EFITA WCCA CIGR
2013 Conference
June 23-27, 2013
TORINO, ITALY
Sustainable Agriculture through ICT innovation

Climate Change Vulnerability Assessment for Agricultural Infrastructure in Korea

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ABSTRACT

The purpose of this study was to evaluate climate change vulnerability over the agricultural infrastructure in terms of flood and drought using principal component analysis. Vulnerability was assessed using vulnerability resilience index (VRI), which combines climate exposure, sensitivity, and adaptive capacity. Ten flood proxy variables and six drought proxy variables for the vulnerability assessment were selected by opinions of researchers and experts. The statistical data on 16 proxy variables for the local governments were collected. To identify major variables and to explain the trend in whole data set, principal component analysis (PCA) was conducted. The result of PCA showed that the first 3 principal components explained approximately 83% and 89% of the total variance for the flood and drought, respectively. VRI assessment for the local governments based on the PCA results indicated that provinces where having the relatively large cultivation areas were categorized as vulnerable to climate change.

Keywords: Climate change; vulnerability assessment; vulnerability resilience index; principal component analysis; agricultural infrastructure; Republic of Korea

1. INTRODUCTION

The linear warming trend over the last 50 years (0.13°C per decade) is nearly twice that for the last 100 years. The total temperature increase from 1850-1899 to 2001-2005 is 0.76 °C. More intense and longer droughts have been observed over wider area since the 1970s. Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought. The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor (IPCC, 2007).
Climate change has recently become a new challenge to sustainable agriculture. Changes in air temperature and rainfall and the resulting increases in frequency and intensity of droughts and flooding require a more secure water management system to adapt to climate change. Securing agricultural water supplies to maintain agricultural

C0241, S. M. Kim, S. J. Kim, M. W. Jang, “Climate Change Vulnerability Assessment for Agricultural Infrastructure in Korea”, EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

sustainability is one of the more pressing adaptation measures needed in order to cope with climate change impacts (Yoo and Kim, 2007).
The Korean government has put a lot of effort into establishing good irrigation systems for stable food production. The percentage of irrigated rice paddy fields to total rice paddy area has increased from 75% in 1980s to ca. 80% in 2005 (Agricultural and Forestry Statistical Yearbook, 2006). Due to this effort, agricultural damage in Korea during 1991−2000 was mostly attributed to rain, typhoons, and heavy snow, while drought did not account for major damage during the same period (Shim et al., 2003). This shows that Korea has fairly high adaptation capacity to respond to drought damage. However, climate change and the variability expected in the future may influence the stability of the current irrigation system, resulting in a reduction of the adaptation capacity. On the other hand, Korean agriculture is highly susceptible to flood damage. Shim et al. (2003) characterized agricultural damage based on contributory causes during 1904~2000 and found that heavy rain and typhoons were the biggest contributor (38%) to total agricultural damage. Climate change is reported to influence the frequency and intensity of heavy rain which have a strong impact on agricultural sustainability. Local distribution of resilience to flood damage can be regarded as one of the most important components comprising the locally−specific adaptive capacity to climate change (Yoo and Kim, 2007).
The purpose of this study was to evaluate climate change vulnerability over the agricultural infrastructure in terms of flood and drought using principal component analysis. Vulnerability was assessed using vulnerability resilience index (VRI), which combines climate exposure, sensitivity, and adaptive capacity.

2. MATERIALS AND METHODS

2.1 Vulnerability Assessment

The word ‘vulnerability’ is usually associated with natural hazards like flood, droughts, and social hazards like poverty etc. Moss et al. (2001) conducted a study assessing vulnerability to climate change in different regions of worldwide.
Vulnerability−Resilience Indicator Prototype (VRIP) model was developed to compare the national vulnerability-resilience indices against a global index (Moss et al., 2001). A country’s or region’s vulnerability to climate change is assumed to be a function of three factors:
• Exposure–the nature and extent of changes that a place’s climate is subjected to with regard to variables such as temperature, precipitation, extreme weather events, sea level; exposure is location-dependent.
• Sensitivity–how systems could be negatively affected by the change in climate, e.g., how much land could be inundated by sea level rise, how much might crop yields change, or how much might human health be affected.
• Adaptive capacity–how much capability a society has to adapt to the changes so as to maintain, minimize loss of, or maximize gain in welfare.

As the climate change vulnerability index by Moss et al. (2001) was not applicable to assess the local vulnerability, we applied the modified index adjusted for the Korean context developed by Yoo and Kim (2008). The procedure for calculating the vulnerability-resilience indicator in this study is presented in Fig. 1.
Proxy variables for the vulnerability assessment for agricultural infrastructure in terms of drought and flood in this study are shown in Table 1. Proxy variable are listed with the three categories of sensitivity, exposure, and adaptation. The data for the proxy variables were obtained from the Korean Statistical Information Service, the yearbook of agricultural land and water development statistics, and Korea Meteorological Administration, etc. Since the units and data range varied across the components, each data set was rescaled fro 1 to 10 scales in order to standardize the data.

