The Simulation Analysis of Waterlogging and the Sponge City Planning Control of Central Urban Area in Fuzhou City : An Analysis Based on Landscape Scale

Dai Shao-qing[1], Jiang Hui-xian[2], Li Jia-jia[3]

[1]College of Geographical Sciences, Fuijian Normal University, email: dsq1993qingge@163.com

[2]Fujian Provincial Engineering Research Center for Monitoring and Assessing Terrestrial Disasters; M.S. email: jhx155@163.com

[3]College of Geographical Sciences, Fuijian Normal University, email: jiajia_gl@126.com

Abstract: In the new normal period of economic transition in China, The Government decision-making, which promoted the idea of people-oriented, came up with the concept of the Sponge City Using RS, GIS and multi-source open data, based on landscape scale, the study was done for the simulation analysis of urban waterlogging and the sponge city planning control in Fuzhou city. The result showed that, 1) The flood level of the 100 years flood of different scenarios are 3.943 m and 4.055 m in the central urban area of Fuzhou city, the flood area includes urban central business district, some villages along traffic arteries, international convention and exhibition center and so on. With the characteristics of high population destiny, high activity intensity, and high comprehensive economic and traffic status, the area is likely to be damage extremely by waterlogging. 2)The amount Sponge natural landscape in the central urban area of Fuzhou city had declined in 2006-2014. The urban residential land accounts for about 40% of the landscape conversion. The disappearance of Sponge landscape increased the risk of waterlogging. Based on Apriori algorithm "sponge" natural landscape disappear area and flooded area of spatial data association rules mining support reached more than 65%.The urban Sponge landscape conversion area and the flood area closely associated torts. 3) The fragmentation degree of urban Sponge landscape get worse, leading to the failure in making up a completed urban ecological function zone. The measures of sponge city planning control in Fuzhou city including building green corridor, green roof, permeable pavement, the comprehensive control of inland rivers was put forward accordingly.

Key words: Sponge City, simulation of waterlogging in urban, landscape, central urban area in Fuzhou

1 Introduction

Xi jinping put forward “new normal” when he investigated Henan province in May, 2015. It’s essential to improve people's living quality and advocate people-oriented government decision-making (Wang, 2014). Along with the rapid development of Chinese economy, environmental carrying capacity reached the upper limit and “new normal” met serious environmental problems in the past three decades. We need a transformation to carbon cycle development mode when economic structure in the process of optimization. Urban waterlog is an important problem in the period of “new normal”. Urban underground pipeline’ discharge capacity is poor and when rain storm come leads hydrops easily. construction land encroach greenbelts and water bodies area in the urbanization process, which leads rapid decline of water conservation and water storage capacity, lack of large foreign projects of drainage , low capability of underground pipe network. All these are the cause of Chinese urban waterlog. Survey on controlling water balance and managing urban waterlog have further development (Liu et al., 2015). IPCC report points out that climate change increases the probability of the occurrence of urban extreme rainstorm (IPCC, 2011). In these years, survey on urban waterlog begin combine low impact development with storm water management model and do some hydrological analysis in foreign (Palla and Gnecco, 2015; Rosa et al., 2015; Carlson et al., 2014).

