PERFORMANCE OF DROUGHT MONITORING METHODS TOWARDS RICE YIELD ESTIMATION IN GREATER MEKONG SUB-REGION(GMS)

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KEY WORDS: Climate Anomaly, Evapotranspiration, Rice crop monitoring, Economic Loss, Investment for Irrigation

ABSTRACT

In the Greater Mekong Sub-region (GMS), rice is the main staple food in most parts of the region and the rice sector is the largest employer in the agricultural economy overall. However 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 build a rice crop monitoring system that provides the dryness of the paddy field and rice growth conditions in quasi-real time by developing vegetation and agricultural climate indices. Furthermore, this research also intends to estimate near-future rice production at sub-provincial level by utilizing the indices with experiential and theoretical prediction model. This method is expected to contribute to a regional agricultural planning policy for an investment in irrigation infrastructure. In this paper, we mainly focus on building rice crop monitoring, and try to read the characteristics in rice cropping at sub-provincial level. First of all, we search paddy fields by visual observation of satellite photographs for 200 provinces each in the GMS countries. Secondly, three types of vegetation and agricultural climate indices are developed to detect climatic drought by combining rainfall and land surface temperature retrievals, and monitor rice growth conditions from a bunch of satellite observations. Thirdly, with that monitoring data, the rice-planting patterns are analyzed at provincial level, especially focusing on the number of rice cropping in a certain year. After that, the performance of vegetation and agricultural climate will be investigated as compared with rice crop yield at the sub-province spatial scale, and finally it is possible to estimate rice production for each region with experiential forecasting model made by means of statistical analysis.

1. INTRODUCTION

1.1 Background

In the GMS countries, rice is the main staple food and the stability of the rice sector that is the largest employer in the agricultural economy is very important. However, it is widely known that rice production in South-east Asia 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, South-east Asian countries have experienced a delay in the monsoon onset, a reduction of rainfall and the following severe drought season, these natural phenomena have a great influence on rice yields. Statistically speaking, in Indonesia, 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 overall economy of the countries 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 HighBeam Research. To cite another example, drought affected large areas of Thailand and Cambodia in 2004, even though total annual rainfall was close to the long-term average. Almost no rain fell in the last three months of the year, a period that is critical for rain-fed rice, resulting in a 30% fall in farm output (IWMI report, 2012). 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, to mitigate drought impacts on rice yield, this study aims to build a rice crop monitoring system that provides the dryness of the paddy field and rice growth conditions in quasi-real time by developing vegetation and agricultural climate indices. Furthermore, this research also intends to investigate the performance of the indices as indicators of rice yield by associating the indices with the past rice production. With the experiential prediction model, we can estimate near-future rice production at sub-provincial level from the present values of the indices. Finally, this method is expected to contribute to a regional agricultural planning policy for an investment in irrigation infrastructure. In this paper, we mainly focus on building rice crop monitoring, and try to read the characteristics in rice cropping at sub-provincial level.

