Assessment of Floods Disaster Risk in Guangxi Province Based on GIS

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Abstract. Through the analysis of major factors within the generation of floods, floods risk assessment index model is explored based on GIS (Geographic information system). Weighting the index system and zoning with different risk levels is used to conduct floods disaster risk assessment in Guangxi province. As seen from the result in the project, the floods disaster risk assessment map, that southern coastal regions and central basin of Guangxi are high flood risk zone, such as Liujiang County, Wuming County, Hepu County. Western regions are in good conditions with relatively low flood disaster risk, like Jingxi county and Youjiang county. On that basis, some constructive suggestions are proposed.

1. Introduction

All around the world, nearly one percent of land suffer from the floods disaster regularly. According to the incomplete statistics of 1984, because of the floods disaster losses, India lost more than 1 billion dollar, Japan more than 600 million dollar, and for the United State at least 2.2 billion dollars (CHEN, 1999). What is more, the floods losses increase year by year. China has a complex terrain conditions which are full of rivers leading to the frequent floods disaster. Guangxi province is included in the flood-prone areas.

Figure 1. Map of China with sign of Guangxi province

Source: www.scgx.com

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Figure 2. Topographic map of Guangxi

Source: maps.google.com

Guangxi, which is located in the south coastal area (Figure 1), has a variety of topography mixed with the mountain, platform, and marine leading to the completed climate resources (Figure 2). In this situation, it is also accompanied with the diversity of crops species, regional planting, seasonal planting and more features.

In the context of the global warming, climate variability, torrential rain and floods, such disaster occurs frequently, causing the terrible disaster accident in some degree. Guangxi is one of the most serious disaster areas in China's agro-meteorology. The number of floods disasters has been increasingly serious in recent years, and the lives and properties of citizens in these cities are heavily influenced which directly threat the human survival ecological environment.

Floods disaster risk refers to an area within a certain time the possibility, the activity, the damage loss, and the influence of the damage on the economic, social and natural environment system of floods occurred (ZHANG, 2007). The United States, Japan and other developed countries as early as the 50s, 60s of the 20th century carried out the study of floods risk (Richards, 1958), while for China, until the middle of 80s of the 20th century (SUN, 1992).

From the former studies, the agricultural floods disaster risk in Guangxi is obviously regionally different to some extent. In the low-lying areas like south, northeast, and northwest part are more likely to get the risk of floods. Compared with high-lying and medium-lying areas are not easy to occur. The most potential disaster areas may occur near the costal south of Guangxi province, such as Beihai region, Qinzhou region, Fangchenggang region, and the Dongxing, Hepu (MO, 2010).

Guangxi is a coastal city in the south of China, which is significantly influenced by the monsoon. In this status, it will bring a lot of rains. Because of the dense river network, the usually independent areas will become connected when it rains, which will enlarge the effect of the rain. What is worse, as Guangxi's diversity topography, it has a wide limestone distribution that the water cannot go through easily. In this situation, the large number of rainfall cannot drain away quickly combined with the poor drainage.

2. Aim and Methodology

According to the introduction, Guangxi Province has the high incidence of floods disasters. Therefore, assessing the floods disaster risk of each area in Guangxi Province is very necessary. Here, establishing floods risk assessment index system combined with GIS analysis to conduct floods disaster risk assessment and risk regionalization. Floods disaster risk assessment of Guangxi Province may provide scientific basis for the establishment of disaster prevention and mitigation policies.

2.1. Floods disaster risk assessment model

2.1.1. Selecting index of floods disaster risk assessment model. Floods disaster risk assessment is to calculate the extent of the losses caused by different intensity of floods, which is based on the natural environmental risk analysis and vulnerability analysis. Therefore, in order to establish the model of floods disaster risk assessment, this project is conducted in the aspects of natural environmental risk analysis and floods vulnerability analysis.

2.1.2. Natural environmental risk analysis. Normally, hazard is refers to the possibility of adverse events. Risk analysis is aimed at studying the possibility of occurrence of adverse events from the predisposing factors of the risk. Natural environmental risk analysis of floods is the research of intensity and frequency of floods which threatened areas may suffer from. The intensity can be represented by inundated area, elevation and other indicators. And for frequency, using the return period (how many years the floods occurs once) to represent (Zhang, Hori & Tatano, 2002). Generally speaking, natural environmental risk analysis is to explore the relationship between floods frequency and the intensity of floods. Based on the previous assessment of floods disaster risk that is mentioned above, and the ease of data acquisition and analysis, natural environmental risk of floods can be calculated and evaluated with choosing precipitation, topography and river impact buffer as the index factors.

