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# A CORRELATION BETWEEN THE INCREASED TEMPERATURES AND THE PRODUCTIVITY OF LADANG IN KUTAI BARAT REGENCY, THE PROVINCE OF EAST KALIMANTAN, INDONESIA

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**Abstract:** The studies on the impact of global warming, particularly in the field of food production, could provide more accurate analysis to support a policy of food security. This research was conducted to find out the trends and the impact of the increase in the air temperature on the production of ladang (swidden field) in the Kutai Barat Regency. The results of the research carried out in some of the traditional rice fields indicate a technology that has barely changed, and organic based cultivation. During the period 1990–2015, air temperature increased leading to daily average of 21.2ºC–25.2ºC or an average increased by 0.16ºC/year. In the same period, the productivity of ladang increased by 1.872–3.195 kg $ha^{-1}$ or an average increased by 261 kg/hectare/year. Linear regression analysis results at the 5% level of significance showed the existence of the real correlation (r=0.7) between the average air temperature change and the productivity of the paddy fields.

**Key words:** global warming, swidden fields, productivity, correlation, organic cultivation, temperature.

## Introduction

The impact of changes in the dynamics of the weather at increased temperatures has been actually identified since early 1990s. Indonesia seems to have not prepared a comprehensive policy and operational strategies to adapt to changes in the dynamics of global weather. Some of the recommendations of the World Development Report (2008) are as follows: plant varieties that are highly adaptive, change the planting period adjusting to weather, and practice agriculture with a shorter growing period. In the context of Indonesia, farmers

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have a high level of vulnerability. In addition, due to the very small land holdings as well as weak access to various agricultural inputs as well as limitations on market access and agricultural processing, farmers' knowledge and 'know how' are very minimal about strategy on the adaptation of agricultural production to changes in global weather dynamics. Therefore, it is urgent to determine the impacts of climate change on crop production. This issue is worthwhile of concern as Eitzinger et al. (2010) have noted that such variability has undesirable effects on food production. This agronomic impact of climate variability on crop yields could trigger economic impulses reflected through its effects on agricultural prices, production, demand, trade, regional comparative advantage and producers' as well as consumers' welfare (Li et al., 2011). A considerable amount of literature has been published on paddy production. These studies show that its cultivation is constrained by factors such as solar radiation, temperature and water.

In East Borneo (Indonesia), shifting cultivation is a common practice for farmers to meet their own personal needs and the needs of fellow villagers (Ave and King, 1986). Swidden or shifting cultivation is an agricultural system practiced mainly in the tropics and is very prevalent in Indonesia (Angelsen, 1995). A so-called lading (swidden field) is planted with rice for one to several years, and rice is often intercropped with other useful food crops such as chilli peppers, cassava or bananas. When sufficient time has passed to restore fertility and reduce the weed population and agricultural pests, the field will be cleared and then reused for cultivation. The lading and fallow are traditionally controlled by the individual (usually male) by whom they were originally cultivated, or by his descendants. This swidden model has historically been practiced by upriver indigenous Dayaks (Inoue and Lahjie, 1990).

## Materials and Methods

Kutai Barat Regency, the province of East Kalimantan, is geographically located at 113°45'05"–116°31'19" L and between 1°31'35"N and 1°10'16"S. The total area of the County reaches 31.629 km$^2$. The topography is dominated by the mountains comprising 1,586,552.08 hectares (approximately 50%), while the flat topography of the region amounts to 10.35% or 327,400.84 hectares. Most of its territory is covered by forests of dipterocarpaceae lowlands (Anonymous, 2012).

The research was carried out in Kutai Barat Regency in several villages where there are still the actively managed traditional fields of rice cultivation system. We have used descriptive research methods, i.e., methods that discuss several possibilities to solve the problem with the actual path of collecting data, compiling, analysing, and interpreting them. The descriptive method of analysis was applied by describing the facts, followed by analysis, data analysis, research conducted using linear equations with two variables in the form of the following equation:

Y = a + bX, where,

Y = the change in productivity of rice fields (kgha$^{-1}$) and

X = annual air temperature changes averaging ($^{o}$C).

