The Influence of Drought and Flood Disasters on Rice NDVI in Summer

Meihua Piao, ZHANG Hongyan*, Jianjun Zhao, Xiaoyi Guo

School of Geographical Science, Northeast Normal University, Changchun, Jilin 130024, China
E-mail: piaomh766@nenu.edu.cn , zhy@nenu.edu.cn

Abstract: During the period from 1995 to 2010, flooding and drought occurred frequently in North Korea. This greatly affected agriculture. The precipitation data was the main factor evaluated in flood and drought monitoring. In this study, the Z index method was used to estimate the change in precipitation, calculated from TRMM (Tropical Rainfall Measuring Mission) data. The Z index and the NDVI were combined with the map of distribution of rice to analyze the relationship between the Z index and NDVI during the growing months of rice in recent 12 years. The results revealed that the Z index is a good indicator to study the relative changes of precipitation in North Korea, and that the relationship between the Z index and NDVI in a quadratic function.

Keywords: Z index, NDVI, flood and drought.

1. Introduction
It has been reported that global warming frequently gives rise to abnormal weather. As such weather causes considerable damage to agriculture, it is important to evaluate the influence quickly and secure the food supply. Remote sensing techniques are advantageous for collecting information over large areas and in places that are inaccessible on the ground, and they can help greatly means to estimate the influence resulting from abnormal precipitation.

Rice is one of the main crops in North Korea. However, natural disasters such as droughts and floods affected the food production, especially the growth of rice, in the years 1996, 1997, 2000 and 2007. What's more, towards the end of the season in late August and early September very intense rainfall resulted in some serious flooding in several parts of the country [1]. However, the details were not reported as soon as necessary.

The Z index is a very useful indicator for reflecting a certain period of drought and flood and is popular for estimating the influence of drought and flood [2], [3]. The TRMM precipitation data have vary in their imaging accuracy and spatial-temporal resolutions. A great deal of work has been done to evaluate the availability of TRMM data in drought and flood monitoring [4], [5]. However, the studies on the relationship between the Z index and changes in rice NDVI are rare.

The purpose of this paper was to study the characteristics of drought and flooding with the Z index and then examine the relationship between Z the index and the NDVI of rice from July to September in recent decades in North Korea.
2. Data and Methodology

2.1 Study area
North Korea is located in northeastern Asia on the northern part of the Korean peninsula; between a latitude of about 38° and 42° N and a longitude of about 125° and 130° E. The territory has a total area of 120,540 km², and a total population of 24,051 million in 2011 [6]. North Korea has a temperate monsoon climate and the average annual rainfall is 1000 to 1200 mm. About 85% of the rain falls in the spring and summer, 60% of which is distributed from June to September. The average annual temperature is 12 °C, with an average of 25 °C in summer.

2.2 Data
The data includes the version 6 monthly TMPA (3B43 V.6). Twelve years (2000–2011) of TMPA monthly precipitation data with a 0.25°×0.25° spatial resolution were provided by TRMM Science Data and Information System (TSDIS) and distributed by the NASA GSFC Distributed Active Archive Center (GDAAC). The images were rotated and reprojected to UTM projection with ENVI 4.7, and the outline of North Korea was extracted with ArcGis10. In this study, we focused only on the summer season from July to September. The value of each pixel is the rate of rainfall; each image represents a relevant month, so each image is multiplied by the whole hours of the month. In this study, the average value was used to represent the average precipitation in each month in every year. So there are 12 average precipitation figures for calculating the Z index in each month.

The MODIS vegetation index product MOD13Q1 was applied in this study to identify the dynamic change in rice NDVI. The MOD13Q1 product is a composite of eight layers including NDVI, EVI, and reflectance at red, near-infrared, and blue wavelength. For this study area, four tiles of the MODIS product image (h27/v4, h27/v5, h28/v4, and h28/v5) are required to cover the entire region. The tiles from July through September between 2000 and 2011 were downloaded via the Data Pool Tool supplied by the USGS Land Processes Distributed Active Archive Center (LP DAAC). The tiles were then reprojected from Sinusoidal to UTM projection and mosaicked into one image with MODIS Reprojection tool, and then the outline of North Korea was extracted with ArcGis 10.

In this paper, the images from Landsat-5 were used; the spatial resolution was 30 meters (http://glovis.usgs.gov/). The map of rice distribution was extracted from the images by combining supervised and unsupervised methods. Then with the help of ArcGis 10, the average NDVI of rice in each month from July to September during the 12 years can be captured and used to analyze the relationship with the Z index.

![Figure 1. The distribution of rice in North Korea in 2000 extracted from the Landsat TM images](image)

2.3 Methodology
The Z index is widely employed for studying relative changes in precipitation compared to normal years [7], [8]. Because the precipitation largely follows a ϱ distribution, the precipitation was converted to standardized anomalies in order to obtain a normal distribution. Then, it was transformed to the Z index as follows (equation 1):


\[
Z = \frac{6}{C_s} \left( \frac{C_s}{2} \varphi + 1 \right)^3 - \frac{6}{C_s} + \frac{C_s}{6}
\]

\[
C_s = \frac{1}{n\sigma^3} \sum_{i=1}^{n} (x_i - \bar{x})^3
\]

\[
\varphi = \frac{x_i - \bar{x}}{\sigma}
\]

\[
\sigma = \left[ \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2 \right]^{\frac{1}{2}}
\]

\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

(1)

Where \( C_s \) is the skewness coefficient, \( \varphi \) the standardized anomaly sequence, \( \sigma \) the mean deviation, \( \bar{x} \) the average in 12 years, \( x_i \) the precipitation in each month during the 12 years; \( n \) is 12 representing the 12 years. According to the standards listed in Table 1, the \( Z \) index was classified into seven types. For each month from July to September during the 12 years, we calculated the \( Z \) index separately. We also calculated the total precipitation of three months as the factor to see the change in the \( Z \) index in the entire summer season. Table 2 shows the results.

