# The Risk Analysis of Rice Production due to Agro-Climate Change in Taiwan

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**Summary:** The study focuses on the water supply from the Irrigation Association (including total water withdrawals (cms), total amount of surface water (cms) and total amount of groundwater (cms)) and climate indices (including average temperature, rainfall, sunshine hours and radiation) relevant to Taiwan's rice production, defining them as the risk factors affecting agricultural production to construct a relational formula for rice production and risk factors. This formula is then used to estimate the rice production based on different climate conditions as well as volume of water supply form the Irrigation Association. Finally, the study conducts the uncertainty and risk analysis to establish a risk calculation model for rice production for determining the chances of specific risk factors (including climate, harvested areas, and water supply from the Irrigation Association) affect rice production to be less than a designated quantity, which is also the risk of inadequate rice production.

**Keywords:** water supply, climate indices, Epidemiology, risk analysis

## 1. INTRODUCTION

Climate change will cause both positive and negative influence on crop cultivation. Bangladesh, Sun and Huang (2011), Hasan (2010) and Lur, et. al. (2009) focus on the stress of climate changed. Hasan (2010) use the four elements “normal, drought, flood, and drought & flood” to measure the climate change risk of rice. Bangladesh, Sun and Huang (2011), Sun and Huang (2011), and Lur, et. al. (2009) found temperature is an important factor of agriculture cultivars. Naylor and Mastrandrea (2010) and Iizumi, et. al. (2011) point out this kind of climate-rice yield model could provide more information of future yield change according from climate change. Haq, et. al (2011) choose the two variables to focus on changed climate. On the other hand, about the soil- rice topic, Römkens, et. al (2011) focus on soil quality, so they choice just the variables include cadmium, ph, and exchange capacity to set up the model. Haq, et. al. (2011) use multi-dimensional approach and then choose temperature and relative humidity to predicted diseases and pest problems under changed climate. According to Saseendran, et. al. (2000), Yan, et. al. (2007), Naylor and Mastrandrea (2010), Hasan (2010), Sun and Huang (2011), and Iizumi, et. al. (2011), to find out which climate events impact the rice agriculture is important.

Chiueh, et. al. (2013) and Wu, et. al.(2014) used the regression model for panel data random effects, estimated rice-climatic indices for the first rice and the second rice in Taiwan. The rice-climatic indices consider the major agricultural climate features, including precipitation, temperature, solar duration, radiation, and uncertainty features such as the ENSO and rainfall extremes. This study choice the most significant factors in Chiueh, et. al. (2013) which influence rice production in Taiwan to setup the rice-climate-risk model, including precipitation indices, temperature indices, sunlight indices and the radiation. This study adapt Chiueh, et. al. (2013) and Wu, et. al.(2014) set up the precipitation indices, temperature indices, sunlight indices. Undoubtedly, under the changing climate with modern agriculture operations not only the climate factors, water supply is an important factor influence rice production.

This study choice the Irrigation Association’s intake of total water withdrawals (cms), total amount of surface water (cms) and total amount of groundwater (cms) to setup the rice-climate -risk model. The study focuses on the water supply from the Irrigation Association ((including inflow gage, estimates of inflow ground, and volume of inflow underground) and climate indices (including average temperature, rainfall, sunshine hours and radiation) relevant to Taiwan's rice production, defining them as the risk factors affecting agricultural production to construct a relational formula for rice production and risk factors.

This formula is then used to estimate the rice production based on different climate conditions as well as volume of water supply form the Irrigation Association. Finally, the study conducts the uncertainty and risk analysis to establish a risk calculation model for rice production for determining the chances of specific risk factors (including climate, harvested areas, and water supply from the Irrigation Association) affect rice production to be less than a designated quantity, which is also the risk of inadequate rice production.