2.1.3. Floods vulnerability analysis. When different disaster-bearing bodies suffer the same intensity of floods, the extent of damage impact will be different; the same disaster-bearing body is subjected to floods with different intensities, the losses will be quiet variable as a result (Zhang, Norio & Tatano, 2002). On the whole, vulnerability would be different in different situation and condition. When it comes to floods vulnerability, it refers to that disaster-bearing body may suffer different degrees of damage because of different intensities of floods. The target of floods vulnerability analysis is to study the characteristics of disaster-bearing body in regions which are vulnerable to be damaged by floods disaster (ZHOU, WAN & HUANG et al, 2000). At the same time, the susceptibility can be preliminarily calculated. Overall, floods vulnerability analysis is aimed at studying the relationship between the intensity of floods and loss rate. Therefore, to identify the objects that may be damaged by floods and to estimate their values are the basic preparations firstly; then to estimate the extent of losses of these objects would become much more persuasive. According to the availability of data, here we select population density and gross domestic product (GDP) as the index factors to evaluate floods vulnerability.

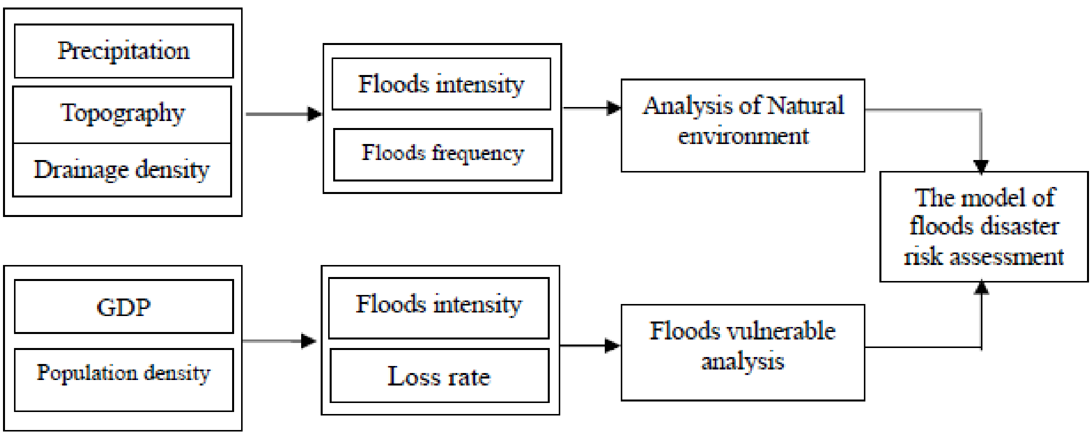

Figure 3. Technical roadmap

Based on the elements that have been mentioned above, the floods disaster risk assessment model will be established preliminarily. It is as the following table.

Table 1. Evaluation model of floods disaster risk

Target Layer	Guidelines Layer	Index Layer
Floods Disaster Risk Assessment	Natural Environmental Risk	Precipitation Topography River impact buffer
	Floods Vulnerability	GDP Population

2.1.4. Property of indicators. Precipitation, population density and GDP are all positive correlation with floods disaster risk. The higher the value of them, the larger risk of floods would occur. While terrain factor and river impact buffer are negative correlation with it, the higher the value of them, which means the smaller risk of floods disaster.

2.1.5. Determining the index weights. Due to the variable natural environment of indicators, the otherness of data and their different importance to the target layer, to determine the index weights is very essential. Here we use the 1-9 scale method which comes from The Analytic Hierarchy Pricess to calculate the weight of each indicator. Examining the extent of the importance of each element to their previous target; constructing judgment matrix between factors; then using summary method to determine the weight of each element; finally, conducting the CR consistency test (LU, ZHENG & ZENG, 2003).

