Vulnerability assessment of water resources to Climate change using GIS

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Abstract

Climate change has influenced on various environmental and social sectors. Especially, it has significant impact on water resource, such as water management, drought and flood. In this study, we assessed the vulnerability of water management, flood, and drought to climate change using GIS-based spatio-temporal information. Vulnerability is assessed in terms of sensitivity, exposure and adaptation. We prepared criteria and indicators for climate change impact assessment to water resources vulnerability, and integrated GIS based data which is correspondent to indicators. As a result, we mapped present and future water vulnerability and suggested adaptation strategies in Korea.

Key words: climate change, water resources, vulnerability, GIS

1. Introduction

Global warming is currently one of the most serious environmental issues in the world. The temperature increase during the recent 20 years is about 0.3 ~ 0.4℃ (Singer et al, 2006). For preparing adaptation measures, climate change impacts have been assessed in terms of vulnerability. The vulnerability to climate change means the degree to which geophysical, ecological, and socioeconomic system is susceptible to adverse effects of climate (Fussel and Klein, 2006). The vulnerability to climate change can be represented by the 3 types of functions, such as the exposure, sensitivity, and adaptive capacity. Exposure refers to the nature and degree to which a system is exposed to significant variation. The sensitivity means the degree to which a system is affected by climate-related stimulation without considering the adaptation. The adaptive capacity means variation of system derived from external stressors, such as climate change (Bae et al., 2005). To assess the vulnerability, it is needed to understand the impact mechanism of climate change on various sectors and consider the availability and applicability of data (Chung et al., 2010). In the study of assessing the water resources, there are both index method and model method. This study, which uses index method, estimates statistical values which influence on the future water resources through analyzing the correlation between meteorological data and statistical data, and then provides the base data for analyzing the vulnerability of future water resources.

2. Materials and Method

2.1 Study area

The study area for this study is located in South Korea, 124°54′ ~ 131°6′ at longitude and 33°9′ ~ 38°45′ at latitude (Fig. 1.). It presented as a raster data in 0.05° of spatial resolution, excluding the part of the ocean.

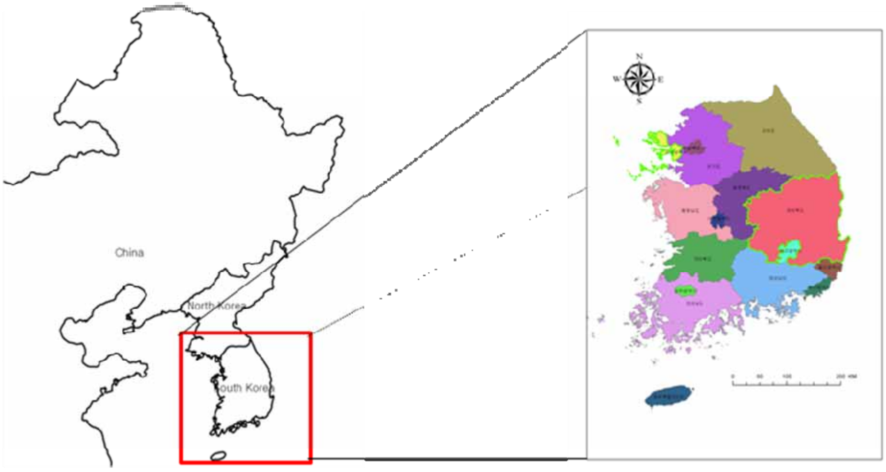


Figure 1. Location of study area

2.2 Material

To assess the vulnerability of water resources, we classified water vulnerability into 3 types, such as flood, drought, and water management. GIS-based spatial data for indicators were prepared as shown in Table 1. Future vulnerability assessment in water management employed the value of excess and deficiency as a indicator by considering the scenario of future water demand and supply defined the report “Water Vision” (Ministry of Land, Transport and Maritime Affairs, 2006).

