ORAL 05

Relationship Between Rice Yield and Abnormally Meteorological Features for El-Niño Years in South Korea

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I. Introduction

The concentration of greenhouse gases such as carbon dioxide, methane, and nitrous oxide has increased since 1750 by anthropogenic activities. The rapid increase of greenhouse gases in the atmosphere has enhanced the greenhouse effect which has been causing the global warming. When calculating by linear trend, the average temperature of the earth showed a temperature rise of 0.85°C (0.65-1.06) in the last 133 years (1880-2012) (IPCC, 2013). Now that global warming is underway, the El Niño/La Niña phenomenon in the equatorial pacific ocean brings us a serious problems. With the global warming, El Niño phenomenon has been the subject of numerous studies because its influence is widespread and strong. In particular, a study on the effect of global warming and change of precipitation patterns occurred by El Niño has been actively investigated. Korea Meteorological Administration (KMA, 2016) reported that abnormally meteorological phenomena are more likely to appear and could lead to meteorological disasters in various forms depending on the area when El Niño occurs. KMA (2016) also reported that the winter of El Niño years was characterized by warm and frequent rainy weather in South Korea. This El Niño affects the global climate change, which will lead to a variety of unusual weather phenomena by region. It is considered to have a major impact on agriculture, which is the most dependent on weather condition. Nevertheless, study assessing the El Niño impacts on agriculture is very little in South Korea. In this paper, we analyze the relationship between rice yield and abnormally meteorological features for El Niño years (with more than 1.0 Oceanic Niño Index) since 1980 in South Korea.

II. Materials and Methods

2.1. El Niño years

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NOAA uses the Oceanic Nino Index (ONI) for identifying El Niño (warm) and La Niña (cool) events in tropical pacific. It is the running 3-month mean Sea Surface Temperatures (SST) anomaly for the Niño 3.4 region. Events are defined as 5 consecutive overlapping 3-month periods at or above the 0.5 anomaly for warm (El Niño) events and at or below the –0.5 anomaly for cold (La Niña) events. The threshold is further broken down into Weak (with a 0.5 to 0.9 SST anomaly), Moderate (1.0 to 1.4), Strong (1.5 to 1.9) and Very Strong (≥2.0) events (Fig. 1). More than Moderate events of El Niño, which consist of 1982-1983, 1986-1987, 1991-1992, 1994-1995, 1997-1998, 2002-2003, and 2009-2010, were selected and used for the study (NOAA, 2016).

2.2. Rice yield analysis

Yearly Rice (the ratio of milled rice to brown rice is 92.9%) yield per unit area (10a=1000 m^2) of paddy field was downloaded from the Korean Statistical Information Service (KOSIS, 2016) operated by the Statistics Korea (KOSTAT) for 30 years from 1981 through 2010. Rice yield which is produced in Seven Metropolitan cities and Jeju Island were excluded from the analysis because their rice cultivation areas are extremely small.

2.3. Abnormally meteorological analysis

Daily meteorological data, such as air temperature, precipitation, and sunshine hours, was downloaded from National Climate Data Service System (NCDSS, 2016) of Korea Meteorological Administration (KMA) for 30 years from 1981 through 2010. Meteorological data of 48 sites was used in this study with excepting for 13 sites where rice has not been cultivated, among 61 observation sites holding continuous climate data during the past 30 years.

Abnormally meteorological analysis was carried out by the standard deviation method defined by the World Meteorological Organization (WMO). That is, when the difference in the normal (M) is higher or lower than ±2 multiplied standard deviation (S), the occurrence of abnormal meteorology was defined. Abnormal meteorology consists of abnormally high (and low) temperature, abnormally long (and short) sunshine duration, and abnormally much (and little) precipitation.

2.4. Statistical analysis

The t-test and one-way ANOVA were used to determine whether the means of two (El Niño years and non El Niño years) and three groups (El Niño start years, El Niño end years, and non El Niño years) are statistically different from each other and one another, respectively. Independent variables for the t-test are rice yields (or occurrence frequency of abnormal meteorology) of El Niño years (n=14) and non El Niño years (n=16), and three variables for one-way ANOVA are rice yields (or occurrence frequency of abnormal meteorology) of El Niño start years (n=7), El Niño end years (n=7), and non El Niño years (n=16).

III. Results

3.1. Change of yearly rice yield

The national averaged rice yield was 427 kg (±30.5) $10a^{-1}$ for the past 30 years (1981-2010). It has tended to increase by 23.4 kg per 10 years with the statistical significance ($p<0.001$) (Fig. 2). An increasing trend of rice yield per unit area was statistically significant in most Provinces (excepting Jeonnam province).

3.2. Relationship between El Niño events and rice yield

3.2.1. t-test

When removing the residuals according to the increase tendency of rice yield, the national averaged rice yield of El Niño years (n=14) was 466.3 kg $10a^{-1}$, and was less than that of non El Niño years (n=16) by 10.2 kg $10a^{-1}$ with non statistically significant (t=1,215, p=0.234). These results were also showed in administrative districts (Provinces) analysis. That is, averaged rice yield for El Niño years was less than non El Niño years, but the trend was not significant statistically.

