Decrease in Rice Production Due to Climate Change in West Java Indonesia

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Abstract: ***The impact of climate change can decrease in rice production. This paper informs results of study on decreasing in rice production due to climate change in Karawang West Java Indonesia. The study aims to assess level of the decreasing in rice production and identify areas that have high or very high level. This study used data of rainfall, temperature, sea level rise, droughts, floods, harvested area, land area, productivity and production of rice. The data was collected by observation, and survey in area of study, and some data get from Bureau of Meteorology Climatology and Geophysics and Central Bureau of Statistics. The data analyzed use empirical formulation. The results was presented in spatial maps using GIS software. The results of this study indicated that in Karawang West Java has experienced climate change that was showed by changing of rainfall patterns, rainy day, and distribution of annual rainfall. Annual rainfall has decreased that showed by some areas become drier. Decrease in rice harvested area in Karawang West Java was average of 77.0 ha per year. While decrease in rice production in that region was average of 926.1 tons per year. Based on the results can be concluded that climate change has founded and reduced harvested area and production of rice in Karawang West Java Indonesia.***

Keywords: climate change, harvested area, rice production

1. Introduction

The influence of global climate change, especially on the agricultural sector has been felt and become reality (Kurukulasuriya, et al., 2003; Semenov, 2009). The climate change was indicated by the floods, drought, and the shift of rainy season (Arnell *et al.*, 2011). In recent years, the shift of rainy season causes the shift of planting and harvesting seasons of food crops (rice, pulses and vegetables). Extreme event such as floods and drought cause failures of planting and harvesting crop (Ruminta and Handoko, 2012 and 2016). In Indonesia, change of rainfall patterns is the greatest threat, because farmers depend directly on rainfall for their agricultural activities and livelihoods. Every changes of rainfall pose a great risk. Rain-fed agriculture is susceptible to climate change, if farming activities remain unchanged. Meanwhile, the quality of fresh water affect farming systems in coastal areas due to sea water intrusion and unsustainable irrigation activities. High salinity due to increasing sea level becomes a threat to food crop production in coastal areas because varieties are not resistant to high salinity. Furthermore, high temperature will affect the agricultural system. Plants are sensitive to high temperatures during critical stages, such as flowering and seed development. Combined with drought, high temperatures can also cause disaster for agricultural lands (Mendelsohn, 2008). Changes in temperature and humidity can lead to the development of sprawl of pests and plant diseases. Floods and droughts also affect agricultural productions (Kurukulasuriya and Rosenthal, 2003). Floods and prolonged droughts, caused by bad water management and low capacity, make significant decrease in productions (CCSP. 2008; IPCC, 2012).

The extent of climate change to affect agricultural systems depends on various factors, including the type of crops, operation scales, farming orientations toward commercial or subsistence purposes, the quality of the natural resource bases, and the influence of human and farm manager (for example, education, risk tolerance, age, etc.) (FAO, 2007; Ruminta and Handoko, 2016). Hazard on rice farming is a decrease in rice productivity (yield), harvested area, and rice land area caused by change of temperature, rainfall, and sea level rise, which affect production and cause a risk on food security disturbance. Hazard analysis is based on assumption that the decrease in plant productivity and harvested area has a strong relationship with changes in air temperature and rainfall, while sea level rise will cause a reduction in agricultural land area (Kumpulainen, 2011; Metternicht *et al.*, 2014). Increase in atmosphere temperature is a climatic stimulus on the increase of crop respiration and shorter crop growing season. In addition, the increase in air temperature cause an increase in potential evapotranspiration that can reduce the area of irrigated field that is supplied with water. Increasing atmosphere temperature causes higher crop respiration rate which sequentially leads to a decrease in crops yield. The decline in crop yields due to shorter crop growing season caused by increasing temperatures is approached with the 'Thermal Unit' concept, *i.e.* the crop development rate is faster by the higher air temperature. Thus, the higher air temperature, the shorter plants age so the biomass accumulated by the crop becomes less which results in crop yield decline. The relationship between the decline in crop yield due to shorter crop growing season and increasing air temperature assumes that crop yield is linearly related with the growing season (Ruminta and Handoko, 2012).

Rainfall determines the availability of water for the crop, especially on rain-fed fields (Aggrawal, 2008). Assuming a period of rainfall is spread equally during the crop growing season, then there is a strong relationship between rainfall with crop yield. Changes in rainfall causing droughts or floods is cause to decrease in crop yield (Kang, et al., 2009). Increase in air temperature will lead to higher crop evapotranspiration, thereby crop water requirement also will increase. As a result, the irrigated field area that can be supplied with irrigation water will be smaller. Potential evapotranspiration is used as the basis for the calculation of crop water use to estimate water supply to the crop using irrigated water. Potential evapotranspiration (ETp) can be calculated from air temperature using Thornwaite and Matter formula which is the function of air temperature (T). In this analysis, it is assumed that irrigated field area is proportional to the ETp and the total supply of irrigated water does not change (Ruminta and Handoko, 2012). Besides its effect on crop yield, low rainfall causes drought which results in crops harvest failure. Conversely, excessive rainfall will cause flood that also lead to harvest failure. In this analysis, a decline in harvested area due to drought and flood derived from the relationship between harvested areas and rainfall changes. Sea-level rise directly drown the cultivation area. Therefore the reduction of field area is calculated using a scenario of sea level rise. The agricultural fields affected will then be delineated to calculate the area decrease.