A simple correlation analysis (bivariate correlation) is used to find out the significance of the relationship between the two variables (productivity of paddy fields and temperature changes) as well as the direction of the relationship going on with the Pearson method:

$$r_{xy} = \frac{n\sum XY - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum x)^2)(n\sum Y^2 - (\sum Y)^2)}} \quad \text{Eq. 1}$$

## Results and Discussion

The research results of diversity of local rice Kutai Barat are the capital base that is very valuable for the development of the agricultural sector of food crops in support of the national food self-sufficiency program. Using microsatellite markers 30, Thomson et al. (2009) obtained 183 local rice cultivars collected from 15 villages along the Bahau and Kayan. From the fields of rice, 183 cultivars were analysed using DNA markers through the kinship, 80% of cultivars were identified and grouped into tropical Japonica and 20% were identified as Indica. In addition, Soedjito (1999) identified at least 44 local rice cultivars in the area of Kantu. In addition, Nurhasanah and Sunaryo (2015) collected 44 local rice cultivars in Kutai Barat Regency, consisting of 39 rice and 5 glutinous rice cultivars. Figure 1 showed that land area of paddy fields continued to decline in the last 10 years with the lowest extents in the year of 2015 (6,403 hectares) in comparison to the year of 1990 when the the productivity of paddy fields showed the highest value of 3.195 kg ha$^{-1}$ (Central Bureau of Statistics[a-e]). The vast acreage of paddy fields decreased due to the more active awareness of traditional belief not to open fields with a ‘slash and burn methods’. Therefore, more investors engaged in the plantation sector managed the traditional fields of the community as the concession (working area).

Air temperature data obtained from various institutions (Figure 2) shows an increase in the annual average temperature which is linier over a period of 25 years, 21.2–25.2ºC (Central Bureau of Statistics[a-e]). Therefore, in Kutai Barat Regency, air temperature changed by 4.0ºC or increased by 0.16ºCyear$^{-1}$. The relationship between changes in the production of paddy fields (Y) and the change (increase) in the air temperature (X) is shown through the equation Y = 1.66 + 0.85X, significant and strongly correlated ($r^2$ = 0.48).

Changes in air quality, microclimate, and soil moisture will produce bio-climates for new production systems of agriculture, particularly rice production systems. The main characteristic of the bio-climate among others is the $CO_2$ concentration, the higher the temperature the more heat, and extreme climate (El-Nino/La-Nina) will occur more frequently. International Rice Research Institute (IRRI) synthesises the influence of climate parameters on changing climate conditions, against the result and the production of rice. The increase in $CO_2$ gives rise to a positive impact on the biomass of rice, but depends on decreased results due to the rise in air temperature. For every 75 ppm $CO_2$ concentration increases, the yield of rice will rise by 0.5 t $ha^{-1}$. However, the result of rice will drop by 500 kg $ha^{-1}$ for every $10^{\circ}C$ rise in temperature. The results of research using the FACE (free-air $CO_2$'s) showed that the increase in yield due to $CO_2$ concentration is not as big as the one of a study using a closed system (enclosure chambers). The studies about wheat production affected by climate change are mainly concerned with future $CO_2$ concentrations (Lal, 2005; Yinhong et al., 2009).

Temperature rise and extreme weather events are one of the indicators of the changes in the dynamics of the weather (Mirza, 2003). Temperature is an indication of the amount of heat energy that is contained in a system or the mass. Temperature affects plants through its influence on the rate of metabolic processes. In addition, the influence of temperature is also seen on the development, the establishment of leaves, the initiation of productive organ, the maturation of the fruit and the age of the plant. Rising temperatures will accelerate the process of photosynthesis and biochemistry of plant development and accelerate the process of respiration. Respiration is limited to the oxidation of carbohydrates into $CO_2$ and $H_2O$ (Las et al., 2007; Amthor, 2002). Temperature increases crop development to some extent. The relationship of temperature with plant growth shows a linear relationship to a certain extent, having reached the point of maximum (peak) of the relationship of the two variables that indicates the relationship of the parabola.

Temperatures increase the rate of growth to form a straight line (linear) where the curve is the exponential function together with temperature. At this stage, the heat energy can turn the entire system (device) growth. Hence, the efficiency of the use of thermal energy by plants is large. Thermal energy is being wasted on a small amount of heat energy, or captured molecules can increase the movement of molecules in the tissues of plants (Allen, 2000; Anwar et al., 2007; Koesmaryono et al., 2002). Research shows that the productivity of rice in China will decrease by 5–12% in a temperature increase of 3.6ºC.The same case on wheat production in Bangladesh is decreasing as its neighbors in 2050 compared to current production if a temperature increase occurs. Possible effects of global warming on the rice cultivation in Indonesia are not much different than in

China or Bangladesh, or perhaps they are much worse during the long dry season when the rainy season fails to come (Challinor, 2008; Jerry and Prueger, 2015).