Step 1: construct judgment matrix

Table 2. Matrix for Guidelines Layer

	A1 Natural Environmental Risk	A2 Floods Vulnerability
A1 Natural Environmental Risk	1	5
A2 Floods Vulnerability	1/5	1

Table 3. Matrix for the first Index Layer

	B1 Precipitation	B2 Topography	B3 River Impact Buffer
B1 Precipitation	1	5	5
B2 Topography	1/5	1	1/2
B3 River Impact Buffer	1/5	2	1

Table 4. Matrix for the second Index Layer

	C1 GDP	C2 Population Density
C1 GDP	1	1/3
C2 Population Density	3	1

Step 2: matrix calculation to get weights based on following formulas and related rules

$$A=\begin{pmatrix} a11a12 \\ a21a22 \\ a31a32 \end{pmatrix} \quad W=\begin{pmatrix} w1 \\ w2 \\ w3 \end{pmatrix} \tag{1}$$

$$\overline{W}_i = \sum_{j=1}^{n} a_{ij} \quad (i = 1, 2 \cdots\cdots n)$$
$$W = \overline{W}_i \Big/ \sum_{i=1}^{n} \overline{W}_i \tag{2}$$

Step 3: CR consistency test: on the basis of formula 3, eigenvalues of matrix and consistency index C I is calculated. Consistency by RI value table will be then tested afterwards. The value of CR that we calculated is less than 0.1, which means the weights are reasonable. Weights detail is as shown in Table 6.

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad \text{CI}=\frac{\lambda_{\max}-n}{n-1} \quad \text{CR}=\frac{CI}{RI} \tag{3}$$

Table 5. RI Value

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Table 6. Index weight of Floods Disaster Risk Assessment Model

Target Layer	Guidelines Layer	Weight	Index Layer	Weight
Floods Disaster Risk Assessment	Natural Environmental Risk	0.833	Precipitation	0.692
			Topography	0.107
			River Impact Buffer	0.201
	Floods Vulnerable	0.167	GDP	0.25
			Population	0.75

2.2. Data source

2.2.1. Core data. Administrative map of Guangxi in vector (used to limit the boundary of analysis layer and extract counties that will be influenced by floods)
Map of river distribution in Guangxi from www.gxwater.gov.cn
Topographic data (elevation) of Guangxi Province from basic geographic information system.
Precipitation from National Meteorological Observatories.
(Source:http://wenku.baidu.com/link?url=oeKuIJWMY91DQIef24AtJxH0efaOpIhtjm7mRPFeNUzZzBmq1B8pB03x1n4DVH0IebaCdx31k6YPmVGAV-aAyV-ZDWVrvUilsEQhXRG-iye)
The population of each administrative county from the Guangxi Statistical Yearbook 2013.
The GDP value of each administrative county from the Guangxi Statistical Yearbook 2013.

2.2.2. Supplementary data. The data, mainly GDP value and population, from Guangxi Statistical Yearbook 2013 are not complete that cannot cover every administrative county researched in this project. In order to obtain the missing data, as supplementary data, some data that come from non-official websites and publications need to be taken into consideration as well as to be adopted.

3. Analysis & Assessment

Natural environmental risk is affected by three factors, namely precipitation, topography and river impact buffer. Three raster maps including rainfall index on flooding, influence of topography and river impact buffer are overlapped and transformed in GIS by the tool raster calculator with the weight(0.692*B1+0.107*B2+0.201*B3). Finally, the natural environmental risk in Guangxi Province is mapped as a result (figure 4).

As seen from the following map, regional rainfall concentrates on zones and areas which near the rivers. They have relatively higher natural environmental risk by contrast. Specifically, the southern part, middle part and northeast part are highly natural environmental risk area. If only taking the natural environmental risk into consideration, the western region of Guangxi Province is least likely to be influenced by floods, because these areas have relatively high altitude and low rainfall.