Table. 1. List of Indicators

Type	Criteria	Indicator
Flood	Sensitivity	Precipitation>80mm(day)
		Maximum precipitation (mm)
		Maximum runoff (m^3/s)
		Sumer precipitation(mm)
	Exposure	Elevation(m)
		Population density(person/km^2)
	Adaptability	River improvement ratio (%)
Drought	Sensitivity	Annual precipitation(mm)
		Precipitation>1mm(day)
	Exposure	Water requirement density(ton)
	Adaptability	area (km^2)
Water management	Sensitivity	Annual precipitation
		Annual temperature
		Conduit water consumption(m^3)
		Ground water consumption (m^3)
	Exposure	Elevation
		Population density
	Adaptability	Conduit water supply rate (%)
		Sewage supply rate (%)

(Sources: Lonergan et al, 2006; Brooks et al, 2005; Bea, 2005; Moss et al, 2001; Ministry of Land, Transport and Maritime Affairs, 2006; World Economic Forum,2002)

2.3 Vulnerability assessment

$$\text{Vulnerability} = (\text{Exposure} \times \text{Sensitivity}) / \text{Adaptability} \qquad \text{Equation (1)}$$

This equation indicates that as the sensitivity and exposure to climate change is increased, the vulnerability is increased under the same condition and implies that the vulnerability is decreased by adaptability. In this study, vulnerability was assessed by 3 criteria, such as sensitivity, exposure, and adaptability as equation 1.

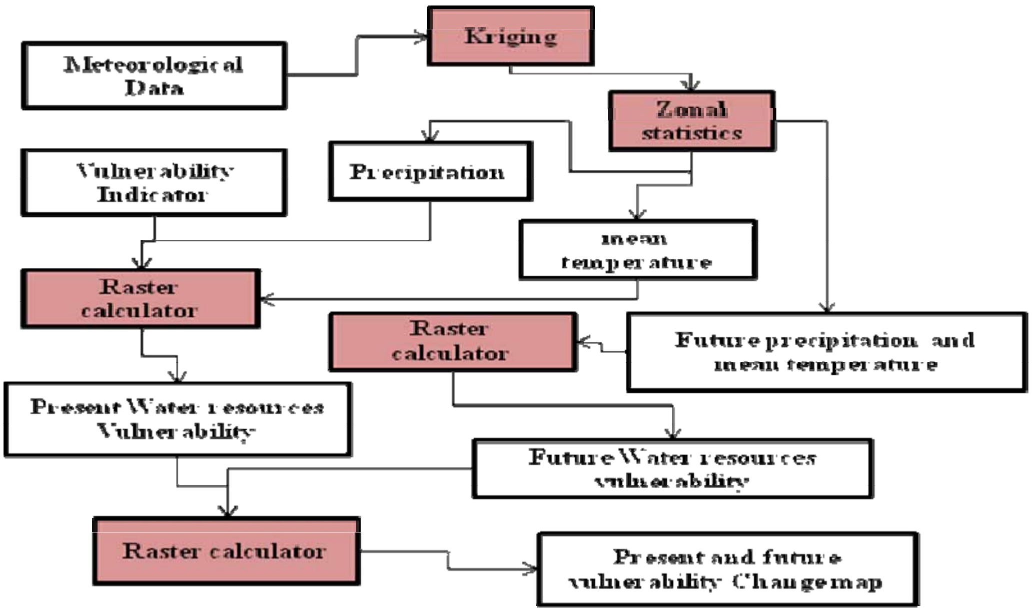


Figure 2. Study process

2.4 Used Arc map tools

2.4.1 Kriging

Kriging is a geostatistical approach that has gained acceptances as a tool for interpolaton of many types of data, including temperature and precipitation. Ordinary Kriging is a method for predicting the value of a random process at a specific location in a region (Kim et al, 2009). This study uses this tool to predict the climate data of unknown space.

2.4.2 Zonal statistics

Zonal is the process, deducting statistic of pixels in the wanted range. In other words, this tool analyzes the statistic as a representative value within a range. In this study, basin and administrative unit are considered as the basic range and statistic is average.

2.4.3 Raster calculator

Raster data can be calculated by raster calculator tool. The vulnerability of current and future water resources is obtained by the mathematical calculation between meteorological data and indicators. As a result, the change of the vulnerability with time is estimated.

3. Results

3.1 The vulnerability map of flood and drought in national scale

National vulnerability of flood and drought are obtained by basin scale. We could find regional and spatial differences in vulnerability of flood and drought (Fig. 3). With respect to the characteristics in the spatial distribution of the vulnerability, national adaptation measures could be prepared.