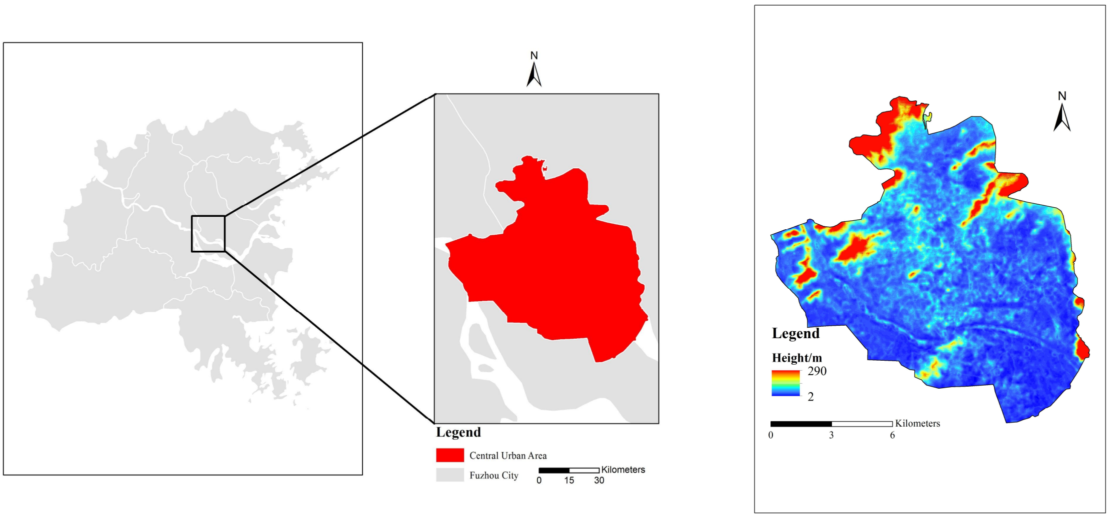
Martin-Mikle et al identifying priority sites for low impact development (LID) in a mixed-use watershed (Martin-Mikle et al, 2015). Zheyu did a research on water-related issues in urban road system and aim to support urban planning (Zhang et al, 2013). While survey on urban waterlog focus on governing and evaluating disaster, neglecting mind permeation of low impact development in China(Fu et al, 2015; Li, 2013; Peng and You, 2006; Shi et al, 2014; Zhou et al, 2014). Such as choosing hydrological model with geographic information system assessment of urban rainstorm and disaster risk, analyzing of flood submerging based on digital elevation model and using virtual reality in the ArcGIS platform to displays it on a 3D visualization(Zhu et al, 2009; Sun et al, 2012; Guo and Long, 2012; Yang et al, 2011; Chen et al, 2014). Besides that, based on digital elevation model and thought of water balance, using bulk method calculate flood submergence area has been widely studied (Zhao et al, 2015; Liu and Huang, 2005; Cai et al, 2013). Ministry of Finance of the People's Republic of China published《Notice on Promote Sponge City Pilot Demonstration by selecting local cities and giving elected ones the central government financial support》 in Dec. 31, 2014 (Chen and Shi, 2016). It's people-oriented practice of urban new form, and extension of low impact development. The sponge city is like a sponge which retains the water, recycles the water, and eliminates the pollution from water runoff at previous stages (Chou, 2015). Sponge city and Low impact development technology practiced in stormwater management in Foreign, examples from a newly developed large supermarket in Munich, Germany and Scharnhauser Park near Stuttgart, German are given(Geiger, 2015). "Low impact development" first proposed in America and Japan, while domestic scholars on this issue relatively lately start, the first large studies comprising LID designs was done in Beijing after 2000 and 2005. "Sponge city" make low impact development technology integrate into Chinese stormwater management system.

Composition of urban underlying surface are the keys to solving urban waterlog (Cao et al, 1998), some scholars studied urbanized area and its runoff capacity (He et al, 2003), while studies on relationship beween composition of urban underlying surface and urban waterlog rarely. Composition difference of urban underlying surface affect disaster evaluation mostly, and research scale more focus on administrative region. In ecology, landscape is included of difference land units mosaic composited significantly visual characteristics geographic entity, which imply economic value, ecological value, cultural value (Xiao et al, 2003). Many scholars using remoting sensing and geographic information system extract landscape and analysis dynamical change of landscape pattern recently. Zhou inquiry impacts of impervious surface srea and landscape metrics on urban heat environment (Zhou et al, 2014), analysis urban form development based on land use and land cover pattern(Guo, 2006). he paper based on landscape scale and theory of sponger city classify urban underlying surface to difference landscape. According to relationship between landscape heterogeneity and storm runoff simulate urban waterlog analysis and implement planning regulation.

2 Study area and data sources

The study area for this research is central city in Fuzhou, China. Which consistent with urban planning area reported in 《The urban master planning of central urban area in Fuzhou city（2011-2020）》(Fuzhou, 2009). Gulou district, Taijiang district, north of Cangshan district and built-up area in Jinan district were Included (26°0′39.41-26°9′23.96″N，119°13′11.46-119°22′33.07″E，Fig. 1（a）). The Fuzhou city rivers crisscrossed, Lake and pond connected. Also including 37 garden woody plants and 42 inland rivers (Fuzhou, 2007). Fuzhou city was selected as the national experimental city in sponge city in 2016(Chen and Shi, 2016). In the process of urban development, some inland rivers were destroyed. Basin is the main topography in Fuzhou city, so central city suffer waterlog frequently. 《Research on water supply and drainage discipline development in Fujian Province》 points that fresh water resources utilization efficiency is low(Liu, 2013), the receiving water and large drainage works are lack, causing great harm to Fuzhou(Yang and Liu, 2014).

This selection of the data include: 1) remote sensing satellite data: urban planning at the county level for the five-year life cycle, select the remote sensing images from the three phases of geospatial data in the cloud (November 6, 2006, May 2010 on the 24th Landsat 5 TM images, December 13, 2014 Landsat 8 OLI images were atmospheric correction and geometric correction); 2) space vector data: Fuzhou cadastral database (derived from Fuzhou City land resources Bureau), 2010 six census data (building scale, from Fuzhou mapping Agency), Weibo poi data (derived from data Church: http://www.datatang.com/); 3) Fuzhou 30 m GDTM DEM (Figure 1 (b), derived geospatial data in the cloud: http://www.giscloud.cn/)



（a） （b）

（a: study area，b: DEM）

Figure 1.Study Area and DEM

3 Research methods

3.1 Technology roadmap

This paper studies simulation waterlogging and sponges urban planning regulation by RS and GIS technology, particularly technology roadmap is as follows.