**Table 1.** The classification used for the \( Z \) index

| \( Z \) index | Grade | Type            |
|--------------|-------|-----------------|
| 1.654<\( Z \) | 1     | Extremely wet   |
| 1.037<\( Z \leq 1.654 \) | 2     | Severely wet    |
| 0.842<\( Z \leq 1.037 \) | 3     | Moderately wet  |
| -0.842<\( Z \leq 0.842 \) | 4     | Near normal     |
| -1.037<\( Z \leq -0.842 \) | 5     | Moderately dry  |
| -1.654<\( Z \leq -1.037 \) | 6     | Severely dry    |
| \( Z < -1.654 \) | 7     | Extremely dry   |

3. **Results and Discussion**

**Table 2.** The grades of drought and flood in each period in recent decades

| Year | July | August | September | July~September |
|------|------|--------|-----------|----------------|
| 2000 | 6    | 4      | 4         | 4              |
| 2001 | 2    | 5      | 4         | 4              |
| 2002 | 4    | 4      | 4         | 4              |
| 2003 | 4    | 4      | 4         | 4              |
| 2004 | 2    | 6      | 4         | 4              |
| 2005 | 5    | 4      | 4         | 4              |
| 2006 | 4    | 5      | 6         | 6              |
| 2007 | 6    | 1      | 1         | 2              |
| 2008 | 4    | 4      | 6         | 4              |
| 2009 | 4    | 4      | 4         | 4              |
| 2010 | 3    | 2      | 2         | 1              |
| 2011 | 4    | 4      | 4         | 4              |
According to the grades of drought and flood in North Korea shown in Table1, the precipitation values in North Korea are divided into certain grades. Figure 2 presents the time series of the Z index.

The changes in drought and flood during the 12 years from July to September can be seen. They included nine normal years, a severely dry year in 2006, a severely wet year in 2007, and an extremely wet year in 2010. Since 2006, the frequencies of drought and flood have tended to be higher, and the frequency of flooding is higher than that of drought. When we take the total precipitation of the three months as the factor for calculating the Z index, the change in the drought and flood situation is not obvious, perhaps due to the offsetting effect of the three month period. But, from an overall point of view, it tells us the precipitation situation in the whole summer, which is the main growth season of crops.

In terms of individual months, July included 2 severely dry years and 1 moderately dry year; August included 1 severely dry year and 2 moderately dry years; for September, there was 1 severely dry year. With the increase in precipitation, dry years were gradually reduced, and the degree of flooding gradually increased. In both August and September, there was 1 severely wet year and 1 extremely wet year. It is obvious that the results in each month in summer are so different, that it is important to know not only the whole situation in summer, but also the separate situation in each month, so as to attain information on the drought and flood situation in each, which have further influences on the rice NDVI.

Figures 2 shows the evolution of drought and flooding in North Korea in recent decades. From 2000 to 2005, the grades of the Z index are basically normal. Since 2006, drought and flooding increased significantly. 2006 was extremely dry, but it was extremely wet in both 2007 and 2010. Figure 3 shows the evolution during July to September in the abnormal years.
Table 3. The correlation between the NDVI and the value of the Z index

| Month | Function between NDVI and the value of the Z index | Value of R |
|-------|----------------------------------------------------|------------|
| 7     | $y = -0.0158x^2 - 0.0060x + 0.7305$               | 0.51       |
| 8     | $y = -0.0122x^2 + 0.0204x + 0.7169$               | 0.68       |
| 9     | $y = -0.0065x^2 + 0.0073x + 0.5841$               | 0.5        |

Table 3 shows that there is a quadratic function relationship between the Z index and the average NDVI from July to September, although the coefficient is different in each month. Throughout the three months, the correlation between the lower or higher Z index and the NDVI of rice is negative, but the degree is differs. The value of R in August is the highest in the three months, hence the normal precipitation in August is more important for the growth of rice than in other months.

4. Conclusions

As rice is the main crop in North Korea, information on the growth of rice and its output greatly influence the food security situation. The NDVI is usually used to reflect the growth of crops, and it is affected by the environment. Because abnormal precipitation caused the drought and floods, it is necessary to determine the relationship between the NDVI and precipitation. Our study showed that the Z index is appropriate for revealing the characteristics of the drought and flood situation in North Korea in recent decades. And there is a quadratic function relationship between the Z index and the average NDVI from July to September. Thus an appropriate amount of precipitation is important for the growth of rice, especially in August.

Acknowledgment

We are grateful to Prof. Dr. Dege and Mrs. Dege are acknowledged for valuable discussions. The authors thank the anonymous reviewers for their constructive comments.

This research was supported by the National Natural Science Foundation of China (Project No.41171072) and the National Grand Fundamental Research 973 Program of China (Project No. 2009CB426305) and the Special Fund of National Seismological Bureau, China(No.201208005). The Institute of Geographic Sciences and Natural Resources Research of the Chinese Academy of Science provided the meteorological data.

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