsidies to the agricultural sector contribute to an increase in greenhouse gas emissions which is one of the causes of climate change. China is one of the countries that have adequate irrigation channels to maintain their paddy productivity. However, they cannot avoid the threat of climate change which at any time can affect the availability of water for their irrigation sources, so they shift the planting season as one of the adopted strategies to deal with climate change (Ding et al., 2020). The result of the study of Sinnarong et al. (2019) using FGLS estimates found that climate change which includes temperature and rainfall affects the level of paddy production in Thailand. Likewise, Guntukula and Goyari (2020) found that the weather greatly affects maize farming in India, thus demanding an adaptation pattern as an alternative solution.

Matchaya (2020) in his research stated that the strengthening of the agricultural sector cannot only focus on spending in the agricultural sector but must be supported by the allocation of intra-sectoral increases by targeting the creation of sectoral growth, for example in research and development, infrastructure, and extension. The Indonesian government has only been seen to focus on strengthening the on-farm sector with various input subsidy programs for paddy farming. The most common government assistance is subsidies for fertilizers, seeds, and agricultural machinery. There have been many studies examining the impact of input subsidies from the government, especially fertilizers, on paddy productivity. However, in this study, we tried to include more complex factors by including climate as one of the variables. This study aims to evaluate how effective the effect of government assistance in the form of input subsidies and agricultural machinery is to increase paddy productivity nationally, followed by climate influences. This study tries to elaborate on data from 20 provinces in Indonesia to further strengthen the results of the study and can produce comprehensive policy implications in the future.

METHODS

This research was conducted on 20 provinces with the largest proportion of paddy fields to the total area. All data used is secondary data obtained from the website of Indonesian government agencies. Data on the proportion of paddy fields to the total area are not available directly, so we calculate the value of the proportion of each province ourselves. We use data on paddy fields obtained from the Center for Agricultural Data and Information Systems-Ministry of Agriculture (Pusat Data dan Sistem Informasi Pertanian-Kementerian Pertanian), then calculate the average value of paddy fields from 2006-2018. We use data on the area of the province in 2018 obtained from the Central Statistics Agency (Badan Pusat Statistika-BPS). Based on the calculations, obtained 20 provinces with the widest proportion, namely (1) Central Java, (2) West Java, (3) East Java, (4) Banten, (5) DI Yogyakarta, (6) Bali, (7) West Nusa Tenggara, (8) South Sulawesi, (9) South Kalimantan, (10) Lampung, (11) South Sumatra, (12) North Sumatra, (13) West Sumatra, (14) Aceh, (15) Bengkulu, (16) Sulawesi North, (17) West Sulawesi, (18) East Nusa Tenggara, (19) Gorontalo, and (20) Southeast Sulawesi (Figure 1).

We use data for 2009-2018 from the Central Statistics Agency which consists of paddy productivity, paddy harvested area, and the number of workers in the agricultural sector. We obtained data on fertilizer subsidies and agricultural machinery grants from the Directorate General of Agricultural Infrastructure and Facilities-Ministry of Agriculture (*Direktorat Jenderal Prasarana dan Sarana Pertanian-Kementerian Pertanian*). Finally, we get temperature and rainfall from the Central Bureau of Statistics and Bureau of Meteorology, Climatology and Geophysics (*Pusat Data dan Sistem Informasi Pertanian-Kementerian Pertanian*). Finally, we get air temperature and rainfall from the Meteorology, Climatology, and Geophysics Agency (*Pusat Data dan Sistem Informasi Pertanian-Kementerian Pertanian*). The descriptive statistics in Table 1 are structured to provide basic information regarding the variables used, including information on variable definitions, units, mean values, and standard deviations.

We analyzed fertilizer and agricultural machinery subsidies data to see allocations by island. Provinces are grouped by the island so