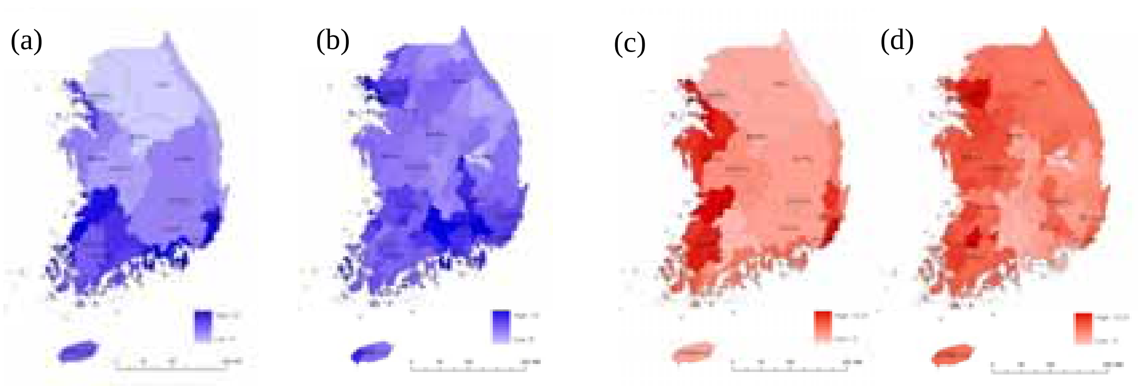


Figure 3. National Vulnerability map of (a) Basin flood, (b) Sub-basin flood, (c) Basin drought (d) Sub-basin drought

3.2 The vulnerability map of flood and drought in regional scale

The regional vulnerability of flood and drought are obtained by watershed with small scale. With the help of this regional vulnerability, we can also identify spatial differences in vulnerability in a local region (Fig. 4 and Fig. 5). This spatial vulnerability can help local government to prepare adaptation measures for local area.

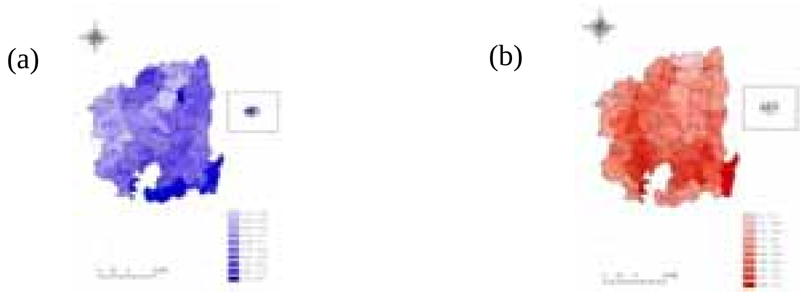


Figure 4. Kyung-buk vulnerability map of (a) Flood (b) Drought

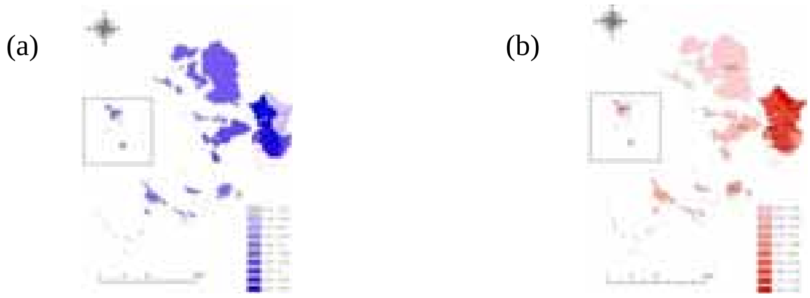


Figure 5. Incheon vulnerability map of (a) Flood (b) Drought

3.3 The vulnerability map of current water management

The vulnerability of water management, the nation was also assessed for national scale and 2 regional sca1e (Fig .6). It is notable that the major cities showed lower vulnerability comparing to the neighboring regions. This can be attributed to the better water supply system in city area.

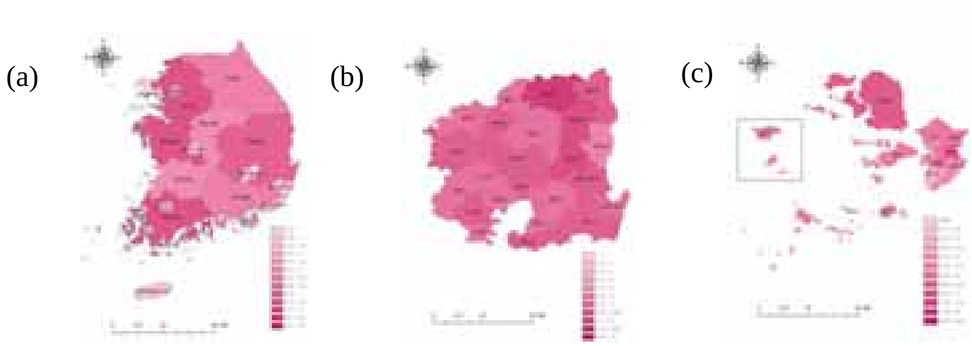


Figure 6. Current vulnerability map of water management map of (a) National level (b) Kyung-buk (c) Incheon

