PERFORMANCE OF DROUGHT MONITORING METHODS TOWARDS YIELD ESTIMATION OVER RICE CROPPING AREA IN JAWA ISLAND, INDONESIA

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ABSTRACT: In Indonesia, drought impacts in rice cropping are getting more and more serious problems due to climate anomalies such as El Ni-no and La Nina. So, it is indispensable to devise a method to detect a drought and evaluate its impact on rice yield in advance. This study aims to develop drought indices and investigate the performance of them as indicators of rice yield. First of all, two types of drought indices are developed to detect climatic drought by combining rainfall and land surface temperature retrievals, and agricultural drought by vegetation index from a bunch of satellite observations. Secondly, the performance of drought indices is investigated as compared with rice crop yield at the sub-province spatial scale (10-50km). It is expected to be an effective countermeasure to mitigate the influence of droughts and used as a cost-benefit analysis of an economic loss due to climate change scenarios and contributed to a regional agricultural planning policy for an investment in irrigation infrastructure.

1. INTRODUCTION

1.1 Background

In most regions of Indonesia, rice is the main staple food and the stability of the rice sector which is the largest employer in the agricultural economy is very important. However, it is known that rice production in Indonesia is strongly influenced by annual and inter-annual changes in precipitation caused by El Nino Southern Oscillation (ENSO) and the Austral-Asia monsoon. Under El Nino, which is the warm phase of ENSO, Indonesia has experienced a delay in the monsoon onset, a reduction of rainfall and the following severe droughts, these natural phenomena have a great influence on rice yields. Statistically speaking, historical data say that a 30-day delay in the monsoon onset and droughts in the planting season causes rice production on Java and Bali to fall by 1.12 million tons on average for the January-April harvest season alone (Naylor and Mastrandrea, 2009). This fact implies that droughts, mainly in the planting season, are related to rice production.

Generally, droughts do heavy damage to the economy of the countriy concerned. For example, from 1997 to 1998 severe droughts were caused in Southeast Asia and Australia by the climate anomaly of strong EL Ni-no, they led to not only a sharp reduction of agricultural produce but also large forest fires. As a result, the amount of damage of the whole world reached thirty four billion dollars according to the report from World Meteorological Organization. To cite a recent example, severe droughts also happened in 2009 and caused a great deal of economic loss to Southeast Asian countries including Indonesia. To make matters worse, droughts' impacts on rice cropping are getting more and more serious from year to year because of the influence of intensifying climate anomalies like El Ni-no and La Nina. For the reasons above, it is longed very much to develop a method to detect a drought and evaluate its impact on rice yield in advance for mitigating the influence of droughts and formulating appropriate agricultural investment policy.

1.2 Objective

Under the Background mentioned above, this study aims to devise a method to detect a drought and evaluate its impact on rice yield in advance. In other words, this study challenges to develop two types of drought indices which show the dryness of the ground from different angles such as climate conditions or vegetation, and to investigate the performance of them as indicators of rice yield by associating the indices with the past rice production. Actually, there are already some researches that investigate a relationship between rice production and agricultural drought index, NDVI which shows vegetation condition of the ground. However NDVI is only a measured value and it is impossible to evaluate future rice production influenced by droughts with NDVI. On the other hand, we can estimate rice yields with climatic drought index, KBDI, by inputting forecasted precipitation and the like into the model. Therefore, KBDI is essential for evaluating droughts' impact on rice yield in advance. In this study we mainly focus on KBDI and investigate the relationship between rice production and KBDI.

