Fertilizer Application, Climate Change and Rice Production in Rural Java

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Abstract. Increasing rice production has always been the target of the Indonesian government in maintaining food security. Fertilizer application is a widely accepted strategy to sustain or improve rice production. The use of fertilizers can also have an impact on climate change and decrease soil fertility. This study aims to examine whether the fertilizer application and climate change affect rice production in rural Java. This study applies Ordinary Least Square (OLS) model to analyze the primary data collected from 4 main rice producer areas in Central Java and East Java Province. The results show that the current seed use and organic fertilizer have positive impact on rice production. The current use of pesticide and chemical fertilizer has negative effect. Rainfall shock as a proxy of climate change does not have any effect to rice production. This is due to farmers in the study area already having mitigation strategy to avoid the negative impact of climate change, particularly rainfall shock.

1. Introduction

In order to achieve food security in Indonesia, the main obstacle to increase rice production is due to land conversion, decreasing farmland area and degradation of the fertility of rice fields. Land is one of the production factors, namely the place where agricultural products are produced, where the amount of production from farming is influenced by the size of the land used [1]. The efforts to intensify paddy fields are still not running efficiently, possibly because of an imbalance in soil nutrients due to an unbalanced fertilizer application. In addition, intensive exploitation of rice field and inorganic chemical fertilizers continues resulting in decreased fertility and physical character of soil. Fertilizer and pesticides application can increase rice production but long term applications harm rice productivity.

The decline in rice production is exacerbated by climate change. Indications of climate change include an increase in air temperature, drought, flood disasters, shifting seasons and rainfall. Climate change has many effects on agricultural practices, particularly for annual crops such as rice. However, the impact of climate change in the tropics countries is greater because it has a fairly large variation in rainfall [2]. This condition should be anticipated carefully because it can affect the stability of rice production in Indonesia. Therefore, this study aims to estimate the effect of fertilizer application and rainfall shock in rice production. Climate change is an inevitable consequence global warming which has a wide impact on various aspects of life, particularly for smallholder farmer's agriculture [3]. Changes in rainfall patterns, an increase in the frequency of extreme climate events, as well as an increase in air temperature and sea level are serious impacts of climate change affecting the
agricultural sector, including rice production food chain and food security. Major types of changes is gradual increase in air temperature, changes in pattern of rainfall and increase in frequency and severity of extreme weather events such as floods, droughts and winds [4]. Understanding the impact of climate change on agricultural production is very important for agricultural climate adaptation. Small farmer also can take adaptation measures against climate change [5].

The rising demand for food has resulted in efforts to increase rice production by using intensive management practices, including increased application of water and N fertilizer. Intensive cultivation causes land degradation by depletion of soil organic matter and erosion. In Indonesian agriculture, rice is the most important food crop [6], [7]. Monoculture farming in rice fields can increase this environmental problem because there is still an unplanted soil surface. The dependence on one plant can invite pests and diseases and cause unprofitable economically [8].

There are many constraining factors related to land such as unbalanced fertilization, more expensive organic fertilizer prices, exploitation of land use and other destructive agricultural management affecting crop productivity and quality [9], but fertilizer has been one of the most important agricultural practices to improve soil fertility and increase crop productivity [10]. Farming methods that are not in accordance with the principles of sustainable agriculture, the use of excessive and unbalanced inputs can cause damage to the environment and natural resources. On the other hand, conservation and storage of soil organic carbon is important to improve land, so that environmental quality can be maintained which has a positive impact on crop productivity [11], furthermore application of inorganic chemical fertilizer could reduce soil fertility and crop productivity in the long term [12]. It is very crucial to balance between increasing crop production without compromise to soil health and environmental sustainability [13]. Organic fertilization can support soil fertility and quality [14]. Long-term application of organic fertilizer also improves soil fertility through significantly altering physicochemical properties [15], overuse of inorganic fertilizers causes a decline in the soil quality [16]. Organic fertilizer has higher matter content and also more environmental friendly than inorganic chemical fertilizer [17].

Pesticides are commonly used in rice farming for pest control, fungal disease eradication and weed control. Regardless of the benefit of pesticides on agricultural production and its economic relevance, the intensive and widespread use of pesticides can cause serious environmental and health problems. Therefore, it is necessary to control the use of pesticides to reduce the negative impact [18]. Pesticides can move offsite to contaminate surface water and leach to groundwater, and also cause damage to non-target organisms and pollution to the air and soil [19]. Therefore, this study aims to examine whether the climate change, pesticide and fertilizer application affect rice production in rural Java