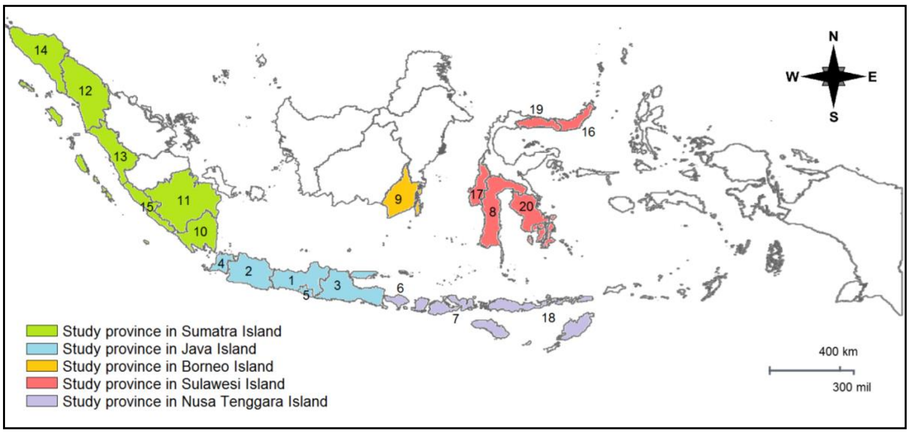

Figure 1. Study province

Table 1. Descriptive statistics of the data used

Variables	Definition	Unit	Mean	Std. Dev.
Prodvt	Paddy productivity	qt/ha	49,70	6,83
Harv	Paddy harvest area	ha	633.775	631.473
Irigat	Paddy field irrigation area	ha	217.480	247.047
Labor	Number of workers in the agricultural sector	person/ha	2,59	1,12
Urea	Total realization of Urea fertilizer subsidy	ton/ha	0,25	0,13
NPK	Total realization of NPK fertilizer subsidy	ton/ha	0,13	0,07
SP36	Total realization of SP36 fertilizer subsidy	ton/ha	0,04	0,02
ZA	Total realization of ZA fertilizer subsidy	ton/ha	0,04	0,05
2WT	Total realization of 2-wheel tractor	unit/ha	0,0013	0,0014
4WT	Total realization of 4-wheel tractor	unit/ha	0,0001	0,0002
WP	Total realization of water pump	unit/ha	0,0008	0,0012
Temp	Average annual temperature	⁰C	26,99	1,05
Precp	Annual precipitation	mm	2237,47	864,63

Source: Secondary data,analyzed (2021)

that five islands are obtained, namely Sumatra Island, Java Island, Kalimantan Island, Sulawesi Island, and Nusa Tenggara Island (Figure 1). The results of the analysis are shown by line charts containing information on the development of the amount of fertilizer subsidy allocation and annual agricultural machinery assistance on each island from 2009-2018. We also track the average amount and trend of subsidies for fertilizers and agricultural machinery to find out the average number of subsidies and the direction of the trend.

We explore the effect of subsidized fertilizers and agricultural machinery on paddy productivity using panel data. Researchers who analyze panel data will encounter problems with serial correlation and cross-sectional correlation (Reed and Ye, 2011). Therefore, we apply Feasible Generalized Least Squares (FGLS) analysis which is commonly used when the data indicates this problem. Previous research stated that FGLS estimation was more efficient than Ordinary Least Square (OLS) on data indicated by heteroscedasticity, serial correlation, and cross-section correlation (Bai et al., 2021). In this study, we used FGLS groupwise heteroscedasticity because we wanted to obtain an efficient model and the data used met the N>T requirements, where N=20 (Cross-section) and T=10 (Time series) (Reed and Ye, 2011). The equation of the research model is as follows:

$$lnProdvt_{i,t} = \beta_0 + \beta_1 lnIrigat_{i,t} + \beta_2 lnLabor_{i,t} + \beta_3 lnUrea_{i,t} + \beta_4 lnNPK_{i,t} + \beta_5 lnSP36_{i,t} + \beta_6 lnZA_{i,t} + \beta_7 ln2WT_{i,t} + \beta_8 ln4WT_{i,t} + \beta_9 lnWP_{i,t} + \beta_{10} lnTemp_{i,t} + \beta_{11} lnPrecp_{i,t} + \varepsilon_{i,t} \quad (1)$$

where the dependent variable lnProdvt shows the value of ln paddy productivity. The independent variables consist of lnIrigat, lnLabor, lnUrea, lnNPK, lnSP36, lnZA, ln2WT, ln4WT, lnWP, lnTemp, and lnPrecp respectively showing the value of ln irrigation land, agricultural labor, Urea subsidies, NPK subsidies, SP36 subsidies, 2-wheel tractors subsidies, 4-wheel tractors subsidies, water pumps subsidies, temperature, and rainfall; $\beta_0$is a constant; β_{1-11} is the variable coefficient; i is the number of provinces (1, 2, 3, ... 20); t is the time period (2009, 2010, 2011, ... 2018); and ε is the error term.