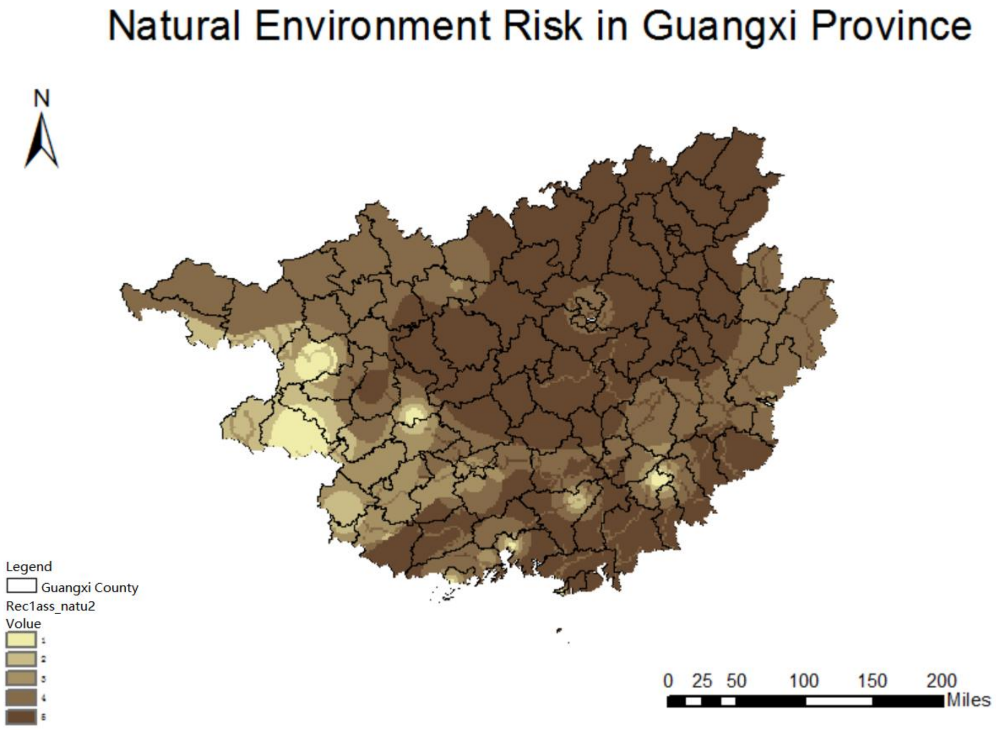

Figure 4. Natural environmental risk in Guangxi province

Floods vulnerability factors include population density and gross domestic product (GDP). The method is the same as what has been elaborated above, according to the formula (0.25*C1+0.75*C2), using raster calculator in GIS to superpose GDP layer and population density layer is the core step during whole process. After calculation, the map of vulnerability of socio-economic properties to flooding in Guangxi Province is mapped as a result.

From this topical map, it can be seen clearly that the vulnerability of socio-economic properties to flooding is quite large in southern coastal area of Guangxi. This is mainly related to the extent of economy, which results in different levels in loss rate of economy. Flooding may cause more damages in the area where there enjoys higher GDP. Small population density exists in western mountain areas, whilst there is a relatively lower GDP. Therefore, the socio-economic vulnerability of these areas is significantly smaller than that in other regions.

Floods disaster risk is affected by two elements, natural environmental risk and floods vulnerability. Similarly, we superpose the layer natural environmental risk and layer vulnerability of socio-economic properties by raster calculator with the weight (0.833*A1+0.167*A2). After raster calculated, the raster map of floods disaster is mapped as a result.

In order to classify floods disaster risk easier, it is compulsory to use the reclassify toolset in GIS to reclassify the value of risk. The method we adopted is called Natural Breaks (Jenks). In natural breaks, classes are based on natural groupings inherent within the data. ArcMap identifies break points by picking the class breaks that best group similar values and maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values.