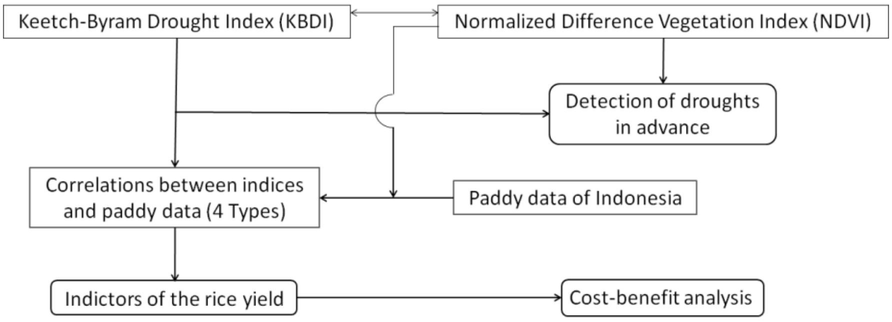


Figure 1. Schematic diagram of this study

2. METHODOLOGY

2.1 Target Area

This study is mainly targeting Java Island (West Java, Central Java and East Java) in Indonesia. In addition, the islands of Bali and Nusa Tenggara are also included. The total population of Java and Bali Island reach as much as over half of the whole Indonesian population, and the islands, which are strong on rice cropping particular in the monsoon season, account for about fifty five percent of the nation's rice production. Moreover, though there are various cropping systems in Indonesia such as the Maluku's dryland cassava system, Borneo's oil plantation and the like, the islands of Java and Bali are dominated by rainfed system, which greatly have a close relationship to the timing of monsoon onset and precipitation in the main plantation season. For the reasons above, these areas are expected to offer the best performance to find out correlation of droughts with rice production. Nusa Tenggara is also in the similar situation.

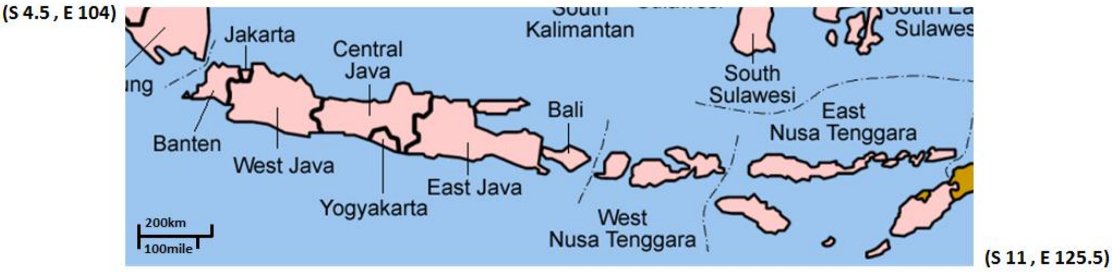


Figure 2. Target area in Indonesia

2.2 Drought Index

The Keetch-Byram drought index (KBDI) is a continuous reference scale for estimating the dryness of the soil and duff layers. The index increases for each day without rain (the amount of increase depends on the daily high temperature) and decreases when it rains. The scale ranges from 0 (no moisture deficit) to 800. The range of the index is determined by assuming that there is 8 inches of moisture in a saturated soil that is readily available to the vegetation (Keetch, 1968). KBDI is world-widely used for drought monitoring for national weather forecast and wild fire prevention. Our challenging in this study is now to find out a relationship between this index and rice production.

2.3 Paddy Data Processing

In this study, we hire the paddy data made public by BADAN PUSAT STATISTIK (BPS), the Indonesian bureau of statistics. Regarding the paddy data of Bali, there were some obvious mistakes (some numbers were one digit off), so we corrected them by inserting 0 into the first digit. Figure3 shows the rice yield per a hectare of the whole Indonesia from1993 till 2010. To exclude the effect of expansion of paddy fields to the growth of rice production, we hire this "rice productivity" as paddy data.

As the blue line in Figure3 shows, though there are some years when the rice production decreased due to severe climatic conditions, the rice yield of each year is gradually increasing because of an investment in irrigation infrastructure, chemical fertilizer, an increase of population and so on. In 2009 the productivity reached as much as 5 tons per a hectare and it can be said that Indonesia is relatively at a high level in terms of rice productivity as compared with that of advanced nations, about 6.5 tons per a hectare. The most important point in Figure3 is that a productivity of a certain year is strongly influenced by dry climate conditions of the end of the preceding year, which is the main plantation season for the January-April harvest season. For example, the productivity of 1998 shows a sharp reduction due to the severe droughts which occurred in the end of 1997.