3.2.2. one-way ANOVA

The national averaged rice yield of El Niño start years (n=7) was 476.7 kg $10a^{-1}$ with the similar to that of non El Niño years (476.4 kg $10a^{-1}$). On the other hand, that of El Niño end years was analyzed to be less than non El Niño years by 20.6 kg $10a^{-1}$ with non statistically significant (df=2, f=2.355, p=0.114). In administrative districts analysis, rice yield of El Niño end years in most provinces was lower, but that the trend is not statistically significant except in Chungnam province. Averaged rice yield of El Niño end years (479.7 kg $10a^{-1}$) was lower than that of El Niño start and non El Niño years by 32.0 and 33.4 kg $10a^{-1}$, respectively, with statistically significant trend (df=2, f=4.607, p=0.018).

3.3. Relationship between El Niño events and abnormal meteorology

Total 18 frequencies of abnormal meteorology have occurred for the past 30 years (1981-2010). In detail, abnormally much precipitation has occurred most often with 6 frequencies, followed by abnormally low temperature (5 frequencies). Whereas abnormally long sunshine hour was analyzed not to occur over the past 30 years even one. Occurrence frequency of abnormal meteorology of El Niño end years was 0.71 per year. It was analyzed to be more than that of El Niño start years (0.43) and non El Niño years (0.63) with non statistically significant trend (df=2, f=0.321, p=0.727). In administrative districts analysis, abnormal meteorology occurred more frequently in El Niño end years than in El Niño start years and non El Niño years. However, the trend was not statistically significant in all provinces.

Occurrence frequency of abnormal meteorology of El Niño end years (0.57 yr^{-1}) in Chungnam province, where rice yield of El Niño end years was low with statistical significance, was more than El Niño start years (0.14 yr^{-1}) but less than non El Niño years (0.62 yr^{-1}). So, we understood that the low rice yield of El Niño end years was not affected by the abnormal meteorology but severe weather such as typhoon, concentration rainfall.

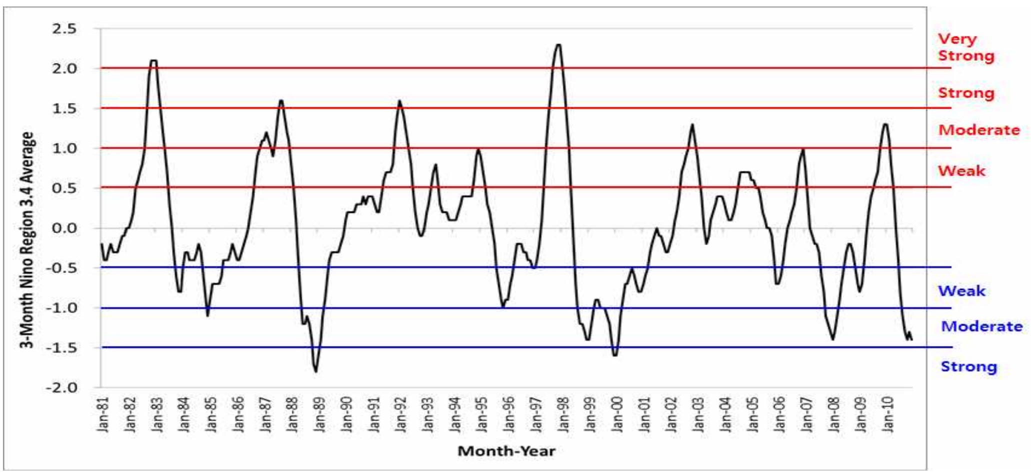

Fig. 1. El Niño and La Niña Years and Intensities Based on Oceanic Niño Index (ONI).

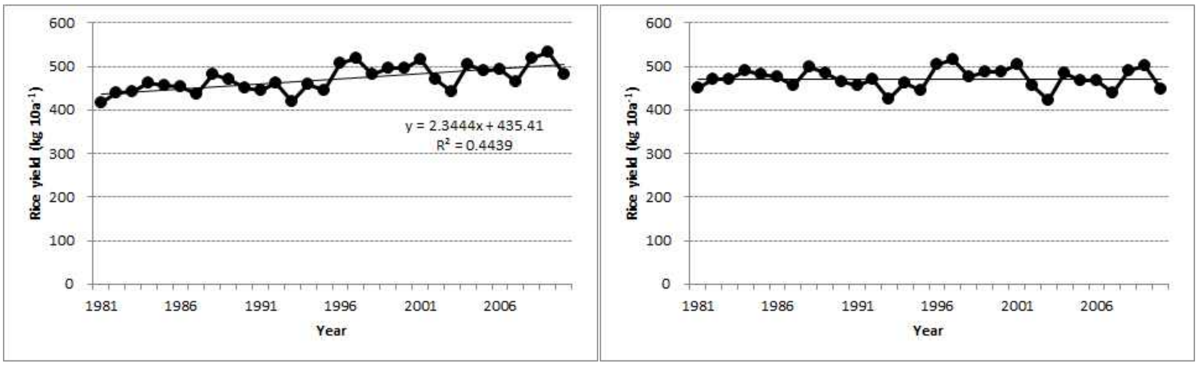

Fig. 2. Yearly change of nationally averaged rice yield (right : rice yield after removing the residuals according to the increase tendency).

Acknowledgements

This study was carried out with the support of “Research Program for Agricultural Science & Technology Development (Project No. PJ01000701)”, National Academy of Agricultural Science, Rural Development Administration, Republic of Korea.

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