RESULT AND DISCUSSION

The allocation of subsidies for fertilizers and agricultural machinery in 2009-2018 to 5 islands is shown in Figure 2 and 3. Meanwhile, the average amount of subsidies and agricultural machinery, and growth trends are shown in Table 2.

Java Island gets the largest allocation of urea fertilizer per hectare, but the allocation from 2009 to 2018 tends to decrease. The trend of decreasing allocation also occurred in 3 other islands, except for Sulawesi Island, which experienced an increase (0.0001 ton/ha). NPK subsidies have increased every year, with Java receiving the largest allocation. Sulawesi Island shows the highest increasing trend for NPK subsidies with a value of 0.0134 ton/ha. The allocation of SP36 fertilizer subsidies tends to increase for Java and Sumatra at the same trend value of 0.000004 ton/ha. Meanwhile, the SP36 allocation for the islands of Nusa Tenggara, Kalimantan, and Sulawesi has a downward trend. The ZA fertilizer subsidy is mostly allocated to the provinces in Java. Unfortunately, the allocation of ZA fertilizer subsidies for 5 islands shows a downward trend where Nusa Tenggara Island shows the largest decrease of -0.0008 ton/ha.

These results show that Java Island receives a higher allocation of subsidies per hectare than the other 4 islands. The government provides a larger allocation because of the role of the provinces in Java Island as the national rice center with the highest production (Santoso, 2015). It is interesting to pay attention to the fertilizer allocation in the second, third, and fourth positions, where Sumatra Island, Nusa Tenggara Island, and Sulawesi Island are in that position. Sumatra Island is known to have a larger proportion of paddy field area than Sulawesi Island and Kalimantan Island. Meanwhile, the islands of Sulawesi and Nusa Tenggara (especially the Province of West Nusa Tenggara) have great potential in providing rice supplies for the Indonesian population. Java cannot always be relied on, because of the large number of land conversion activities that will threaten food production and availability for the Indonesian population (Sudono et al., 2016).

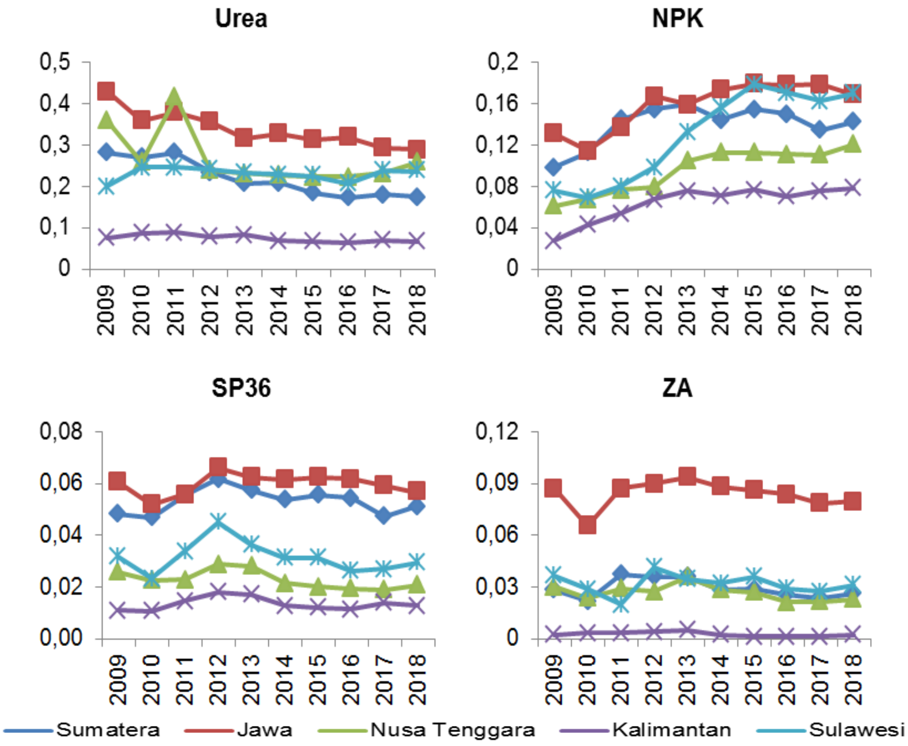

Figure 2. Fertilizer subsidy allocation by island (ton/ha)
Source: Secondary data, processed (2021)