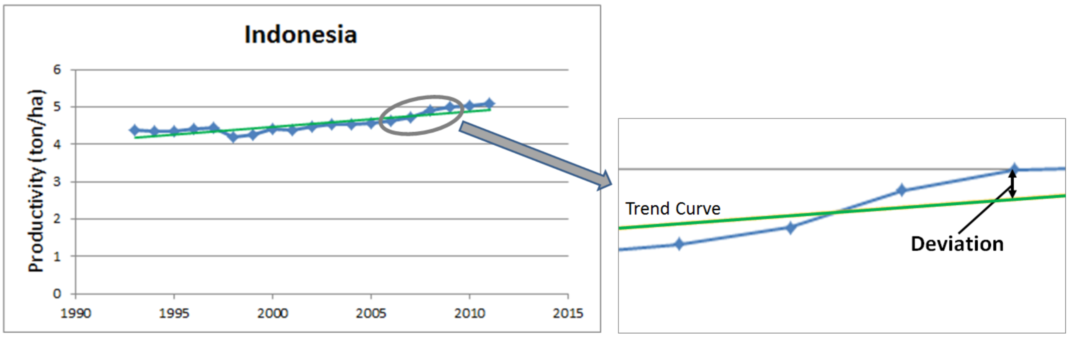
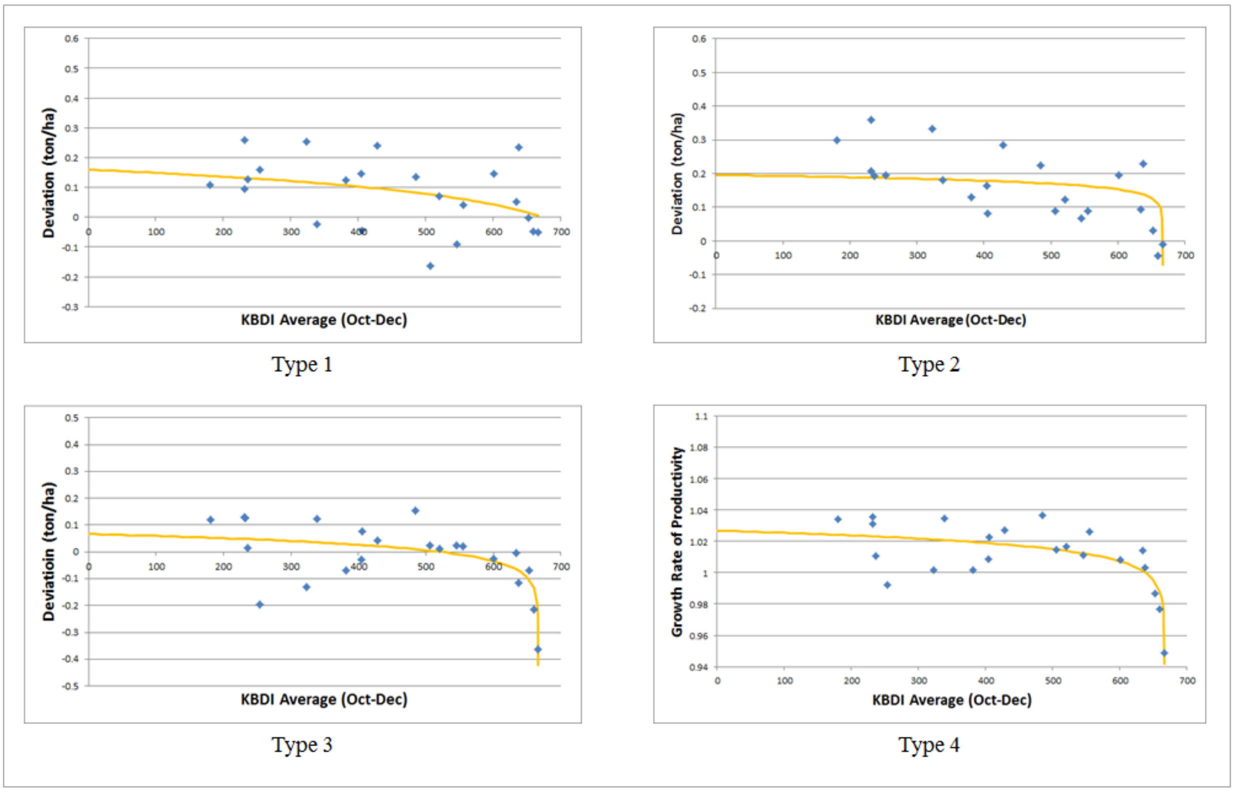