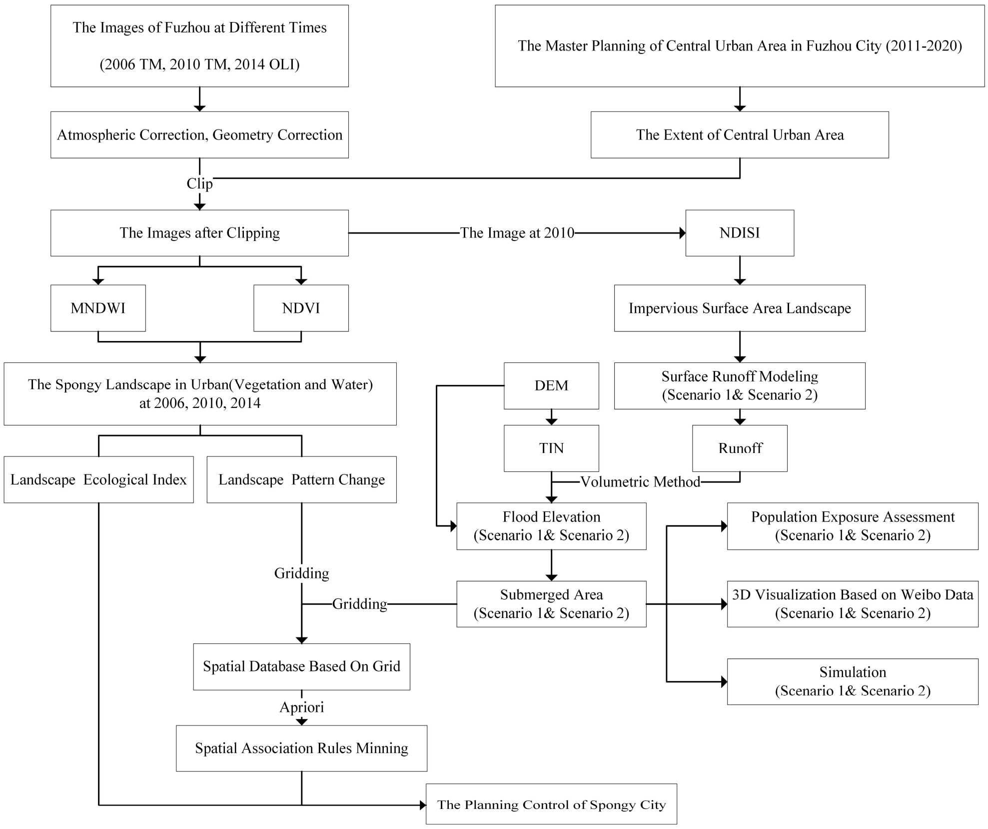


Figure 2.The Flow Chart of Study

3.2 Extraction impervious surface landscape based on a normalized index impervious surface

Urban surface, for infiltration of rainwater have important implications for the impervious surface. Impervious surface refers to a variety of cities to impede penetration of covering the surface below the surface (Arnold and Gibbons, 1996). For impervious surface extraction, normalization impervious surface index Fast information presented currently widely used (Xu, 2009). Index expression is:

$$NDISI = \frac{TIR - (MNDWI + NIR + MR_1)/3}{TIR + (MNDWI + NIR + MR_1)/3} \qquad (1)$$

Formula (1), TIR represents the thermal infrared band, MNDWI to improve normalized difference water index, NIR representatives of near-infrared bands, MR representative of the mid-infrared. When calculating the thermal infrared band and normalized water index made 0-255 gray scales linearly stretched. Select cloud geospatial data acquired in 2010 pretreated TM5 image extraction impervious surface landscape

3.3 Impervious surface runoff

Impervious surface runoff is calculated as follows(Hao, 2012):：

$$Q = \psi q F \qquad (2)$$

Formula (2), Q is the surface runoff $(L{\cdot}s^{-1})$, q is the rainfall intensity （$L{\cdot}s^{-1}{\cdot}ha^{-1}$）, F is impervious surface area (*ha*), Ψ for the runoff coefficient. According to Shao Wei (Shao and Pan ,2012) proposed in the "face of Runoff between urban and impermeable," a text, the current general formula Fuzhou rainfall runoff coefficient is 0.75.

3.4 Storm intensity

"Fujian Provincial Construction Department approved the release of the provincial construction on local standards (Fujian cities and some county storm intensity formula) notice" (Fujian et al,2003) selected according to the intensity of rain in Fuzhou is calculated as follows:

$$q = \frac{2136.312(1+0.700\lg Te)}{(t+7.576)^{0.711}} \quad (3)$$

Formula (3), q is storm intensity （$L \cdot s^{-1} \cdot ha^{-1}$）, Te is the return period （a）, t is the rainfall duration (min).