Rice (*Oryza sativa*), one of staple food crops in West Java, is a plant that needs a lot of water during his life even though it is not a water plant. Because of catastrophic climate change have an impact on the amount and spatial distribution of water, rising sea levels, increasing extreme events and it is a risky on rice productivity (Bar *et al.*, 2014) Analysis of food crops decrease was carried out by using rice which are the eminent crops in Karawang West Java Indonesia. By considering the impact of increasing air temperature, precipitation changes, and an increase in sea level on yield, harvested area, land area, and production of rice in that areas, the analysis was focused on potential decrease in rice harvested area and rice production. The purpose of this paper is to present the extent of impacts of climate change on rice production in Karawang West Java Indonesia.

2. Materials and Methods

This study was carried out in Karawang that's area of rice production center in West Java Indonesia from 2015 to 2017. The location of study was susceptible from the threat of climate change (Aldrian, 2007). This analysis used data of rainfall, temperature, sea level rise, droughts, floods, harvested area, land area, productivity, and production of rice. The data was collected by observation, and survey in study field, and some data get from Bureau of Meteorology Climatology and Geophysics and Central Bureau of Statistics. The data analyzed use empirics formulation that was used by Handoko (2007) and Wiratmo *et al.* (2016).
Decrease in irrigated lowland rice production due to the increase in temperature and rainfall changes is calculated as follows:

$$\Delta G_1 = \Delta Y_{a1}.\ A_{o1} + \Delta A_{p1}.Y_{o,1} \quad (1)$$

ΔG_1: decreased of irrigated-farm rice productions (ton), $\Delta Y_{a,1}$: decreased of irrigated-farm yields (ton/ha), $A_{o,1}$: initial irrigated farm area (ha), ΔA_{p1}: potency of decreased harvesting area due to the temperature rise (ha), and $Y_{o,1}$: the yields of harvest of irrigated farm before temperature rise (ton/ha).

The calculation of decrease in rain-fed and low-land rice production is same with irrigated lowland rice, except the harvest area is influenced by rainfall and no irrigation effects. Here is the calculation of reduction in rain-fed and low-land rice production.

$$\Delta G_2 = \Delta Y_{a,2}.A_{o,2} + \Delta A_{p2}.Y_{o,2} \quad (2)$$

ΔG_2: decreased of farm rice productions (ton), $\Delta Y_{a,2}$: decreased of rain-fed yields (ton/ha), $A_{o,2}$: initial rain-fed area (ha), ΔA_{p2}: potency of decreased harvesting area due to the change of rainfall (ha), and $Y_{o,2}$: the yields of harvest of rain-fed before temperature rise (ton/ha).

Sea level rise will reduce the affected rice land area, both irrigated and rain-fed rice. Here is the calculation of reduction in the production of rice.

$$\Delta G_3 = Y_{ox}.\ \Delta A_x \quad (3)$$

ΔG_3: production decreased of rice (ton/ha), Y_{ox}: initial production of rice before climate change (ton/ha), and ΔA_x: loose of land area of rice *x* (ha).

Critical review of hazard reduction in rice production due to a decrease in productivity (yield), harvested area, and land area has to be done so that it can be taken into consideration in the preparation of guidelines for local adaptation.

3. Results and Discussions

Hazard analysis was considering the impact of increasing air temperature, precipitation changes, and an increase in sea level on productivity, harvested area, land area, and production of rice in Karawang West Java and the hazard analysis was focused on potential decrease in rice harvested area and potential decline in rice production. Rice production is a result of yield (Y) multiplied by harvested area (A), so the hazard potency of redused rice production is derived from those two variables that have been analyzed previously. The results of analysis in the reduced rice harvested area and rice production in Karawang West Java was shown in Figures 1 and 2.

Figure 1 and 2 show the distribution of hazard index of reduced rice production derived from a combination of a reduction in productivity, land area, and harvested area. The red color indicates the high index value hazard. Teluk Jambe Timur, Banyusari, Telagasari, Karawang Timur, Rawamerta, Kutawaluya, Pedes, Tirtajaya, Batujaya, and Pakis Jaya have the large hazard index which means the region was affected or cannot cope with the adverse effects of climate change. Therefore, the government should to do efforts so the impact of climate change is not too detrimental to the people engaged in agriculture.

