On The Impact of Climate Change to Agricultural Productivity in East Java

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Abstract. Many researches showed that climate change has significant impact on agricultural sector, which threatens the food security especially in developing countries. It has been observed also that the climate change increases the intensity of extreme events. This research investigated the impact climate to the agricultural productivity in East Java, as one of the main rice producers in Indonesia. Standard regression as well as panel regression models have been performed in order to find the best model which is able to describe the climate change impact. The analysis found that the fixed effect model of panel regression outperforms the others showing that climate change had negatively impacted the rice productivity in East Java. The effect in Malang and Pasuruan were almost the same, while the impact in Sumenep was the least one compared to other districts.

1. Introduction
Agriculture is one of the important sectors to support Indonesian economic which significantly depends on climate. Numerous studies have been conducted to predict the future climate condition. Since IPCC report in 1990, maximum effort has been carried out to understand the climate change impact on agricultural system. As the results, better changes have been gained to support studies on the impact of climate change such as better data collection, development of new methodology or model, as well as observation about actual change on climate and its impact. All of them are very useful to support the technological development and policy to mitigate and adapt the climate change.

Latest research on climate change impact on agricultural sector concludes that the climate change has negatively impacted the food production, as well as lead to a public perception that climate change causes food degradation globally. However, the impact is different every country with also different vulnerability level. Some countries such as US and European countries are able to adapt against climate change by change in a farmer level such as potential product, crop management, as well as anticipation in the form of investment. Meanwhile in developing countries, there are several reasons why farmers and agricultural supporting institutions are less adaptation to climate change.

Indonesia is one of the countries that is highly vulnerable to climate change with refer to agricultural and food sector. Increasing intensity of extreme climate events over the year has caused significant losses in agricultural sector. Many studies that have been conducted in Indonesia were limited on qualitative study or description about the fact. Nevertheless, due to the fact that climate change is a dynamic event with various impact over the time, it is necessary to carry out a study which is able to generate information about the impact of climate change to Indonesian agriculture over time. In statistical language, it is necessary to develop model which is able to explain the dynamic effect of
climate change. With this model, mitigation strategy will be able to be formulated in order to reduce the negative impact which threatens the food security.

Several studies have been conducted e.g. [1] which studied the impact of climate change on agricultural sector in Semarang. This study used cross sectional data modeled with log linear regression and hence, the dynamic impact cannot be identified. Rasmikayati [2] investigated the climate change impact to farmer behavior. Santoso [3] used simple time series model to forecast agricultural production in Maluku as the result of climate change, however the study quantified only the food production data without clear effect of climate change. Widayat et. al [4] studied the climate change impact on the coffee production in Aceh using Structural Equation Modeling (SEM). This paper differs from the aforementioned studies in term of the model as well as the obtained information from the dynamic model using panel data analysis in order to investigate the effect of the climate change to agriculture in Indonesia especially East Java.

Researches in the developed countries have considered the dynamic effect. Mendelsohn [5] studied the potential impact of climate change including the temperature and precipitation variation to food production. Another research tried to simulate climate change effect to agriculture with several inputs such as [6, 7]. Several latest researches have used statistical and econometric approach on time series, cross section and panel data (see [8, 9] among others). Another strength of panel approach is the location-specific fixed effects information to absorb time invariant missing variable. Furthermore, panel model is able to identify shock happening over the years, which is different from climate permanent shift [10]. This research focuses on East Java Province as one of the provinces in Indonesia with significant contribution of agricultural producton in Indonesia.

2. Research Methodology

This research analyzes two kinds of data as follow:

- Data to characterize the climate change
  
  The variable used as the basis of describing climate change is daily rainfall intensity. In the model, the daily rainfall data is aggregated into monthly data. The data spans from 2006 to 2016 which can be downloaded from the BMKG website at www.dataonline.bmkg.go.id.

- Agricultural Data
  
  This is the data of rice production, rice productivity and yield. The data is mostly collected from Statistics Office and Ministry of Agriculture East Java Province. The rice productivity and yield are used for descriptive statistic, while the rice production is used for panel data modelling.