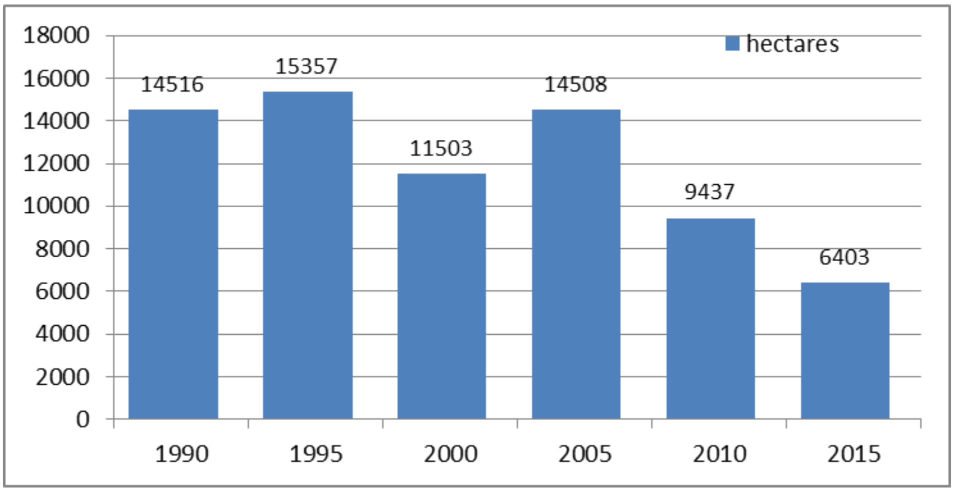


Figure 1. Land area of paddy fields.
(Central Bureau of Statistics[a-e])

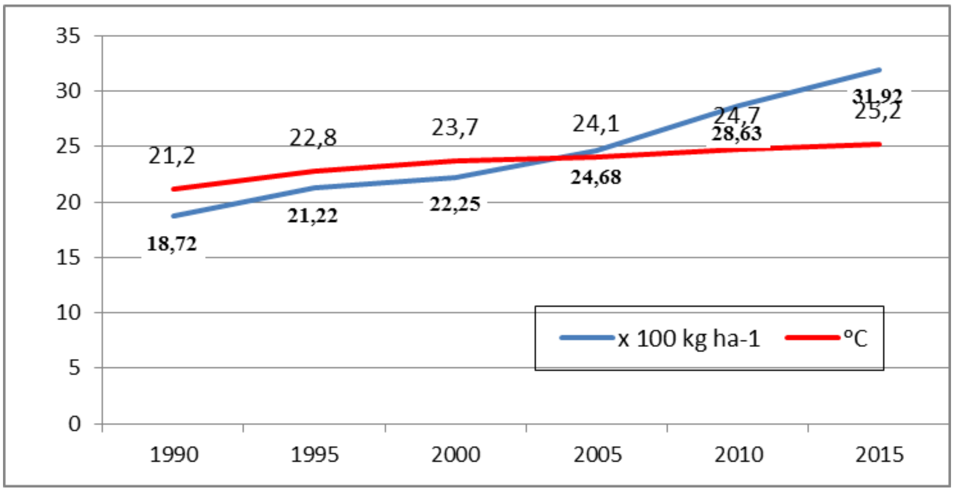


Figure 2. Temperature average (°C).
(Productivity kgha$^{-1}$)

The contribution of Kutai Barat Regency in sufficient food needs (rice) nationally is still low, although it has the potential of vast paddy fields. This is due to the level of a relatively low soil fertility causing the productivity of rice (the rice and paddy fields) in Kutai Barat to be low, i.e. 2.5 to 3.5 $tha^{-1}$. Regarding the rice plant, a floret, anthers and pollen are more sensitive to high temperature than ovules, and floret sterility at temperatures ≥30°C has been correlated with diminished anther dehiscence, production of fewer pollen grains, pollen sterility, and reduced *in vivo* pollen germination. Grain sterility temperature quickly rises, more than 35°C (Mitsui et al., 2000; Jagadish et al., 2010), and the increase in $CO_2$ in conjunction with high temperatures can make things worse, because of the fall in the cooling of the plant through transpiration (Amthor, 2001; Yinhong et al., 2009).