Figure 3. The rice productivity of Indonesia (Sourced by BPS)

Then, we move on to the explanation of how to process the paddy data. The first step is to calculate the trend curves. In this study, we hire three types of trend curves; the curves computed by Type1.liner approximation, Type2.moving average and Type3.compound growth rates. In the way with compound growth rate, at first we calculate every-year annual growth rates of rice productivity based on the actual paddy data. Next, we take averages of them in the past five years and can finally get the calculated values of each year by multiplying the averages (compound growth rates) and the each productivity of the preceding year. This turns out to be the trend curve. For example, if you want to get the calculated rice productivity of 2010, you will compute the compound growth rate from five annual growth rates between 2004 and 2009 and multiply it by the productivity of 2009. Regarding 5-year moving average and liner approximation, it is unnecessary to explain. Finally, the deviations can be calculated by subtracting computed values from the actual rice productivity for each type (shown in Figure3) and these deviations are used as a variable corresponding to KBDI. In addition to that, we also hire Type4.annual growth rates of productivity as a variable.

3. RESULTS AND DISCUSSION



Type 1

Type 2

Type 3

Type 4

Figure 4. Correlation of KBDI with paddy data

Figure4 shows the correlation of averaged KBDI from October to December (observed from the end of 2006 to 2009), the main plantation season for the January-April harvest season, with deviations of each type or growth rates of productivity. However, the deviations of East Java and West Nusa Tenggara in 2008 are both removed because they obviously seem to have other influential factors except droughts underlying fluctuations in rice productivity. As mentioned above, a productivity of a certain year is strongly influenced by dry climate conditions of the end of the preceding year; we supposed that the averaged KBDI of 2006 is corresponding to the paddy data of 2007 for instance. The yellow curves in Figure4 are approximated curves by the equation1.

$$y = \log_a (b - x/100)/c + d \tag{1}$$

Each fixed number is calculated to minimize RMSE with the Microsoft Excel solver. Computed fixed numbers and RMSE are shown in Table1.

Table 1. RMSE and correlation coefficient for each type

	a	b	c	d	RMSE	Correlation Coefficient
Type1	1.82E+01	7.74	4.40	0	0.11	0.38
Type2	2.27E+14	6.67	1.65	0.16	0.08	0.60
Type3	4.67E+05	6.67	1.76	-0.02	0.08	0.72
Type4	2.30E+14	6.67	3.57	1.011	0.013	0.80

As Table1 shows, there seems to be strong correlation described as the equation between the growth rates of rice productivity and averaged KBDI from October to December. When the value of averaged KBDI exceeds a threshold, about 600, growth rates are rapidly decreasing, though there appears to be some potential effects that make growth rates thrust up such as expansion of investment in agriculture. However, at relatively low KBDI, the correlation gets weak and the unevenness is enlarging. Actually, when we applied this method to other regions where KBDI is rather at low level, it didn’t work well because other effects except dry climatic conditions get more influential. In addition, it’s needed to give enough thought to the fact that two rice crops are raised in the islands of Java and Bali, though a monsoon season’s harvest is larger.

4. CONCLUSION AND FUTURE WORKS

The results imply that KBDI is possibly related to rice production. However, there is no clear evidence that proves the correlation at the moment. On the other hand, there are already some researches that investigate a relationship between rice production and agricultural drought index, NDVI, and it is known that they are related to each other. So the next work is to investigate a correlation of KBDI with NDVI. For example, if NDVI of a certain place where droughts take place is decreasing, it can be said that there are some correlations. After that, we finally use this method as a cost-benefit analysis of an economic loss due to climate change scenarios and contribute to a regional agricultural planning policy for an investment in irrigation infrastructure.

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