The steps of the analysis can be described as follows. We firstly perform descriptive statistic about the variable i.e rainfall as well as rice yield and productivity during the periods of observation in four districts. Furthermore, we investigated the best model by performing regression models i.e. OLS regression and panel regression models. The panel regression models include fixed and random effect model by which the model can be written as follow:

\[ Y_{it} = \beta_{i}X_{it} + \alpha_{i} + u_{it} + \epsilon_{it} \]

where \( \alpha_{i} \) is the unknown intercept for each entity (in this case district), \( Y_{it} \) is dependent variable for entity \( i \) at time \( t \), \( X_{it} \) represents one independent variable with hcoefficients \( \beta \), while \( u_{it} \) and \( \epsilon_{it} \) are between and within entity error respectively. The fixed effect model control for, or partial out, the effects of time-invariant variables with time-invariant effects so that

\[ Y_{it} = \beta_{i}X_{it} + \alpha_{i} + u_{it} \]

while in a random effects model, the unobserved variables are assumed to be uncorrelated with all the observed variables

\[ Y_{it} = \beta X_{it} + \alpha + u_{it} + \epsilon_{it} \]

The best model is the one with highest R-square.
3. Results and Discussion

3.1. Descriptive Statistic

Many researches concluded that agricultural production (in this case is rice) in a region depends on the weather and climate in that region. Therefore, information about climate variability is important in order to formulate the strategy to reduce the impact of climate change. Figure 1 depicts the cumulative monthly rainfall observed in several stations in East Java.

![Figure 1. Monthly total rainfall in East Java.](image)

Figure 1 clearly shows the seasonal pattern of the monthly rainfall. There was a consistency or similarity in the pattern among those 8 stations. October, November and December were the months with high rainfall intensity. The Figure covers only observations from 8 stations with most completed and reliable dataset. Moreover, the distribution of the stations has represented the East Java province well.

3.2. Descriptive statistics of rice production, yield and productivity

This research focuses on rice as the main source of food in Indonesia especially in East Java. Figure 2 summarizes total production of rice in five highest rice producer districts during 2005-2014 (in Ton).

![Figure 2. Largest total rice production in East Java (source BPS and Agricultural Office East Java, 2015).](image)

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As we can see from the figure that Jember, Lamongan, Bojonegoro, Banyuwangi and Ngawi have been main rice producers in Indonesia. There have been significant increase in the rice production.
However, in 2011 there was a significant decrease caused by a specific factor. The information about rice production is equipped with figure about total yield as performed in figure 3 below.

![Figure 3. Largest yield in East Java (source BPS and Agricultural Office East Java, 2015).](image)

In line with the total rice production, the yields increased also over the year. There was significant decrease also in 2011. In general the yield of rice at East Java in 2008 to 2014 can be seen on figure 4, which gives information that there were a regular seasonality pattern where the yield on March is always the highest compared to others.

![Figure 4. Total of rice yield in East java.](image)

3.3. Panel Analysis
This subsection discusses the result of analyzing the dataset using panel regression. There are many advantages of panel regression such as the information about specific time effect, fixed effect, etc. Figure 5 presented the rainfall pattern observed from four meteorological stations, representing the climate condition in the corresponding district. We see that the quarterly rainfall did not show significant increase or decrease over the year. Moreover, the rainfall intensity in Banyuwangi was higher than in other three districts. We can see also an indication of seasonality, although the regular pattern was somehow does not appear. Different pattern was observed for the rice productivity in those four districts. We can clearly see that the productivity increased over the years. In line with the rainfall intensity, the rice productivity in Banyuwangi was higher than the others.
Another important information is about the heterogeneity of the productivity and rainfall across districts as shown in figure 5. The productivity of heterogeneity gives information about how the productivity differs among the districts. As can be seen from the left panel of figure 5, the heterogeneity of rice productivity was increasing, which also means that the productivity distinguished significantly. Meanwhile, the rainfall heterogeneity seemed to be constant indicating that the climate change impact is almost the same across the district. Figure 6 showed that the variability of rainfall intensity in Pasuruan was higher than the others during the period of 1997 to 2015, while Sumenep had the least rainfall with low heterogeneity too. From the heterogeneity plots, we see that the pattern of the rice productivity showed linear increasing pattern especially during the past five years. However, the yield was constant over the time.
Figure 6. Productivity and rainfall heterogeneity plots across periods.