3.5 Normalized Difference Vegetation Index

Use a combination of satellite data to detect different bands together to analyze vegetation coverage index, normalized difference vegetation index is calculated as follows (Xu, 2005):

$$NDVI = \frac{NIR - R}{NIR + R} \quad (4)$$

Formula (4), $NDVI$ normalized difference vegetation index, NIR representatives of near-infrared bands, R on behalf of the infrared band.

3.6 Modified Normalized Difference Water Index

In Fast information presented NDWI (Normalized Difference Water Index) basis, according to a new index to extract water information values of radiation bands improvements obtained, and its accuracy is much higher than NDWI (Xu, 2005). Modified Normalized Difference Water Index is calculated as：

$$MNDWI = \frac{Green - MR}{Green + MR} \quad (5)$$

Formula (5), $NDWI$ to improve normalized difference water index, $Green$ on behalf of the green band, MR representative of the mid-infrared。

3.7 Based spatial association rule mining algorithm Apriori

Apriori algorithm is a Boolean association rule mining frequent itemsets algorithm. Its core is based on a two-stage frequency set recursive algorithm thought. Apriori algorithm based on a priori nature: all non-empty sets frequent item sets must also be frequent. I assume that all items set for: $I=(i_1,i_2,\ldots i_m)$， D is the set of all transactions (ie database) that is: D = (T1, T2, ... Tn). For simplicity, the (A contained in T) => (contained in B T) is expressed as A => B, where "=>" known "correlation" operation, A prerequisite called association rules, B says the result of association rules).

Transaction set D rule A => B is supported by the degree of s (support) and confidence c (confidence) constraints.D

$$support(A => B) = P(A \cup B) \quad (6)$$

$$confidence(A => B) = P(B|A) \quad (7)$$

At the same time meet the minimum support threshold (min_sup) and minimum confidence threshold (min_conf) rules called strong rules.

3.8 Landscape ecological indices analysis

Select the number of landscape patches (NP), the mean plaque area (MPS), the total length of the border (TE), the weighted average plaque area fraction (AWMPFD) dimension of landscape ecology indices were analyzed, which is calculated as follows (Guo, 2012)：

$$NP = N \quad (8)$$

$$MPS = \frac{A}{N} \quad (9)$$

$$TE = \sum_{j=1}^{n} p_{ij} \quad (10)$$

$$AWMPFD = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[\left(\frac{2\ln 0.25 p_{ij}}{\ln a_{ij}}\right)\left(\frac{a_{ij}}{A}\right)\right] \quad (11)$$

Formula (8) - (11), N，A is the total number of all types of landscape patches, total area, P_{ij}，$A_{ij}$is the i-type landscape in the j-th block plaque side length and area.

4 Results and analysis

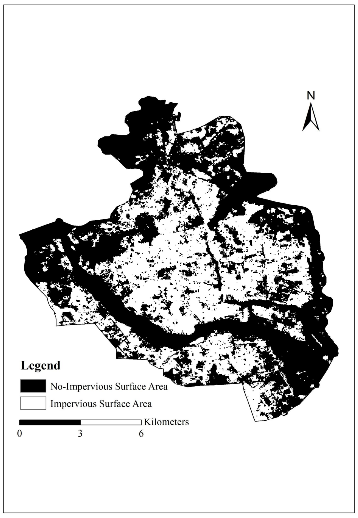
4.1 Landscape and Urban Impervious Surface Storm scenario simulation waterlogging inundated areas Analysis and Visualization

The actual control in ENVI 5.1 image, choose 0.175 as the threshold to give landscape impervious surface (Fig. 3 (a)), the statistics can be obtained in an area of 6062.31 ha in ArcGIS10.2. After calculating the waterlogging runoff, GIS-based applications (Zhao, 2010), "rainfall volume method" submerged height value Select 100-year rainstorm, rainfall duration is set to 2 h and 4 h storm scene. It can calculate the corresponding indicators (Tab. 1).。

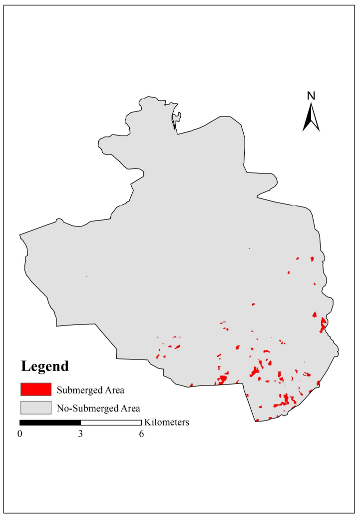
Table 1.The Simulation Result of Strom Water Scene