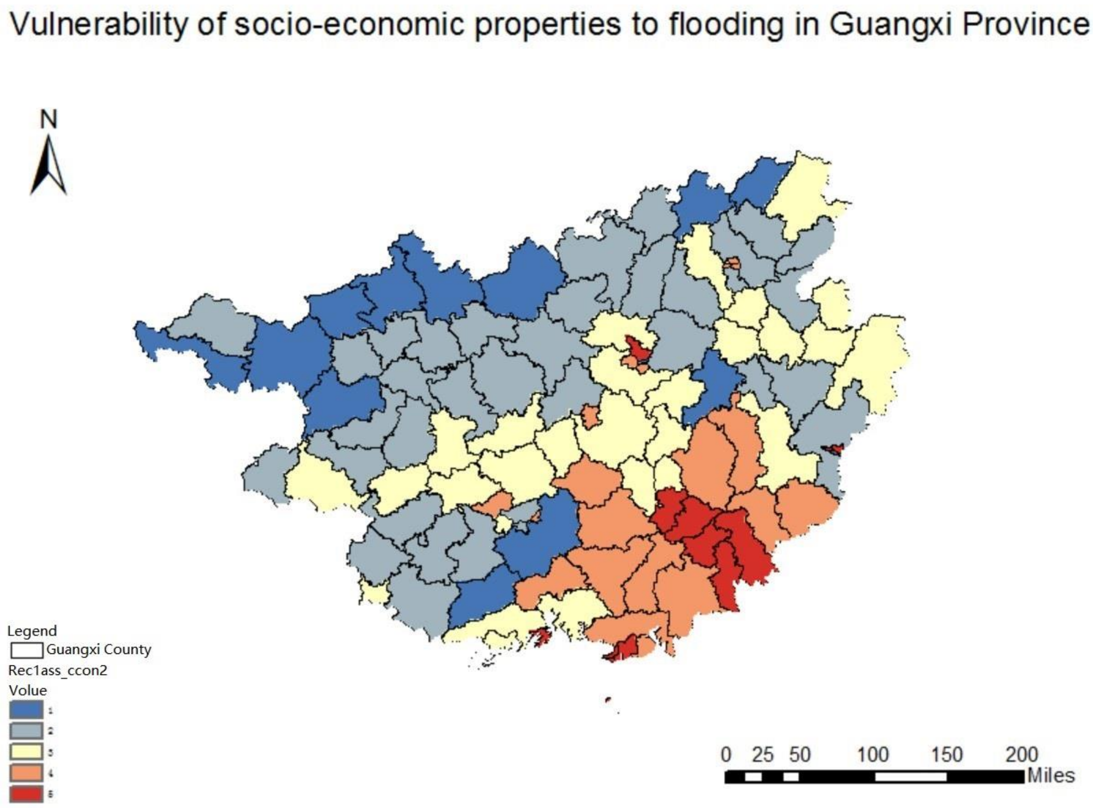

Figure 5. Vulnerability of socio-economic properties to flooding in Guangxi province

In addition, the literature said dividing floods disaster risk into five categories is better (GUO & ZHA, 2010). Therefore, Natural Breaks (Jenks) is used to divide the value of risk into 5 categories. The content detail is shown in the following table.

Table 7. Classification of floods disaster risk

Value of risk	Degree of influence	Connotation
1-1.32941	1	Low-risk area
1.32941-2.33333	2	Relatively low-risk area
2.33333-3.16471	3	Moderate risk area
3.16471-4.01176	4	Relatively high-risk area
4.01176-5	5	High-risk area

The final result of map of floods disaster risk in Guangxi Province is shown as below. From this map, it can be seen that southern coastal regions involving Hepu County, Bobai County and central basin areas involving Wuming County, Liujiang County are high-risk area of floods disaster. While the west and north-west regions involving Jingxi County and Youjiang County exist low floods disaster risk.

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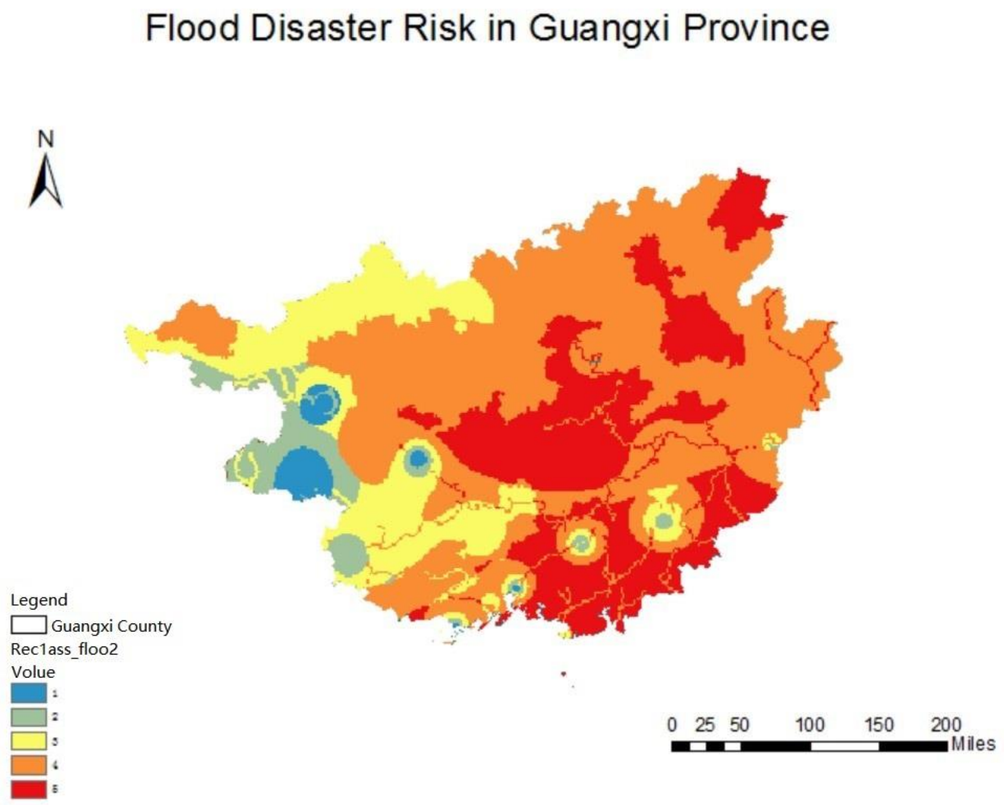