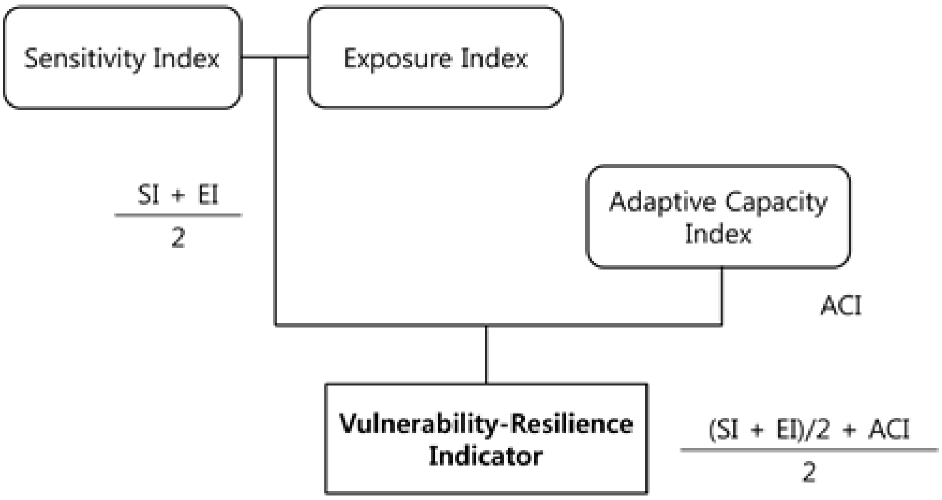

Fig. 1. Calculation procedure of Vulnerability Resilience Indicator (VRI) (Yoo and Kim, 2008)

2.2 Principal Component Analysis

To identify the major variables and to explain the trend in whole data set, principal component analysis (PCA) was conducted. PCA is a multivariate technique for finding patterns in data of high dimension. PCA helps expressing the data in such a way as to highlight their similarities and differences. The advantage of PCA is that it can compress the data by reducing the number of dimensions without much loss of information.

Table 1. The selected proxy variables and codes for flood and drought

Category	Classification	
	Flood	Drought
Sensitivity	Average daily rainfall (≧80mm) (FS01) Day of rainfall (≧80mm) (FS02) Maximum daily rainfall (FS03)	Annual rainfall (mm) (DS01) Maximum continuative non rainfall days (DS02)
Exposure	Farmland area or ratio (FE01) Greenhouse cultivation area (FE02) Farmland mean altitude (FE03)	Farmland area or ratio (DS03) Rain-fed paddy field area or ratio (DS04)
Adaptation	Drainage canal length (FA01) Drainage pumping station capacity (FA02) Land Consolidation area (FA03) River improvement (%) (FA04)	Well-irrigated paddy area or ratio (DA01) Forest area or ratio (DA02)

3. RESULTS AND DISCUSSION

3.1 Statistics for the Proxy Variables

The data of 10 proxy variables for flood and 6 for drought were collected. The average, variance, and other statistics were calculated for the proxy variables. Fig. 2 shows the part of calculated data for proxy variables. The spatial unit for analysis was conducted at the county (Si, Gun, Gu) level.

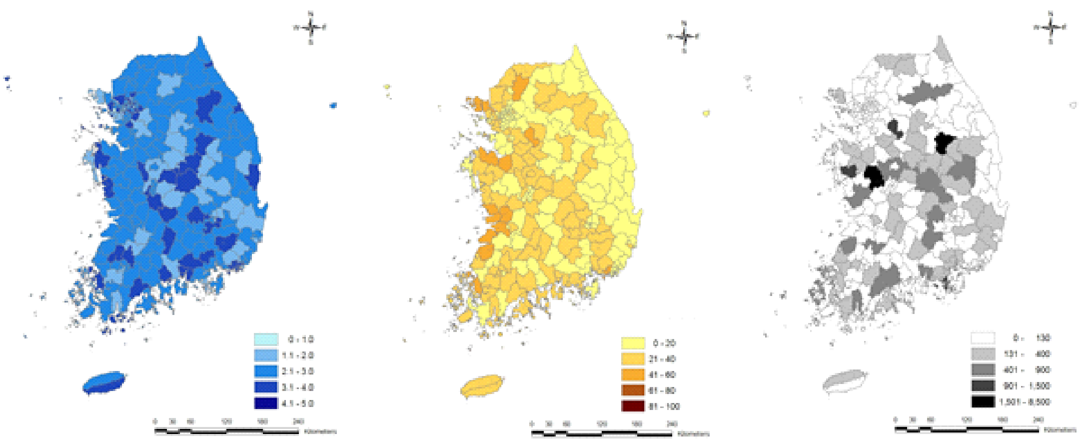

Fig. 2. Average days over 80 mm of daily rainfall (left), cultivation area percent (middle), drainage canal length (right)