## 2. Modeling Agro-climate-risk analysis

### 2.1. The Agro-climate -risk model

This study adapt Chiueh, et. al. (2013 ) and Wu, et. al.(2014) to set up the precipitation indices, temperature indices, sunlight indices and radiation indices.This study choice the Irrigation Association's intake of total water withdrawals (cms), total amount of surface water (cms) and total amount of groundwater (cms) to setup the rice-climate -risk model. Then, we adapt Wu, et al (2014) to establish a relational formula for rice production and risk factors. Considering that there are eight items of risk factors and observational information regarding rice production and risk factors are very limited coupled with varying relevance between them, the study first used the Multivariate Monte Carlo simulation Method (Wu, et al, 2006) to derive agricultural production quantities and risk factors, complementing it with multivariate regression analysis to establish a relational formula for rice production. In addition the study also uses uncertainty and risk analysis as well as the advanced first-order and second-moment (AFOSM) principle to establish the risk calculation model for rice production. Because it is necessary to have a relational formula for input and output variables when AFOSM is used to establish a risk calculation formula, the established relational formula for rice production and risk factors is integrated into the risk calculation model. The work procedure is described below as follows:

#### 2.1.1 Statistical Property Analysis of Rice Production and Risk Factors

The study collects information on the rice production quantity of Yunlin County from 1995 - 2008 as well as the water supply from the Irrigation Association (including inflow gage, estimates of inflow ground, and volume of inflow underground), climatic factors (including average temperature, rainfall, sunshine hours and radiation), and planting areas, as well as calculating statistical properties, including average values, variances, deviation coefficients, kurtosis coefficients, and various indicators and relevant coefficients of rice production.

#### 2.1.2 Derivative of Rice Production and Risk Factors

Multiple derivations of rice production and corresponding risk factors are formed based on the statistical properties of rice production and risk factors complemented by the Monte Carlo Simulation for Correlated and Non-normal Multivariate. The derivations of rice production and corresponding water supply form the Irrigation Association, climatic factors, and planting area found in the sensitivity analysis of rice production may be used to establish the risk calculation model for it.

#### 2.1.3 Relational Derivation of Rice Production Quantities and Risk Factors

Using the derivative values of rice production and risk factors, the study uses the multivariate regression analysis method to establish relational formula between rice production and climatic indicators, as shown below:

$$\omega = \alpha + \beta_1\theta_1 + \beta_2\theta_2 + \beta_3\theta_3 \tag{1}$$

Where $\omega$ represents agricultural production; $\theta_1$ represents rice planting areas; $\theta_1$ represents water supply from the Irrigation Association (including inflow gage, estimates of inflow ground, and volume of inflow underground); $\theta_1$ represents climatic factors (including average temperature, rainfall, sunshine hours and radiation) and; $\beta$ represents the coefficient value.

#### 2.1.4 Establishment of Risk Calculation Model for Rice Production Quantity

The study uses the AFOSM formula, complemented by the relational formula for agricultural production and risk factors, to establish the risk calculation method for agricultural production. This method is, in turn, used to calculate when demand for agricultural products becomes greater than the production quantity, which is lesser than a designated quantity. This is also considered the risk of inadequate agricultural production, as seen in the formula below:

$$Risk = \Pr(W > \omega) \tag{2}$$

Where $\omega$ represents agricultural production; the rice production risk calculation model estimate the probability distribution function of rice production.

## 3. Sensitivity and Risk Analysis of the Effects of Water Supply and Climatic Factors on Rice Production

This study classifies the first phase as dry season and the second phase as rainy season. Then, according to the climatic and water supply information for dry and rainy seasons, it uses the non-dimensional regression analysis to assess the effects of the uncertainty of water supply (including inflow gage, estimates of inflow ground, and volume of inflow underground) of the Irrigation Association and climatic factors (including average temperature, rainfall, sunshine hours and radiation) on the sensitivity and risks of rice production. Aside from considering the Irrigation Association's water supply and climatic factors, the study also factors in the planting area.

### 3.1. Sensitivity Analysis

The results can be summarized as follows: For the whole year, coefficients for inflow ground (-0.085) and inflow underground (about 0.074) are a lot smaller than the coefficients of other factors. This means that inflow ground and inflow underground have a smaller effect on rice production compared to the other factors. In addition, aside from the coefficients of temperature (-0.124) and all-day radiation (-0.319) being negative, coefficient values of all other factors are positive. This shows that higher temperatures are detrimental to rice cultivation; causing a reduction in production quantities and these results can be seen in both dry and rainy seasons (coefficients of average temperatures and all-day radiation are negative). These figures are similar to the statistical analysis of the previous section.