Figure 6. Floods disaster risk in Guangxi province

4. Conclusion

Based on the application of GIS, AHP method to establish floods disaster risk assessment model of Guangxi province, it is divided into five risk levels. Compared with the actually historical situation, we found that high-risk areas are basically consistent. Therefore, the results may provide the basis for disaster prevention and mitigation in Guangxi province.

From the classification results, the lower the terrain, the more rainfall, nearer the river and the better socio-economic status, the greater risk of floods it would have. Southern coastal regions and central basin of Guangxi is high floods risk zone, such as Liujiang County, Wuming County, Hepu County. Western regions exist low floods disaster risk, like Jiangxi county and Youjiang county.

The low floods disaster risk areas and relative low flood disaster risk areas in Guangxi province mainly include Jingxi, Youjiang, Debao, Napo, Tianlin, Xilin, Longzhou, Leye, Tiane and other western counties. These areas are mountain area with elevation of 500 meters above. High terrain, low density of river network, and high vegetation coverage which has strong function of soil and water conservation results in low incidence of floods. In addition, in these areas, population density is relatively low, whilst the economy is undeveloped. So even if the floods occurred, the losses in these areas would be less than that in the area where has higher density of population and higher GDP.

From the final result, it can be seen that Jingxi county and Youjiang county have the lowest flood disaster risk. According to the model of flood disaster risk, these two regions have relatively low precipitation, high terrain which is about 500 to 700 meters, and minor rivers. As a result their natural environmental risk is low. Coupled with the low vulnerability (low population density and small GDP), their flood disaster risk would be much smaller. Apart from this, there are other causes of this phenomenon. In Jiangxi County, limestone landscape distribute widely, and a lot of underground rivers exist. Affected by the flow orientation of underground rivers, groundwater is low in its southeastern region. So it has relatively good drainage. In Youjiang County, there are a large amount of forests. Forests have the function of water conservation which can help to reduce the frequency of occurrence of floods.

It is worth mentioning that northwestern region of Longshank County and Fuzhou County have relatively low risk. However, the regions surrounding them are high risk areas since there are mountains in the south of these two regions similarly, which are able to screen the rainfall from monsoon. Therefore, they have relatively low precipitation. In the floods disaster risk assessment model, there is no doubt that precipitation is the biggest factor. As a result, these two regions are in relatively low-risk area.

The high flood disaster risk areas and relatively high flood risk areas in Guangxi province mainly include Guangzhou, Lingui, Lichen, Liujiang, Xingjian, Banyan, Cenci, Bobbi, Hope and other south and central counties. These areas are mainly composed of river alluvial plain, and relatively large plain involving Xinxiang, Yuliana, Banyan plain and Nanliujiang delta as well. These areas are all have the common characteristics of low terrain, small elevation difference, high river network, many vegetation crops and small vegetation coverage.

What is more, these areas have a high density of population combined with the relatively developed economy. When it comes to the rainfall, it is vulnerable to suffer from floods disaster which will bring harm to the cities and economy.

Haicheng district suffers from highest flood disaster risk. This area is located in the coastal south of Guangxi which is influenced by monsoon climate. In addition, rainstorm risk and river network density are extremely high. Meanwhile, the high density of population and arable land even make the whole area become more vulnerable than other areas. In this situation, in order to prevent the losses of soil erosion, the government should improve the vegetation coverage. For the authorities, they should facilitate the meteorological department of fine service requirements to monitor, warn, and forecast the meteorological disasters on time, accurately and comprehensively. Also, the areas with high risk should improve the construction of water conservancy facilities.