3.2 Principal Component Analysis

Through the principal component analysis, 3 principal components for flood and drought, respectively, were obtained (Tables 2 and 3). The results of PCA showed that the first 3 principal components explained approximately 78% of the total variance for flood and 68% for drought.

Table 2. Initial eigenvalues, extraction sums of squared loadings, and rotation sums of squared loadings for flood

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.78	37.84	37.84	3.78	37.84	37.84	3.78	37.83	37.83
2	2.66	26.55	64.39	2.66	26.55	64.39	2.62	26.19	64.01
3	1.42	14.21	78.61	1.42	14.21	78.61	1.46	14.60	78.61
4	0.79	7.89	86.50						
5	0.55	5.46	91.96						
6	0.27	2.69	94.66						
7	0.24	2.41	97.07						
8	0.21	2.05	99.12						
9	0.09	0.87	99.99						
10	0.00	0.01	100.00						

Table 3. Initial eigenvalues, extraction sums of squared loadings, and rotation sums of squared loadings for drought

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	2.49	31.10	31.10	2.49	31.10	31.10	2.47	30.90	30.90
2	1.77	22.14	53.24	1.77	22.14	53.24	1.77	22.12	53.01
3	1.17	14.61	67.86	1.17	14.61	67.86	1.19	14.84	67.86
4	0.87	10.87	78.73						
5	0.69	8.61	87.34						
6	0.54	6.81	94.15						
7	0.36	4.56	98.71						
8	0.10	1.29	100.00						

3.3 Vulnerability Assessment for Drought and Flood

Fig. 3 shows the climate change regional vulnerability assessment the agricultural infrastructure in terms of drought, flood and comprehensiveness.

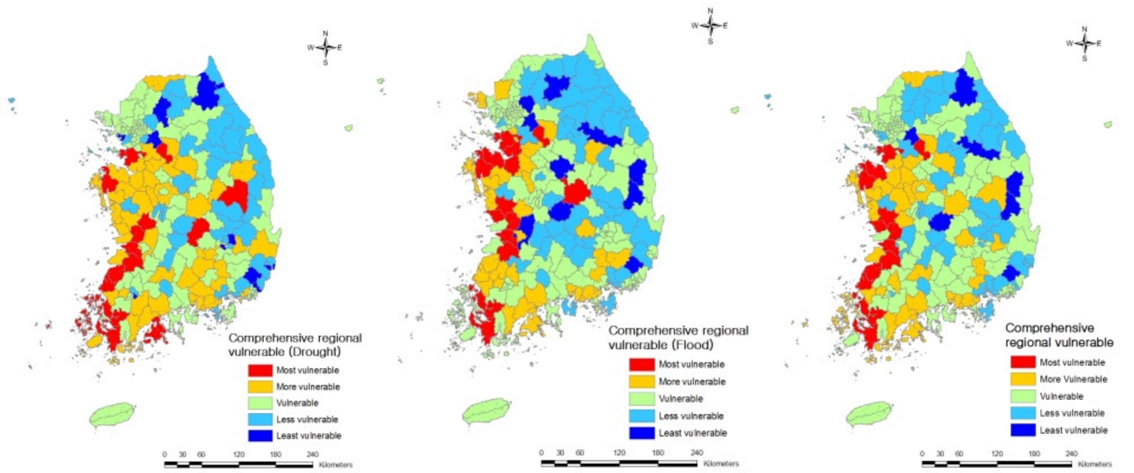

Fig. 3. Classification of drought (left), flood (middle), and comprehensive (right) regional vulnerability assessment

4. SUMMARY AND CONCLUSIONS

A methodology to assess agricultural infrastructure vulnerability for flood and drought was developed in this study. The results of the vulnerability assessment would provide the basis for suggestions for regionally adjusted adaptation policies and provide the quantitative backgrounds for policy prioritization. Adaptation policies aim to reduce vulnerability by decreasing sensitivity and/or by increasing adaptive capacity. However, this study has limitations and leaves room for future research. The vulnerability index suggested in this study requires further improvements. For a more robust index, various aspects of adaptive capacity, both physical and socio-economic, should be considered.

5. ACKNOWLEDGEMENTS

This work was carried out with the support of “Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ008335012013)” Rural Development Administration, Republic of Korea.

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