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Risk estimate of rice damaged due to flood

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ABSTRACT

Flood is one of the main disasters which cause rice damage in many countries. In this paper we investigate the risk of rice damaged due to flood by analyzing its statistical property and deterministic behavior from the thirty-six years of data in Taiwan. First, we calculate the Jarque–Bera coefficient, skewness, and kurtosis to see that the rice damage is not a normal distribution. Next, we use the correlation dimension (CD) and statistical correlation dimension (SCD) to see that both of the time series of flood and associated damages show the chaotic behavior. Finally, we also use the Hurst rescaled range analysis to confirm the properties. The results we found are useful in the risk estimate of rice damaged due to flood.

1. Introduction

It is known that the major portions of the world obtain more than half of their daily dietary calories from rice [1]. The rice production is largely concentrated in Asia, where it is considered to be the major source of food [2,3]. The agricultural system plays important roles in food security and in evaluating the economic value of multifunctionality of agriculture and rural areas in each country [4–6]. It affects the environment in retaining water in a landscape and thus reduction of flood intensity, minimizing soil loss, contributing to the country's economy, and reducing rural poverty [7,6].

This fact may be traced to the fact that the rice morphological development can be divided into three main phases: seedling, vegetative, and reproductive, and assigning rice growth stages based on discrete morphological criteria will result in unambiguous growth-stage determination and an adaptive rice growth staging system is needed for present application and future needs of farmers, consultants, crop insurance, scientists, educators, and researchers [1]. For the process of rice cultivation, paddy fields form shallow plates filled with water. Irrigation water constantly permeates into the soil, thereby maintaining a steady level of groundwater. However, if paddy fields are abandoned, the ground will crack, and the capacity to maintain a steady groundwater level will be reduced. The land, used for paddy fields, swamp land and fish ponds have the lowest potential for landslide although for some type of soils, such as volcanic soils, susceptibility to landslide may increase due to soil saturation by water [6].

Note that it has been argued that rice paddies provide a significant degree of storage during floods in Japan [8]. The adverse effects of flooding are multiple and complex. The effects of loss include crop damage, agricultural mechanical damage, replacement cost for landslide prevention [4–6], leaching cost and treatment cost increased due to infected pests and diseases. The assessments of the relation among the total rainfall amount, flood volume, a flood of several return periods, hydrograph of each land, total runoff hydrograph, maximum drainage capacities, storage capacities and estimating of the flood-prevention function of paddies are very important in planning watershed management and crop risk management for major flood events [9].

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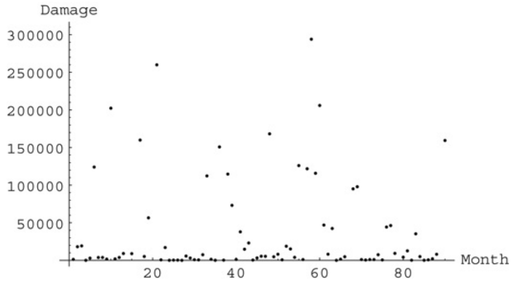

Fig. 1. Diagram of rice damage vs. month.

In natural disasters, many phenomena appear more unstable, and the natural disasters worldwide have caused great damage to crop production [10–17]. In the Subtropical Monsoon region, flooding is one of the natural disasters, and it is here that chaos theory has most relevance. A chaos-based risk assessment model may capture the complexity of natural disaster with more verisimilitude than traditional statistical analysis. When we are trying to understand broad-based phenomena such as arrival of the flood issues and associated rice damage, we should assume floods are dealing with a chaotic system and consider fitted methods aimed at understanding, rather than quantitative ones aimed at prediction and control. In Taiwan, nearly 80% of annual precipitation falls during the May–October typhoon season and torrential rainfall usually results in flooding disaster [18]. Over a 30-yr period, Taiwan was hit by a mean 1.2 flooding events per year. This is the result of heavy rainfall and leads to severe damage to crops and great property losses [12,13,19–21,8].

From 1971–2006, rice losses resulting from flooding damaged as much as 31% of Taiwan's rice crop. Earlier studies of rice crop loss estimation from flooding included the assumption that flooding was normally distributed. The normalized distribution assumption is widely applied to estimate the loss of crop in earlier studies. In this paper, we will first use the statistical analysis to show that the rice damage is not a normal distribution. Next, as the weather is a non-linear dynamics it is natural to ask a question as to whether the rice damaged due to flood is also a chaotic behavior? It is the next problem we will investigate in this paper. We will use the correlation dimension (CD) and statistical correlation dimension (SCD) to see that both of the time series of flood and associated damages show the chaotic behavior. We also use the Hurst rescaled range analysis to confirm the properties. The results we found are useful in the risk estimate of rice damaged due to flooding.

Note that the Grassberger–Procaccia correlation dimension (CD) and Foulkes's statistical correlation dimension (SCD) which, contrary to other statistics, calculate distances for all pairs of data points and could be applied to test the nonlinearity in stochastic processes [22,23]. We also evaluate the Hurst scaling exponent [24] to see that our data sets show the chaotic behavior.

In this paper we use the thirty-six years of data of the rice damaged due to flood in Taiwan to investigate the problems.

2. Materials and methods

In this paper we apply the method of a dataset consisting of floods losses in Taiwan, from published government statistics which are included in Taiwan Agricultural Yearbook, Production Cost and Income of Farm Products Statistics, and Taiwan Area Agricultural Products Wholesale Market Yearbook, which records rice losses due to major natural disasters in Taiwan over the years 1971–2006 and is available at http://www.coa.gov.tw. Although there were 10 types of natural disasters damaged rice, since 31% losses were caused by floods. Hence we only consider the rice loss data due to the flood disasters.

In this section we first describe the formulations of statistics analysis of rice damage. Then we will define the correlation dimension (CD), statistical correlation dimension (SCD) estimates and rescaled range analysis (R/S). The formulas will be used to analyze the statistical behavior of the time series of flood and associated rice damage in Section 3.

2.1. Statistics analysis of rice damage

In Fig. 1 we first plot the rice damage vs. month from the thirty-six years of data, in which the unit of rice damage is a thousand Taiwan dollars. We have neglected the months which do not suffer the flood disaster. It is seen that most floods produce little damage.

To proceed with the analysis, let us consider the sequence represented by the data set $X(i)$, $i = 1, \dots, n$ and define the following values

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X(i), \qquad \bar{x}_k = \frac{1}{n}\sum_{i=1}^{n}(X(i) - \bar{X})^k, \quad k = 1, 2, 3, 4. \tag{1}$$

Then, the skewness β_1 and kurtosis β_2 are

$$\beta_1 = \frac{\bar{x}_3}{\sqrt{\bar{x}_2^3}}; \qquad \beta_2 = \frac{\bar{x}_4}{\bar{x}_2^2}, \tag{2}$$