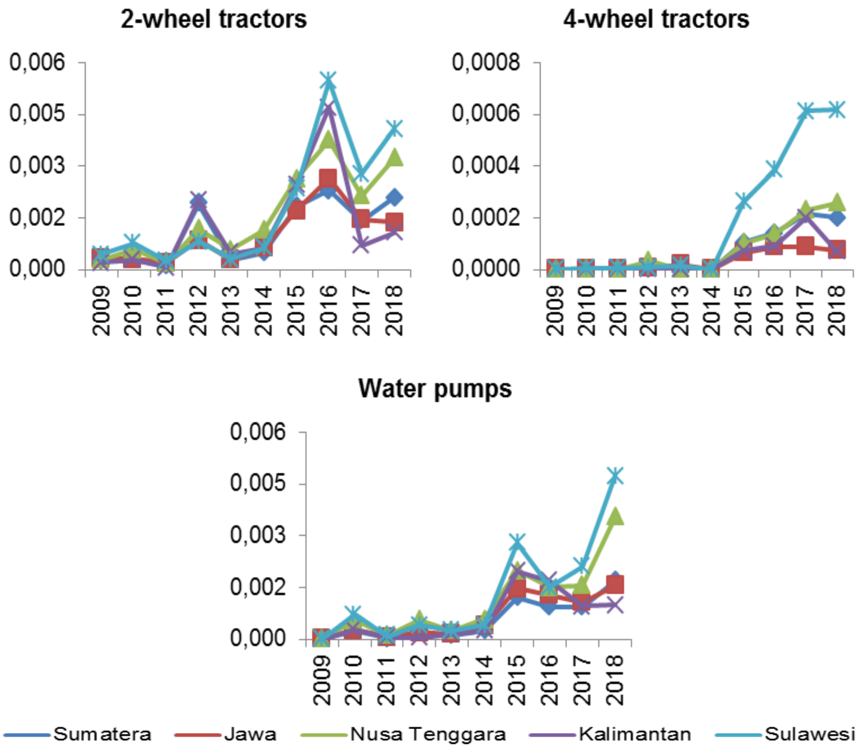

Figure 3. Agricultural machinery subsidy allocation by island (unit/ha)
Source: Secondary data, processed (2021)

Figure 3 shows the distribution of agricultural machinery subsidies. The island of Sulawesi gets a higher allocation of agricultural machinery subsidies than the other 4 islands. The average subsidy for 2-wheel tractors, 4-wheel tractors, and water pumps for the provinces on Sulawesi Island is 0.0018, 0.0002, and 0.0013, respectively (units/ha). The reason is the ownership of large paddy fields by households. The BPS (2019) survey shows that the area of irrigated and non-irrigated paddy fields by farmer households on Sulawesi Island is 1.268 ha and 0.69 ha, respectively. Another study stated that the majority of farmers in Southeast Sulawesi and South Sulawesi cultivate paddy on an area of 0.76-2 ha (Asaad et al., 2018; Sunanto and Rauf, 2018). Water pumps are also allocated more to the provinces on the island of Sulawesi because potential land is found with insufficient water availability, so farmers can only plant paddy once per year (Hikmatullah and Suryani, 2014). Irawan (2013) stated that the problem on the island of Sulawesi is the use of river water that is not optimal. Although 70% of villages are crossed by rivers, only 30% of villages use it for irrigation. The reason is the limited capital for pumping. From 2009 to 2018 agricultural machinery subsidies showed an increasing trend for all islands. The trend of increasing 2-wheel tractor in Sulawesi Island is 0.0005 units/ha, it is the highest increase compared to other islands. Nusa Tenggara Island is in the second position as a recipient of agricultural machinery subsidies. This confirms that the government has not only allocated a large fertilizer subsidy for Sulawesi Island and Nusa Tenggara Island, but also a large subsidy for agricultural machinery to support increasing paddy productivity.

In this study, we divide the effect of subsidies into 3 different models. In Model I there are independent variables of agricultural input subsidies, including subsidies for urea fertilizer, NPK fertilizer, SP36 fertilizer, and ZA fertilizer. Model II includes subsidy variables for 2-wheel tractors, 4-wheel tractors, and water pumps. Then Model III includes climate variables, namely temperature, and rainfall. We use Feasible Generalized Least Squares (FGLS) analysis on STATA14 software where the analysis output is shown in Table 3. Panel data analysis was carried out on 20 provinces for 10 years, so the number of observations was 200. Ordinary Least Square analysis was used to determine the adjusted R^2 (adj. R^2). value adj. R^2 increased along with the addition of agricultural machinery variables (Model II) and climate indicator variables (Model III).