3.4 The vulnerability map of future water management

The future vulnerability assessment in water management was assessed for near future (2010~2050) and far future (2071~2100) (Fig. 7). In near future, the vulnerability of water management was assessed to increase in southern Korea. And in far future, most Korean area was assessed to have higher vulnerability. This vulnerability change can help central government to prepare the adaptation measures for near and far future. For the local area for Kyung-buk and Incheon, we could also indentify that there appears spatial differences in vulnerability increase of water management (Figure 8.).

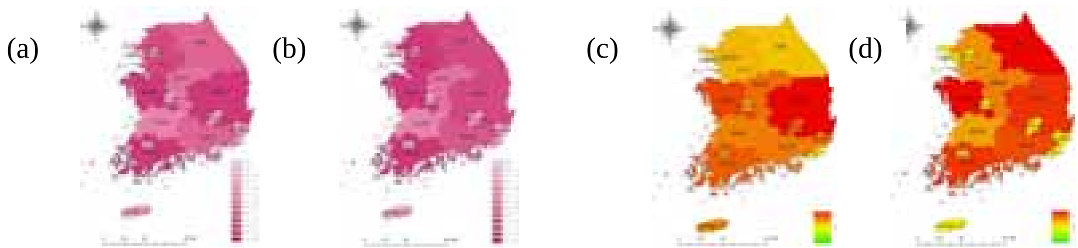
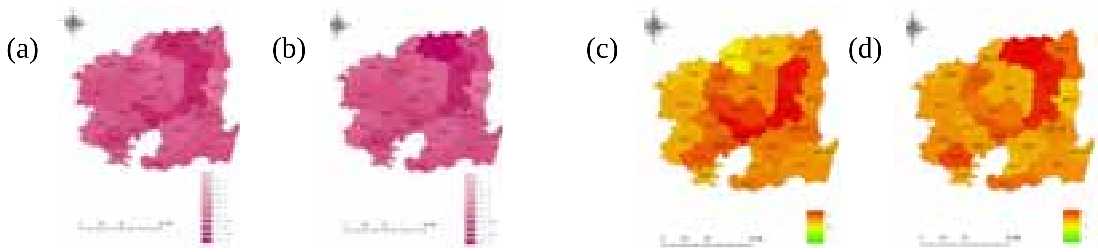


Figure 7. Near and far future vulnerability and change of vulnerability of (a) Near future in national scale, (b) Far future in national scale, (c) The change between current and near future in national scale, (d) The change between current and far future in national scale



(e) (f) (g) (h)

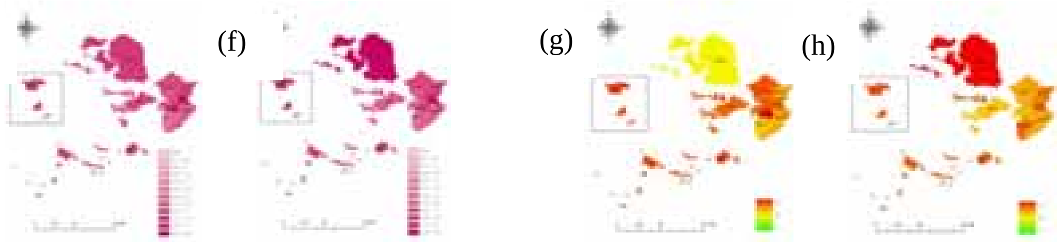


Figure 8. Near and far future vulnerability and change of vulnerability of (a) Near future in Kyung-buk, (b) Far future in Kyung-buk, (c) The change between current and near future in Kyung-buk, (d) The change between current and far future in Kyung-buk, (e) Near future in Incheon, (f) Far future in Incheon, (g) The change between current and near future in Incheon, (h) The change between current and far future in Incheon

4. Discussion

The assessment result is greatly influenced by the scale of watershed identification. The spatial variation represented in the vulnerability result of Nation, Kyung-buk, and Incheon shows that it is needed to make a suitable standard changed by purpose and size in order to make effective national and local strategies to climate change. These results are more meaningful in terms of interpretative assessment about what data are selected and how data are converted in the process. The uncertainty in vulnerability assessment can be solved by accumulating the analysis result between actual values and indicators in the process of interpretation and verification.

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