For dry and rainy seasons, the effects of inflow ground and inflow underground on rice production showed opposite results. For example, during the dry season, the coefficient of inflow ground is positive (0.338) and the coefficient for inflow underground is negative (-0.106). The abovementioned results represent that during the dry season, surface water provides more support for the water supply, thereby reducing the volume of groundwater extracted. Conversely, during the rainy season, the coefficient of inflow ground is negative (-0.727) and the coefficient for inflow underground is positive (0.211). This shows that the great amount of rainfall during the rainy season may affect the growth of the rice plants, but increasing the volume of inflow underground during rainless periods may increase the rice production.

### 3.2. Risk Analysis

Using the 200 sets of simulation values for annual rice production and various risk factors of Yunlin County obtained from the above steps, the study uses multivariate regression analysis method to establish the relational formula for RICETON and risk factors, as seen below:

$$\omega = -4134.9 + 7.13(\theta_1) + 0.38(\theta_2) - 0.352(\theta_3) + 0.132(\theta_4) + -24.759(\theta_5)^{\beta_5} + 0.033(\theta_6)^{\beta_6} + 0.109(\theta_7) - 0.409(\theta_8) \quad (3)$$

Where a represents constant term; $\theta_1$ represents rice planting areas (hectares); $\theta_2$ represents volume of inflow gage of the Irrigation Association (cms.); $\theta_3$ represents inflow ground volume of the Irrigation Association; $\theta_4$ represents volume of inflow underground of the Irrigation Association (cms.); $\theta_5$ represents average temperatures (degree); $\theta_6$ represents amount of rainfall (mm); $\theta_7$ represents sunshine hours (hr.) and; $\theta_8$ represents average all-day radiation (MJ/m2).

Form the results we found that the higher the inflow gage and the inflow underground are, the greater the risk for water shortage due to a reduction in the amount of irrigation water obtained from rainfall. Consequently, it becomes necessary to obtain extra water supply from irrigation ditches and underground water sources to irrigate the fields, which increases the risk of inadequate rice production.

## 4. CONCLUSION

The empirical results of the sensitivity and risk analyses for rice production can be summarized as follows: (1) The average inflow gage, inflow ground, and inflow underground provided by the Irrigation Association are 510.8 cms. 10.3 cms., and 33.4 cms., respectively. From this, it can be seen that, aside from irrigation canals, 6% of groundwater is still needed to bolster the water resources provided by the Irrigation Association. In addition, compared to Tables 2 and 3, the study also finds that the rice production volume during dry season account for 70% of the total production volume, which means that the corresponding volume during rainy season account for the remaining 30%. (2) The amount of rainfall is greater during the rainy season (average amount of rainfall during the dry and rainy seasons are 736 mm and 1185 mm respectively), increasing the risk of flooding, which, in turn, causes the quantity of rice harvested to go down. (3) For decrease in inflow gage and inflow ground due to reduced amount of rainfall during the dry season, necessitating extraction of groundwater to irrigate fields, average volume of inflow underground during rainy season (17 cms.) is higher than the volume during the dry season (15 cms.). In terms of average temperature, the average temperature during rainy season (about 25 degrees) is higher than the temperature during the dry season (about 21 degrees). The rice production during the rainy season is less than that during dry season; this shows that higher temperatures are detrimental to plant growth, which causes production to go down. (4) From the results of the sensitivity analysis, it can be seen that the volumes of inflow ground and inflow underground within the water supply from the Irrigation Association affect rice production on a lesser scale compared to other factors. In addition, temperature coefficient and radiation having an inverse relationship with rice production, showing that higher temperatures are detrimental to rice growth. These results may be seen both in dry and rainy seasons. (5) From the results of the risk analysis, it can be seen that the higher the inflow gage and volume of inflow underground is, the lower is the volume of irrigation water derived from rainfall, which could result in a water shortage risk. Furthermore, increase in the variation coefficients of variable climatic factors like temperature, rainfall, and radiation also increases the risk of inadequate rice production. This means variation in the amount of radiation in the sky has a greater effect on the inadequacy of rice production than temperature and rainfall.

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