Table 2. Average value and trend of fertilizer and agricultural machinery subsidies by island allocation

Subsidy	Sumatra	Java	Kalimantan	Sulawesi	Nusa Tenggara
			Mean		
UREA	0,2187	0,3376	0,0742	0,2302	0,2661
NPK	0,1394	0,1584	0,0638	0,1291	0,0955
SP36	0,0531	0,0597	0,0134	0,0315	0,0229
ZA	0,0292	0,0838	0,0026	0,0316	0,0266
2WT	0,0011	0,0010	0,0013	0,0018	0,0016
4WT	0,0001	0,00003	0,00004	0,0002	0,0001
WP	0,0006	0,0006	0,0006	0,0013	0,0011
			Trend		
UREA	-0,0138	-0,0129	-0,0022	0,0001	-0,0127
NPK	0,0034	0,0064	0,0048	0,0134	0,0068
SP36	0,00004	0,00004	-0,0000003	-0,0005	-0,0007
ZA	-0,0006	-0,00001	-0,0002	-0,0002	-0,0008
2WT	0,0002	0,0002	0,0002	0,0005	0,0004
4WT	0,000003	0,00001	0,00002	0,0001	0,00003
WP	0,0002	0,0002	0,0002	0,0004	0,0003

Source: Secondary data, analyzed (2021)

Table 3. Feasible generalized least square panel data estimation for paddy productivity

Variable	I	II	III
Constant	4,0218***	4,0528***	6,0468***
	(32,40)	(32,37)	(14,55)
LnIrigat	0,0175**	0,0189***	0,0208***
	(2,51)	(2,71)	(3,01)
LnLabor	-0,0644**	-0,0498**	-0,0261
	(-3,31)	(-2,40)	(-1,18)
LnUrea	0,0671***	0,0756***	0,0802***
	(4,48)	(4,95)	(5,07)
LnNPK	0,0569***	0,0329*	0,0378**
	(3,42)	(1,71)	(2,01)
LnSP36	-0,0063	-0,0006	-0,0100
	(-0,40)	(-0,04)	(-0,63)
LnZA	0,0181**	0,0173**	0,0174**
	(2,48)	(2,38)	(2,34)
Ln2WT	-	0,0091**	0,0082*
		(2,32)	(1,95)
Ln4WT	-	0,0006	0,0012
		(0,79)	(1,37)
LnWP	-	0,0003	0,0007
		(0,31)	(0,61)
LnTemp	-	-	-0,6027***
			(-5,33)
LnPrecp	-	-	-0,0073
			(-0,47)
Wald chi^2	205,19	230,19	270,12
Prob	0,000	0,000	0,000
R^2	0,4124	0,4249	0,4412
Adj-R^2	0,3941	0,3977	0,4085
Number of groups	20		
Time periods	10		
Obs	200		

Note: ***, **, and * represent the 1%, 5%, and 10% significance levels, respectively.
I - Model of input subsidies
II - Model of input subsidies and agricultural machinery
III - Models of input subsidies, agricultural machinery, and climate indicators
Source: Secondary data, analyzed (2021)

The increase in irrigated land has a positive effect on increasing national paddy productivity in the three analytical models. Irrigation is an important factor in efforts to increase paddy productivity which has an impact on the intensity in terms of land cultivation and can spur the adoption of technology that has an impact on the intensity of paddy cultivation (Damayanti, 2013). However, this is contrary to the research conducted by Panuju et al. (2013) which showed that irrigation was not correlated with increasing paddy productivity, but irrigation networks contributed greatly to paddy production, especially in Java, Bali, Sumatra, and Sulawesi. The role of irrigation as infrastructure is very important in ensuring the availability of water, but its development is very centralized on the island of Java. Ignoring the important role of irrigation is tantamount to increasing threats to food security. The challenges faced by the government in the future will be increasingly difficult along with the depletion of water availability in various parts of the world and the threat of climate change which is increasingly difficult to predict (Azmeri et al., 2019).

An interesting finding from this study is that an increase in the number of agricultural workers will reduce national paddy productivity (Models I and II), while in Model III it has no significant effect. These results indicate that in conditions of fertilizer subsidies even without the help of agricultural machinery, an increase in labor will reduce paddy productivity. Likewise, when there is the influence of fertilizer subsidies and agricultural machinery assistance. Previous research stated that agricultural labor in Indonesia has begun to decrease in productivity due to age who has reached the age of 60 years. The absorption or regeneration of labor in the agricultural sector towards the younger generation is getting lower every year, most of which are more interested in the industrial and trade sectors (Nugroho et al., 2018). Another factor is the effect of mechanization which has been widely applied by farmers in Indonesia, which among the negative impacts is the loss of job opportunities for farm workers which have implications for loss of income. Low adoption ability is also an inhibiting factor because farmers are not ready to accept the existing technology (Purwantini and Susilowati, 2018). However, when the climate effect is included (Model III), the labor force does not affect increasing paddy productivity.