Storm scenarios	Scenario 1 (100 years, rainfall duration 2h)	Scenario 2 (in 100 years, rainfall duration 4h)
Sorm Intensity（$L{\cdot}s^{-1}{\cdot}ha^{-1}$）	163.183	101.847
Runoff（$L{\cdot}s^{-1}$）	5.342×10^{6}	6.668×10^{6}
Submerged elevation（m）	3.943	4.055
Maximum Submergerd depth（m）	1.943	2.055
Submerged area（km^2）	1.361	6.102

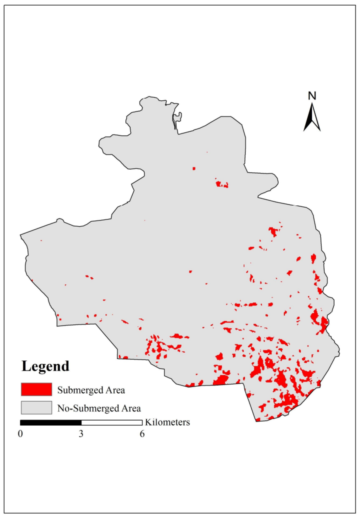
In this paper, the simulation scenarios rainstorm waterlogging, that whole area evenly rain, it will be seen as a passive process waterlogging submerged state (Zhou et al, 2014), to give 1,2 storm scenarios flooded area (Figure 3 (b), (c)). Flooded area in Fuzhou Fujian Strait International Conference & Exhibition mainly around the regional center, near the first mountain, Gushan town along the Fuzhou-Xiamen Railway - Ring Road area, near the Cangshan District People's Government of the region, near the Regional Land Development Center of Fujian Province, May Square. Selection of the 2010 sixth census data flood exposure assessment (Fig. 3 (d), (e)), the submerged area of the exposed population reached 1.259 million and 4.430 million. Weibo poi check-ins and photos frequency can be characterized urban land use in human activity intensity, in ArcScene and City Engine in Scenario 2 flooded area and the intensity of human activities (Weibo poi kernel density analysis) three superimposed visualization and and drowned scenario simulation . The results showed that the number of people exposed to inundation area is large, a plurality of three-dimensional thermal peak inundated areas in FIG. Description waterlogging inundated areas are among the larger urban area population density and activity intensity, harmfulness.