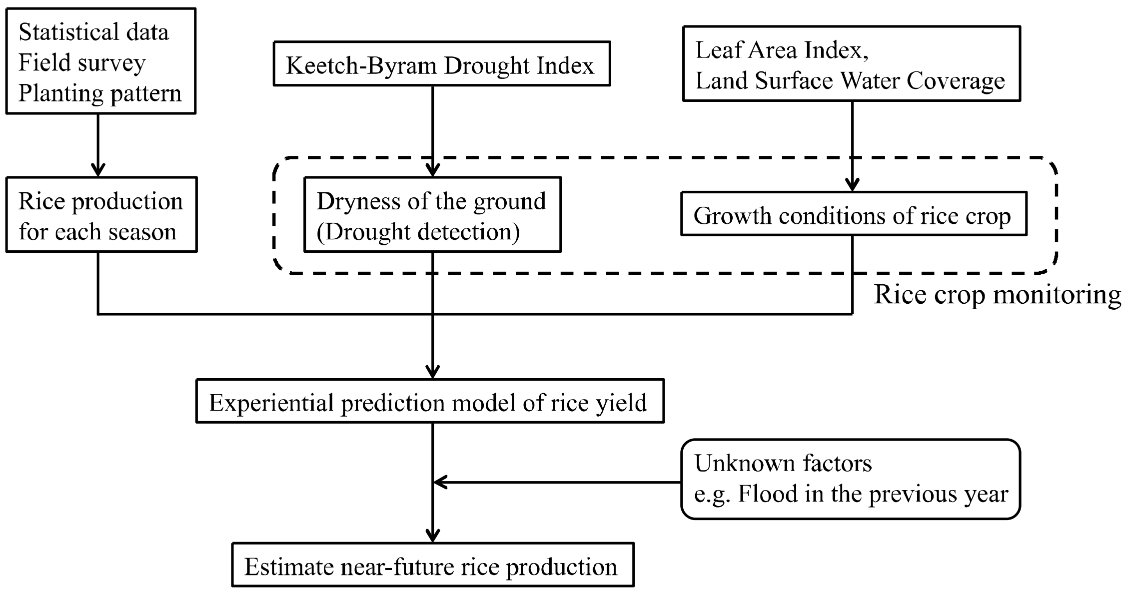

Figure 1. Schematic diagram of this study

2. METHODOLOGY

2.1 Target Area

This study is mainly targeting the Greater Mekong Sub-region. According to IWMI research report 136, the total population around the GMS reaches as much as 275 millions in 2012, and the area is very strong on rice cropping. Actually, the large irrigated areas around the Southeast Asian big rivers including Mekong is called as “rice bowls” of the region. In 2005 they produced half of the region’s production and around 8% of the global crop, though they constitute only 10% of the total land area. Moreover, most of the agricultural lands in the GMS are dominated by rain-fed system, which greatly have a close relationship to the timing of monsoon onset and precipitation in the main plantation season. IWMI report in 2010 also said that around 75% of crops are yielded from rain-fed agriculture. For the reasons above, these areas are very suited for applying the rice crop monitoring method and expected to offer the best performance to find out correlation of droughts with rice production.

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 to find out a relationship between this index and rice production.

2.3 Leaf Area Index

Monitoring the distribution and changes of Leaf Area Index (LAI) is important for assessing growth and vigor of vegetation on the planet. It is fundamentally important as a parameter in land-surface processes and parameterizations in climate models. This variable represents the amount of leaf material in ecosystems and controls the links between biosphere and atmosphere through various processes such as photosynthesis, respiration, transpiration and rain interception. LAI is one of the primary measures used in remote sensing and process-based models to characterize plant canopies. LA1 estimates are used for measuring the leaf reflective surface within a canopy. Until now excellent measurements of LA1 have been made for small-stature vegetation such as agricultural crops and plantations. In this study, we use this index for monitoring rice growth conditions.

2.4 Land Surface Water Coverage

Land surface water coverage (LSWC) indicates the quantity of water content on land surface (Takeuchi et al., 2009). LSWC is calculated by integrating normalized difference water index (NDWI) and normalized difference frequency index (NDFI). NDWI is a satellite-derived index from the visible (VIS) and Short Wave Infrared (SWIR) channels derived from Moderate resolution imaging spectro-radiometer (Takeuchi et al., 2004), and it is sensitive to vegetation water content and open water. NDWI can monitor flood patterns at finer spatial resolution than AMSR-E at the expense of cloud contamination. On the other hand, NDFI is derived from the brightness temperature of vertical polarization at 18.7GHz and 23.8GHz. It is less affected by atmospheric conditions and not dependent on the soil temperature. NDFI provides a sensitive indicator of the presence of surface water and it has a good capability to distinguish the water surface and land surface (Takeuchi et al., 2006).

2.5 Planting Pattern Analysis

First of all, we search paddy fields by visual observation of satellite photographs for 200 provinces each in the GMS countries. Secondly, three types of vegetation and agricultural climate indices are developed to detect climatic drought by combining rainfall and land surface temperature retrievals, and monitor rice growth conditions from a bunch of satellite observations. At last, with that monitoring data, the rice-planting patterns can be analyzed at provincial level, especially focusing on the number of rice cropping in a certain year.