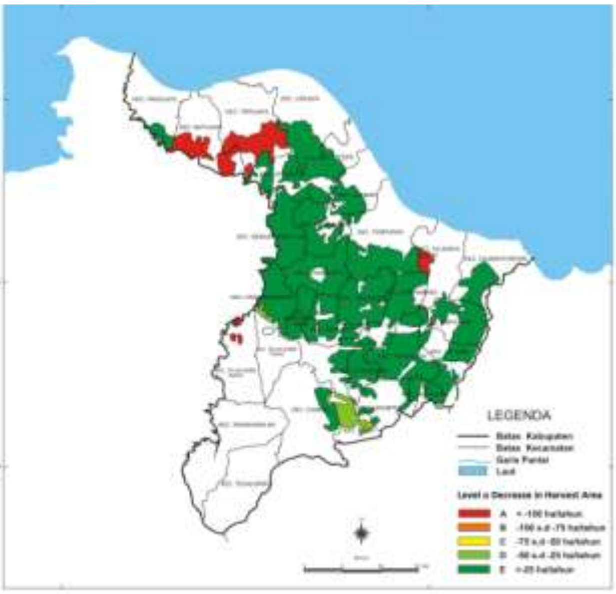

Figure 1: Level of decrease in rice harvested area in Karawang Java Indonesia

The impact of climate change has reduced harvested area and production of rice in Karawang West Java. The hazard potential in the decrease of rice harvested area in Karawang West Java is about 100 ha per year occurred in Pangkalan, Teluk Jambe Barat, Cilamaya Kulon, Tirtajaya, and Batujaya. Meanwhile, the hazard potential in rice production decrease in Karawang West Java is about 1000 tons of dry milled grain (DMG) per year occurred in Teluk Jambe Timur, Banyusari, Telagasari, Karawang Timur, Rawamerta, Kutawaluya, Pedes, Tirtajaya, Batujaya, and Pakis Jaya. Generally, climate change in Karawang West Java lead to the decreasing of rice production. This is due to the potential decrease in productivity and harvested area of rice which is the consequences of air temperature increase, rainfall decrease, drought, and flood (Li *et al*., 2009).

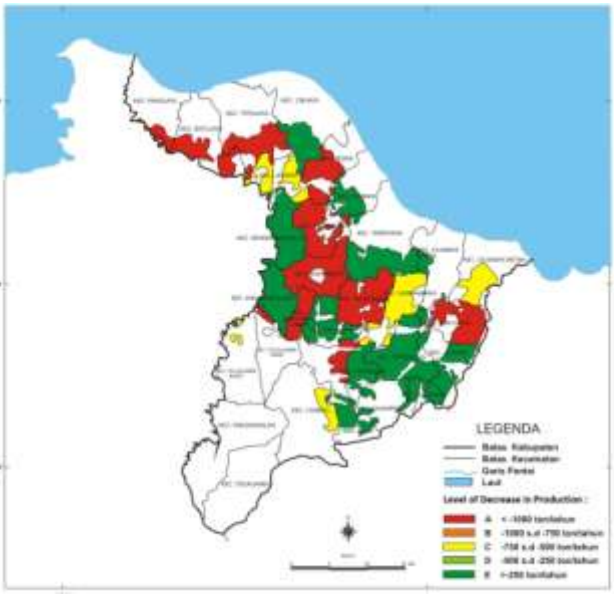

Figure 2: Level of reduced decrease in rice production in Karawang West Java Indonesia.

Potential areas for decreasing rice production in Karawang West Java are Teluk Jambe Timur, Banyusari, Telagasari, Karawang Timur, Rawamerta, Kutawaluya, Pedes, Tirtajaya, Batujaya, and Pakis Jaya. Potential reduction in productivity and harvested area cause decreasing rice production in Karawang West Java. If hazard becomes real, there will be a decrease in food supply, especially rice (paddy). Therefore, food security and food balance in West Java, as well as West Java's contribution as the national provision of rice stock, will be disturbed.

Local governments, farmers and related institutions need to adapt to face in the decline of rice production as a impacts of climate change in Karawang West Java (UNDP, 2007). Adaptation efforts are needed to prepare and anticipate the oncoming impacts (Howden *et al*., 2007; COST, 2012). The adaptation efforts to various climate change impacts need different strategies, such as adaptation to air temperature rise, drought disaster, wet season shift, change of precipitation frequency and quantity, and also other extreme events (FAO, 2007; Metternicht *et al.*, 2014).

4. Conclusions

If The impact of climate change has reduced harvested area and production of rice in Karawang West Java Indonesia. Decrease in rice harvested area was average of 77.0 ha per year. Decrease in rice production was average of 926.1 tons per year. Some area of Karawang West Java had high level of decrease in rice harvested area above 100 ha/year and decreased rice production over 1000 tons/ha.

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