N
Legend
No-Impervious Surface Area
Impervious Surface Area
Kilometers
0 3 6

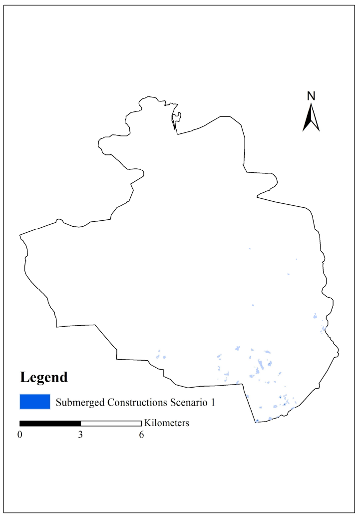
（a）


N
Legend
Submerged Area
No-Submerged Area
Kilometers
0 3 6

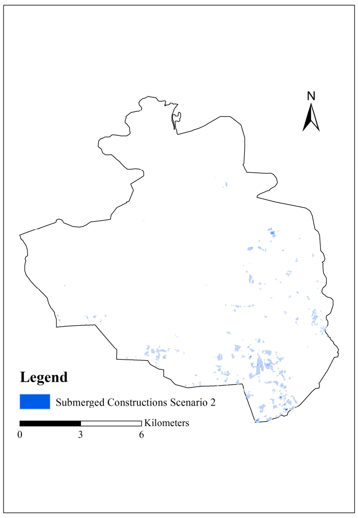
（b）


N
Legend
Submerged Area
No-Submerged Area
Kilometers
0 3 6

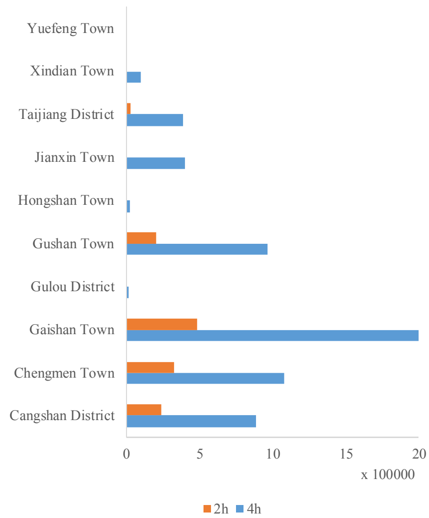
（c）


N
Legend
Submerged Constructions Scenario 1
Kilometers
0 3 6

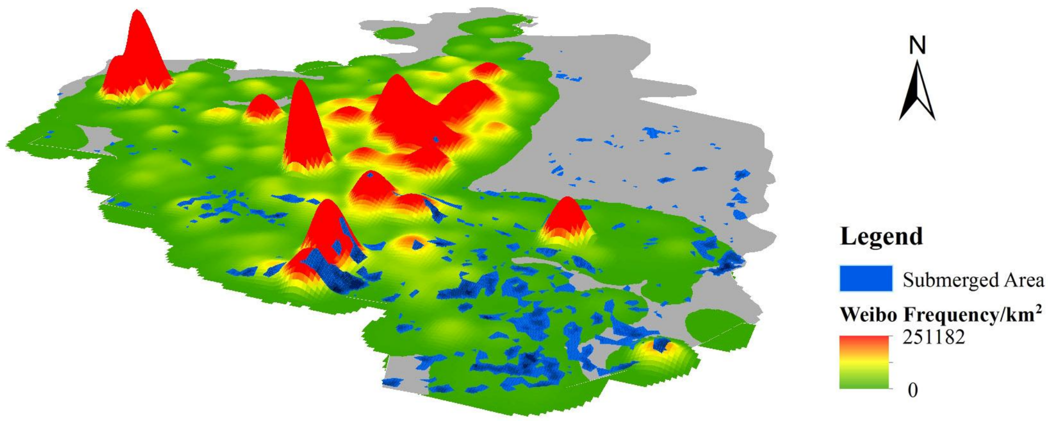
（d）


N
Legend
Submerged Constructions Scenario 2
Kilometers
0 3 6

（e）


Yuefeng Town
Xindian Town
Taijiang District
Jianxin Town
Hongshan Town
Gushan Town
Gulou District
Gaishan Town
Chengmen Town
Cangshan District
0 5 10 15 20
x 100000
2h 4h

（f）


N
Legend
Submerged Area
Weibo Frequency/km²
251182
0

（g）

（h）

（i）

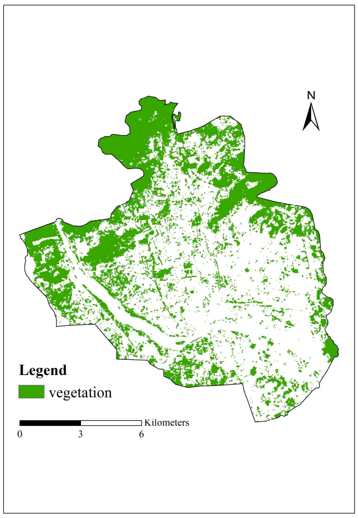
（Fig. a is a center of Fuzhou city landscape impervious surface extraction results; Fig. b, c of the central city of Fuzhou 100-year storm 2h, 4h scenarios Waterlogging flooded area; Figure d, e is submerged within the area of the building, Fig. f for different administrative inundation area statistics; Fig. g is microblogging sign photos frequency three-dimensional thermal map and flooded area overlay plot; Fig. h, i of the road near the Strait international Conference and Exhibition Center 100-year storm 2h, 4h waterlogging flooding simulation scenarios）

Figure 3.The Analysis of Urban Submergence and 3D visualization based on Impervious Surface and Scenario of Rainstorm

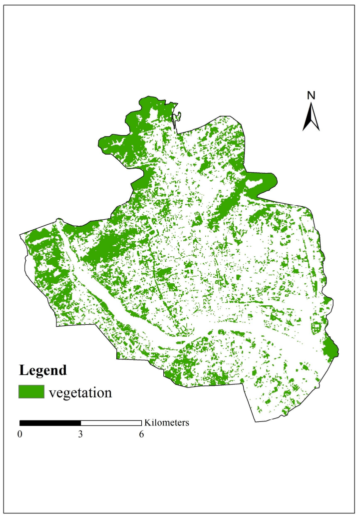
4.2 Changing urban landscape pattern analysis "Sponge"

The city is a sponge to solve urban waterlogging new initiatives, it is based in that city construction "cavernous" landscape. Urban surface, in addition to impervious surface landscape, there is vegetation and water bodies receiving such water landscape, the landscape is one of "Sponge" Fuzhou in the urban development process, receiving water and other cities "Sponge" landscape was severely damaged, which is the central city waterlogging aggravated part of the reason, but the change "Sponge" landscape pattern and urban waterlogging impact mechanism remains Unable to quantitative description. Therefore, this paper association rules on the basis of changes in the landscape pattern mining techniques attempt to quantitatively describe the impact mechanism between the two.