Urea fertilizer subsidies have a positive effect on the three models of analysis carried out. The application of Urea fertilizer in the right dose at the beginning of the growth of paddy plants can have a significant impact on the growth rate. This is because the element of N (Nitrogen) content in Urea fertilizer is needed by paddy plants compared to the elements in other fertilizers (Ambarita, 2017). Therefore, the availability of fertilizer at the beginning of the growth period is very important. Giving the right dose also greatly determines the level of productivity of the paddy plant. This is based on several studies which found that the use of excessive doses affects decreasing the productivity of paddy plants (Akbar et al., 2018).

NPK fertilizer subsidies also showed a positive effect on paddy productivity in models II and III. These results are consistent with previous research which states that increasing the application of N, P, and K fertilizers (to some extent) affects increasing paddy productivity (Jiang et al., 2019; Murthy et al., 2015). NPK fertilizers with higher N content were able to increase the number of tillers and plant height. The higher the paddy plant, the higher the number of leaves as well, thus facilitating the rate of photosynthesis and ultimately increasing output (Herve et al., 2017). The use of NPK fertilizer in the long term will increase plant growth, root exudates, soil nutrients, and the ability to induce high soil nutrients (Zhang et al., 2018). However, it is necessary to pay attention to the method of applying NPK fertilizer to the soil. The method by planting fertilizer into the soil is known to increase grain yields higher than the spread method, either in the wet or dry growing season (Miah et al., 2016).

ZA fertilizer subsidies have a positive relationship to paddy productivity in the three models compiled. ZA fertilizer has a positive relationship to productivity, meaning that an increase in ZA fertilizer subsidies can increase paddy productivity in Indonesia. The need for ZA fertilizer in Indonesia is quite large. Data sourced from APPI (2020) shows that the demand for ZA fertilizer in 2017 reached 979,473 tons. This figure increased in 2018 and 2019 which reached 1,004,034 tons and 1,016,981 tons, respectively. The high demand for ZA fertilizer shows the important role of ZA fertilizer in increasing the production and productivity of agricultural commodities, especially for paddy cultivation.

The increase in 2-wheel tractor subsidies has a positive impact on increasing paddy productivity. These results are consistent with models II and III which show that an increase in 2-wheel tractors will increase paddy productivity in the presence or absence of the influence of climate change. Previous research has stated that 2-wheel tractors can support the development of lowland paddy production (Bachrein et al., 2009). Two-wheel tractors or mini tillers are mostly used by small-scale farmers with land areas below 0.25 ha, where the adoption of these technologies is known to increase paddy productivity (Abeyratne and Takeshima, 2020; Paudel et al., 2019). This is following agricultural conditions in Indonesia. The number of “gurem” farmer households or farmers who control paddy fields under 0.5 ha in 2018 is 75% (BPS, 2019). The 2-wheel tractor subsidy will be beneficial for increasing their farm productivity.

The temperature variable harms paddy productivity. The projected temperature will increase by 1.1 to 2.6 in 2081-2100 (RCP4.5) compared to 1986-2005 IPCC (2014) will reduce paddy yields if CO2 fertilization, an effective adaptation strategy, and genetic improvement are not applied (Zhao et al., 2017). According to previous research, an increase in temperature harms the milk and dough stage (maturation phase) causing the filling of rice seeds to be disrupted, resulting in a decrease in crop yields (Abbas and Mayo, 2021).

CONCLUSION

Our conclusion is that fertilizer subsidies and agricultural machinery play an important role in increasing paddy productivity in Indonesia. In general, Java Island is the region with the largest number of subsidies compared to Sumatra Island, Sulawesi Island, and Nusa Tenggara Island. This result implies that the input subsidy in Java has a major effect on the total paddy production that can be produced nationally. Paddy productivity can be increased by increasing subsidies for urea, NPK, ZA fertilizers, and subsidies for agricultural machinery. In addition, the availability, access, and stability of input subsidies in each region need to be carefully considered, so that paddy productivity and production in Indonesia can increase.

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