Table 1 below summarizes the regression result. The analysis is begin with OLS regression without neglecting the time or location specific effect. The regression shows that rainfall significantly influenced the rice productivity in East Java positively. However, the coefficient determination of the model is very low i.e. 3%. It indicated that the variability of the data cannot be covered by the model well. Furthermore, the fix effect on the districts can be seen form the following table.

**Table 1. Summary of regression results**

| Model          | OLS     | Fixed Effect | Random Effect |
|----------------|---------|--------------|---------------|
| Variable       | coefficient | p-value       | coefficient | p-value | coefficient | p-value |
| Intercept      | 55.94   | <2e-16 ***   | Intercept    | 57.9270  | <2e-16 ***   |
| Rainfall       | 0.00232 | 0.00586      | Rainfall     | 0.0004613| 0.57        | Rainfall    | -0.00033  | 0.6782   |
| Banyuwangi     | 58.914  | <2e-16 ***   | Malang       | 61.051   | <2e-16 ***   |
| Pasuruan       | 61.895  | <2e-16 ***   | Sumenep      | 50.221   | <2e-16 ***   |
| Sumenep        | 50.221  | <2e-16 ***   |              |          |             |
| R-square       | 0.003312|              | R-square     | 0.9883   |              |
|                |         |              | R-square     | 0.00076316|            |
The panel regression indicates that the coefficient of the rainfall variable is negative, which can be seen as the negative effect of climate change to rice productivity. Moreover, the p-value greater than 0.05 indicating that rainfall does not significantly influence the rice productivity. Meanwhile, the rice productivity in each district significantly greater than zero where Pasuruan and Malang have higher level than Banyuwangi and Sumenep. Surprisingly the coefficient determination of the model is very high i.e. 98.83%.

In order to know which model is actually better to describe the climate change effect to rice productivity, we can performs F-test with the null hypothesis of OLS model better than fixed effect model. As the p-value is significantly lower than 0.05, thus we conclude that the fixed effect model is better than the OLS model. It suggests to analyze the specific location effect individually. Note that this paper did not focus on time specific effect as many researches agreed that the climate change impact influenced many sectors over the time. Moreover, the fixed effect model itself assumes that there is no autocorrelation among the time implying also there is no autocorrelation in the error term.

Another effect that we need to investigate within panel regression model is random effect. From the table, the coefficients can be interpreted as the within-entity and between-entity effects. In this case, it represents the average effect of rainfall over the rice production when rainfall changes across time and between districts by one unit. Furthermore, it against shows that the rainfall does not significantly influence the rice production as the P-value is greater than 0.05.

In order to know the effect, Hausman test has been performed with the null hypothesis that random effect is better than fixed effect. As the P-value is greater than 0.05, it means that the random effect is better than fixed effect. However, the P-value is only slightly different from 0.05 which suggest also that both models compete each other. From the result above, the panel regression model can be written as

\[
\text{Rice Productivity}_{it} = -0.0004613 \times \text{Rainfall}_{it} + \alpha_i
\]

where \(\alpha_i\) is the specific district effect with the values listed in table 1. The model suggests that rainfall happening at a specific time period will tend to decrease the rice productivity at that time. However, the decreasing level was very low. Furthermore, the model indicated that extreme or heavy rainfall will lead to higher decrease of rice productivity, which may lead to a puso.

4. Conclusion
This paper examined panel data analysis to investigate the impact of climate change to rice production in East Java. Using the dataset observed in four districts, it showed that the climate change indicated by the rainfall intensity does not significantly influence the rice productivity. The model indicated that the individual district effect is highly significant with different levels among the districts. Furthermore, the pool model indicated that rainfall intensity gave significant impact to rice productivity. However, the model has very low R-squares, which means also that the model has very low prediction ability. In order to improve the model, further study needs to be carried out by involving more data from other districts. Moreover, considering time lag influence may give better result.

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