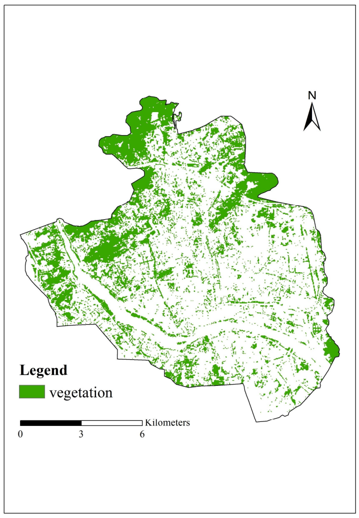
Were selected based on remote sensing images acquired 2006,2010,2014 NDVI results 0,0.11,0 threshold value extraction and enhancement, according to the results 2006,2010,2014 MNDWI acquired remote sensing images were selected as the threshold 0.85,0.85,0.88 extraction and enhancement. Get map and landscape vegetation water landscape (Fig. 4, 5), analyze the city center from 2006 to 2014 in Fuzhou City "Sponge" dynamic landscape pattern change.



（a）2006

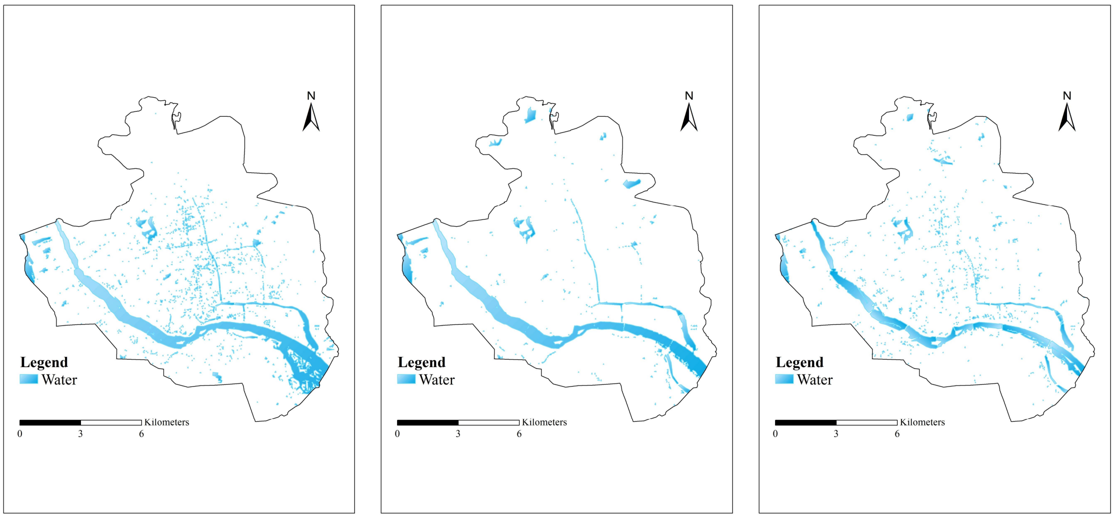


（b）2010



（c）2014

Figure 4.The Vegetation Landscape of Central City Region in Fuzhou



（a）2006 （b）2010 （c）2014

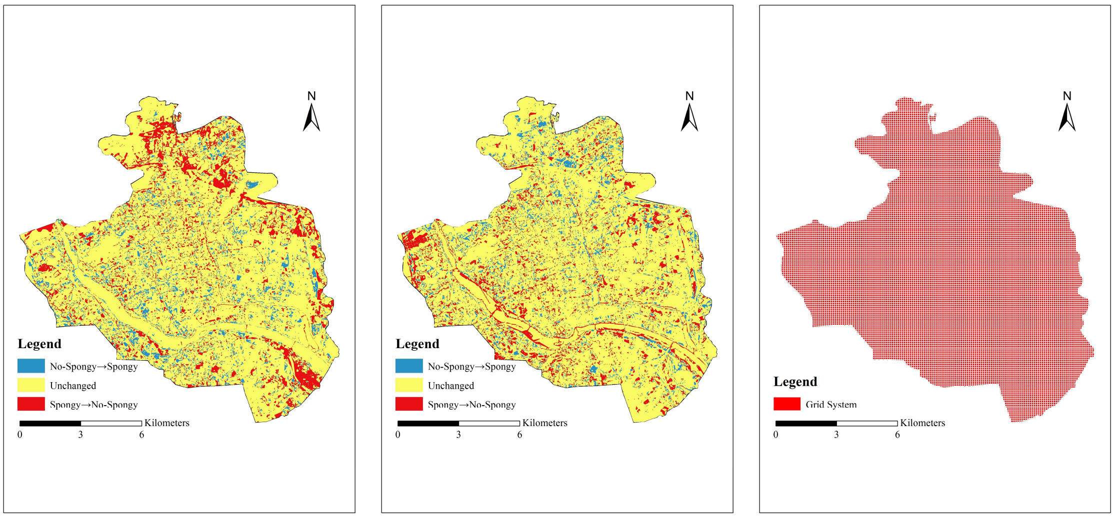
Figure 5.The Water Landscape of Central city Region in Fuzhou