3. RESULTS AND DISCUSSION

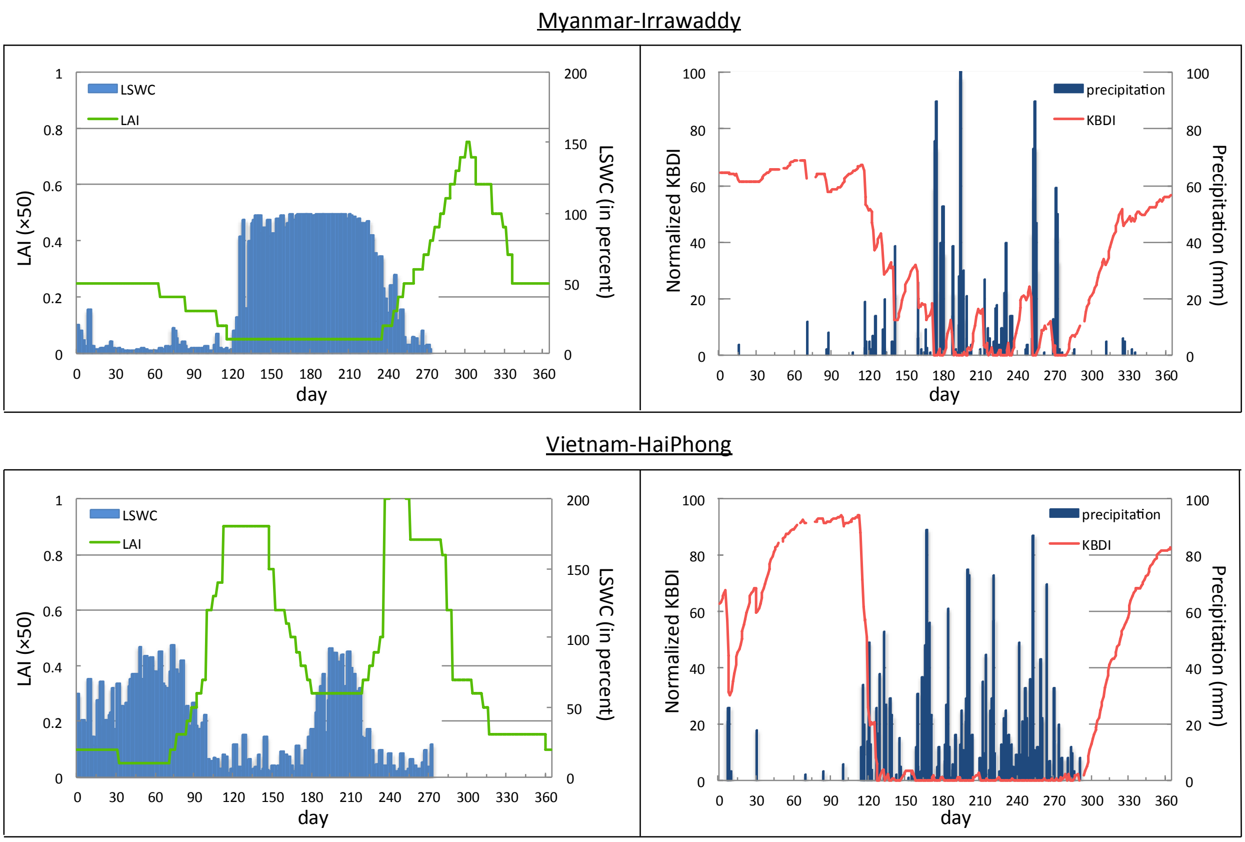

Figure 2. KBDI, LAI and LSWC in 2011

The figure above shows the result of index calculation, especially for two of 200 provinces. Looking at the result of Irrawaddy, it can be observed that LAI approaches the peak after LSWC increased rapidly. This fact implies that after water content on land surface gets larger and deeper some vegetation grow. This is exactly what single-season cropping is conducted at Irrawaddy in 2011. On the other hand, in the graph of HaiPhong, LAI peaks twice after the sharp increases of LSWC. Based on this result, it turns out that double-season cropping dominates in HaiPhong.

Next, taking notice of relationship of KBDI with LSWC or precipitation, there seems to be a correlation between them in the graph of Irrawaddy. However, in the graph of HaiPhong, KBDI is just influenced by precipitation, and the value is still at high level when LSWC gets increased. This difference can be accounted for by the result that most of paddy fields in HaiPhong are irrigated.

4. CONCLUSION AND FUTURE WORKS

The graphs show that the dryness of paddy fields and rice growth conditions can be monitored in quasi-real by developing vegetation and agricultural climate indices. Moreover it is proved that rice-planting patterns can be analyzed at provincial level by the indices. With this information, we can take an annual rice yield apart to that of each season. What to do next is to investigate the performance of vegetation and agricultural climate as compared with the rice crop yield. Actually, there are already some researches that investigate a relationship between rice production and LAI. However LAI is only a measured value, and LAI doesn't make it possible to evaluate near future rice production under droughts. On the other hand, we can estimate rice yields with drought index, KBDI, by inputting forecasted precipitation 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 will investigate the relationship between the index and LAI, namely rice production.

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