The average air temperature in the House plant belongs to the optimum temperature for rice crops, namely within the range of 20–28ºC (Yamaguchi, 1983). Salisbury and Ross (1995) describe the thermo-periodisme that is a phenomenon that shows that the growth and development of crops are enhanced by the day and night temperature alternately. The establishment of a rice grain enhanced by a low night temperature rise in the temperature of the night has been the main cause of the rise in global temperatures since the mid-20$^{th}$ century and the results showed negative correlations of rice with nighttime temperatures. The reason for this negative correlation is variation of solar radiation, the loss due to respiration or the effect of differential influence of night temperature. A significant difference of grain yield between low night temperature and high night temperature treatment was observed in all experiments. Grain yield at high night temperature was decreased by 16.7%, 9.1%, 9.6% and 8.0% in the four consecutive seasons, respectively (Sheehy et al., 2005)

Warming will accelerate a lot of processes in the system soil-microbiology puddles, which is consequently in a cycle of N and C. Soil temperature rise can also raise the $CO_2$ auto-trop from land loss due to roots, root exudate and turnover of fine roots. Rice plant that grows at high ground temperature can change the partition of C and N compared with this growing at low soil temperatures (Lynch and St. Clair, 2004). The temperature of the heat is the appropriate temperature for rice crops. A rice plant can grow well at a temperature of 24–30ºC. The optimum temperature is the right temperature for rice growth and development circumstances. The relationship of temperature with plant growth is explained in a ‘remainder index’ or heat unit, i.e. a method of approach between agronomy and climatology. Temperature of a raw plant was measured in a controlled experiment in the growth chamber. Cardinal temperature is a temperature point that shows the non-occurrence of the physiological processes of the plant. Raw temperature varies for each plant and in every process of development. Examples of raw temperatures are as follows: for potato 7.2ºC, corn 10ºC, rice 10ºC, soybean 7.8ºC and cotton 16.6ºC (Hatfield et al., 2011). Figure 2 shows the temperature conditions based on an annual average in the center of rice fields are in the optimum temperature range for rice cultivation including the paddy fields.

## Conclusion

The area of paddy fields at Kutai Barat Regency shows a declining trend, with increasing air temperature positively and strongly ($r^2$ = 0.48) with increased production of rice fields, because the temperatures of the center of paddy production are in the optimum temperature range.

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# KORELACIJA IZMEĐU POVEĆANIH TEMPERATURA I PRODUKTIVNOSTI NA GAZDINSTVIMA U ADMINISTRATIVNOJ OBLASTI KUTAI BARAT, PROVINCIJA ISTOČNI KALIMANTAN, INDONEZIJA

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## R e z i m e

Istraživanja o uticaju globalnog zagrevanja, posebno u oblasti proizvodnje hrane, mogla bi pružiti tačniju analizu, koja bi podržala politiku prehrambene sigurnosti. Ovo istraživanje je sprovedeno kako bi se utvrdili trendovi i uticaj povećanja temperature vazduha na proizvodnju na gazdinstvu (raskrčeno zemljište) u administrativnoj oblasti Kutai Barat. Rezultati istraživanja sprovedenog na tradicionalnim pirinčanim poljima obuhvataju tradicionalnu tehnologiju i organski sistem proizvodnje. Tokom perioda 1990–2015, temperatura vazduha se povećala vodeći ka dnevnom proseku od 21,2ºC–25,2ºC i prosečno se povećala za 0,16ºC godišnje. U istom periodu, produktivnost proizvodnje na gazdinstvu povećala se za 1,872–3,195 kg $ha^{-1}$, što je u proseku bilo povećanje od 261 kg po hektaru godišnje. Rezultati linearne regresione analize na nivou značajnosti od 5% pokazali su da postoji realna korelacija (r=0,7) između promene prosečne temperature vazduha i produktivnosti pirinčanih polja.

**Ključne reči:** globalno zagrevanje, raskrčeno zemljište, produktivnost, korelacija, organska poljoprivreda, temperatura.

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