References

[1] Chen, W. X. (1999). The Flood Disaster Loss Assessment System. CHINA WATER CONSERVANCY AND HYDROPOWER PRESS, 4-5.

[2] GUO Yong-fang & ZHA Liang-song. (2010). Risk Regionalization of Floods and Water Logging Disaster and Analysis of Variation Tendency of Damage Area in Anhui Province. Chinese Journal of Agro-meteorology, 31(1), 130-136.

[3] HE Hui, LU Hong, OU Yi. (2009, may). Flood Characteristic of the Xijiang River Basin in 1959-2008. Advanced in climate change research, 5(3), 134-138.

[4] Jiquan Zhang, Tomoharu Hori & Hirokazu Tatano, et al. (2002). GIS and Floods Inundation Model-based Floods Risk Assessment in Urbanized Floodplain. GIS & RS in Hydrology, Water Resources and Environment. Volume 1, Guangzhou, Sun Yat- Sen University Press.

[5] LU Yue-jin, ZHENG Wei & ZENG Xue-lan.(2003). Exponential Scale Not Being Consistent With 1-9 Scale. JOURNAL OF ENGINEERING MATHEMATICS, 20(8), 77-81.

[6] LI Junling, LIU Zhongyang, ZOU Chunhui.(2010). Assessment and Zonation of Flood Disaster Risk in Henan Province Based on GIS. Meteorological Monthly, 36(2), 87-92.

[7] MENG Jianfei, LU Jia, LI Yanlan, KUANG Shaomin. (2012, January). GIS-Based Assessment of Agricultural Flood and Water-logging Risk in Guangxi. Journal of Catastrophology, 27(1), 38-43.

[8] Mei Yong, Tang Yunhui, Kuang Xing.(2009). The Study of Risk Zoning of Rainstorm and Flood Disaster Based on GIS in Chongqing. Chinese Agricultural Science Bulletin, 27(32), 287-293.

[9] Mo, J. F., Lu, J. & Li, Y. L. (2010). GIS-based Sensitivity Assessment on Environment of Developing Flood Hazards in Guangxi Province. JOURNAL OF CATASTROPHOLOGY, 25 (4), 33-37.

[10] MENG Jianfei, LU Jia, LI Yanlan, CHEN Yanli. (2010, December). GIS-Based Sensitivity

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Assessment on Environmental of Developing Flood Hazards in Guangxi Province. Journal of Catastrophology, 25(4), 33-37.

[11] Richards, B. D. (1958). The Estimation and Control of the Flood. WATER POWER PRESS, 16-31.

[12] Sun, G. (1992). The Flood Risk Analysis Drawing a Practical Guide. WATER POWER PRESS.

[13] T. S. Cheong, M. L. A. Felix, S. M. Jeong.(2014). Development of GIS-based Disaster Assessment System to Reduce Flood Risks in Urbanized Creeks. Desalination and Water Treatment, 52(13-15), 2817-2825.

[14] You-peng Xu, Jin-kang Du, Li-feng Zhang, Xiao-ping Ge, Bu-zhu Peng.(2002). Research on System of Flood Disaster Control and Reduction Supported by GIS in Medium and Small Basins. Chinese Geographical Science, 12(1), 30-34.

[15] Zhang, J. Q. & Li, N. (2007). The Main Meteorological Disaster Risk Assessment and Management of the Quantification Method and Its Application. BEIJING NORMAL UNIVERSITY PRESS, 124-127.

[16] Zhang Jiquan, Okada Norio & Hirokazu Tatano, et al. (2002). Risk Assessment and Zoning of Floods Damage Caused by Heavy Rainfall in Yamaguchi Prefecture, Japan. Floods Defence 2002. New York: Science Press, 2002: 162-170.

[17] ZHOU Cheng-hu, WAN Qing, HUANG Shi-feng & CHEN De-qing.(2000). A GIS-based Approach to Floods Risk Zonation. ACTAGEOGRAPHICA SINICA, 55(1), 15-24.

[18] Zhang Jing, Hao Lisheng, Xu Xiaoguang.(2009). GIS-based Zoning and Analysis of Flood Disaster Risk in Hebei Province. Journal of Catastrophology, 24(2), 51-56.