2. Methodology

This study was conducted in Central Java and East Java Provinces, the main rice producer areas but do not have global competitiveness. From those provinces, we selected the 4 largest rice producer districts, namely Cilacap, Grobogan, Lamongan and Jember. Then, 324 samples selected through random sampling method. We recalled the data in 2 seasons of planting, season 1 and season 2 in 2018. This study applied Ordinary Least Square (OLS) model to estimate the effect of inorganic chemical fertilizer use and rainfall on rice production. OLS is an analysis method to test the extent of the causal relationship between the independent variables and the dependent variable. OLS is used to estimate a regression line by finding the minimum value for the sum of squares of error between the predicted value and the real value. The advantages of the linear regression method include generalizing and extracting from certain data patterns, being able to acquire knowledge even though there is no certainty, and being able to perform calculations in parallel [20].

\[ Y_t = C + \beta_1 S_t + \beta_2 Or_{rg_t} + \beta_3 Or_{rg_{t-1}} + \beta_4 Pe_{st_t} + \beta_5 Pe_{st_{t-1}} + \beta_6 R_t + \beta_7 Chem_t + \beta_8 Chem_{t-1} + \epsilon_t \]

Where, 
\[ Y_t = \text{Production of rice at } t \text{ (kg)} \]
$S_t$ = Quantity of seed at $t$ (kg)
$Org_t$ = Quantity of Organic fertilizer at $t$ (ml)
$Org_{t-1}$ = Quantity of Organic fertilizer at $t-1$ (ml)
$Pest_t$ = Quantity of pesticide at $t$ (ml)
$Pest_{t-1}$ = Quantity of pesticide at $t-1$ (ml)
$R$ = Rainfall (mm)
$Chem_t$ = Quantity of chemical fertilizer at $t$ (ml)
$Chem_{t-1}$ = Quantity of chemical fertilizer at $t-1$ (ml)
$\varepsilon$ = Random disturbance
$t$ = Season

3. Result and Discussion

Farmers in the study area used several chemical fertilizers, namely urea, phonska, TSP, NPK and ZA. The largest use of fertilizer is urea, only slightly different from the use of phonska, and then followed by TSP, NPK and ZA which were less used. Rice farmers tend to reduce the use of chemical fertilizers in season 2 compared to season 1. The use of organic fertilizers in both seasons is relatively the same in quantity. Besides using these fertilizers, farmers also use organic fertilizers and manure. The use of manure is greater, about twice the use of urea (Figure 1)

![Figure 1. Organic and Inorganic Fertilizer](image)

Table 1 describes the estimation result of impact of seed, organic fertilizer, pesticide, rainfall, and inorganic chemical fertilizers use on the rice production. The results showed that the use of seeds and organic fertilizers would definitely increase rice production in the same season, because the estimated parameter has a significant positive effect. Meanwhile, the use of pesticides and inorganic chemical fertilizers in the previous season had a positive effect on rice production. In the following season, the use of these two production factors will actually reduce rice production. In other words, initially the use of pesticide and chemical fertilizers will increase rice production, but the use of these inputs in the next seasons will decrease rice production. This finding is in accordance with Zhang et al. (2015), Tam (2016), and Umme et al. (2019). Therefore, it is suggested to rice farmers must implement the management of fertilizers and pesticides appropriately to maintain the sustainability of rice production [23]. The use of inorganic chemical fertilizers and pesticides can increase production in the short term, but it threatens the future production.

| Variable | Coefficient | Standard Error |
|----------|-------------|----------------|
| Seed$_t$ | 45.48975*** | 11.86117       |
| Organic$_t$ | 41.26698* | 22.77939       |
| Variable       | Coefficient | Standard Error |
|----------------|-------------|----------------|
| Seed<sub>t</sub> | 45.48975*** | 11.86117       |
| Organic<sub>t</sub> | 41.26698*  | 22.77939       |
| Organic<sub>t-1</sub> | -39.39242* | 22.77386       |
| Pesticide<sub>t</sub> | -1.415068*** | 0.4804425     |
| Pesticide<sub>t-1</sub> | 1.402712*** | 0.4513234     |
| Rainfall        | 0.098971    | 0.098971       |
| Chemical<sub>t</sub> | -3.20007*** | 1.209932       |
| Chemical<sub>t-1</sub> | 10.96331*** | 0.9532115      |
| Constant        | 49.90764*  | 20.0236        |

Rainfall variable has no significant effect on rice production. This finding is contrast with Sujariya (2020). This result indicates that farmers already have good climate change mitigation management. Farmers in Central and East Java have local wisdom to anticipate the negative impacts of weather changes and extreme rainfall.

4. Conclusion

The use of chemical pesticides and fertilizers can increase rice production, but only temporarily. This is due to in the following season, it will reduce production. Conversely, the use of organic fertilizers will increase rice production in the current season. Rainfall shock as a proxy of climate change does not any effect on rice production. This is due to farmers in the study area already having mitigation strategy to avoid the negative impact of climate change, particularly rainfall shock.

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