From the spatial distribution patterns can be found in the central city of Fuzhou City "cavernous" gradually landscape fragmentation. From the quantitative trends, calculate vegetation, water types of urban "Sponge" area change (Tab. 2). Vegetation and water bodies in 2006 and 2014 showed a downward trend, the rate of change is more stable. Analysis of 2006 and 2010, 2010 and 2014 the city "Sponge" shift change landscape (Fig. 6 (a), (b)). It can be found in 2006--2010 years, "cavernous" basic transfer area on the edge of the downtown area, 2010 - The 2014 " Sponge " fundamental shift area near the river. Analysis of types of land "Sponge" transfer region cadastral library binding land-use data. In 2006 to 2010, for example, there are 28.17% of "cavernous" In order to change the landscape of urban residential land, the proportion of other types of land are no more than 10%, and a larger proportion of other types of land also belongs to the type of built-up area of land (overall the proportion of about 40%). As can be seen, a large city "cavernous" landscape into built-up areas (mostly in urban residential land).

Table 2.2006, 2010, 2014 Changes of Vegetation and Water area in Urban

Year	2006	2010	2014
Vegetation area /km^2	48.254	42.503	38.838
Water area /km^2	13.739	10.892	8.769

In order to further explore the quantitative description, selection of association rule mining analysis. Establishment of District 100 × 100 m grid system to give 14,552 cells grid. Then Scenario 1 Scenario 2 waterlogging inundated areas, 2006-2010, 2010-2014, " Sponge " landscape changes related to the transfer of data stored in the grid system. Setting Scenario 1 Scenario 2 flooded area, 2006-2010,2010- 2014 " Sponge " area coverage grid landscape shift change to the Boolean value 1, other grid Boolean value 0, imported into SPSS Clementine 12.0, the use of Apriori algorithm for mining association rules (Tab. 3). As can be seen, "2010-2014 City ' Sponge ' transfer region" => Scenario 2 flooded area, "City 2006-2010 ' Sponge ' transfer area => Scenario 2 flooded area" of support for the two rules are up about 65% confidence level of about 10%, the ability to deploy the rules in about 60%, and strong association rules; illustrates that the association " Sponge " area of landscape changes and close the submerged area. Thus, the city "cavernous" landscape disappeared aggravated urban waterlogging, mainly urban surface in built-up area of impervious surface landscaping, water seepage, poor receiving water, drainage capacity, the city " Sponge " landscape a lot of rain can not penetrate further missing, so when the storm drain and ground to form a runoff, a lot of water formed waterlogging.



（a） （b） （c）

（Fig. a, b, respectively 2006-2010,2010-2014 FIG City " Sponge " landscape shift change; Fig. c grid system）

Figure 6.The Area of Sponge Landscape Conversion in Urban and Distributions of Submergence, Water-logging monitoring sites

Table 3.The Results of Association Rules Mining

Rule	Support/%	Confidence/%
2010-2014 City " Sponge" transfer area => Scenario 2 flooded area	65.159	10.726
2006-2010 City " Sponge " transfer area => Scenario 2 flooded area	65.455	11.412
2006-2010 City " Sponge " transfer area and 2010-2014 City " Sponge " transfer area => Scenario 2 flooded area	49.189	10.729

4.3 Landscape Ecological Analysis Aid Plan Regulating Index

City " Sponge " disappearing landscape where waterlogging has become a large area, and how to rebuild the city "cavernous" Landscape keeping urban surface water drainage is a key feature of Fuzhou city construction sponge. Landscape ecology ideas through analysis of landscape ecology indices ecological significance of the city " Sponge " A Landscape, city analyzing " Sponge " ecological problems existing landscape, from ecology concept, thinking of effective to aid government decision-making center of Fuzhou city planning regulation sponges city. To do this select the number of plaques (NP), the mean plaque area (MPS), the total length of the border (TE), the weighted average plaque area fraction (AWMPFD) dimension four kinds of landscape indices calculation landscape index analysis, ArcGIS 10.2 processed and city " Sponge " view data into Fragstats 4.2 in the calculation, the results are shown in Tab. 4.

Table 4.The Change of “Sponge”Landscape Index in Urban

Landscape Index	NP	MPS	TE	AWMPFD
2006	2784	1395027	2.210	1.228
2010	2743	1409336	1.944	1.203
2014	3669	1547027	1.297	1.186

From the point of view of landscape changes in the index, the number of patches of landscape as a whole increased year by year, the average plaque area decreased year by year, gradually increases the length of the border, area weighted mean patch fractal dimension gradually reduced. Increasing the number of plaques and the length of the border represents an edge length increased while the average plaque area has been reduced, which represents the city " Sponge " fragmentation of the landscape by human disturbance growing, area weighted mean patch fractal dimension reduce the number, it said in a fragmented landscape change trends at the same time, relatively simple shape. Landscape architecture presents complicated, affected by human activities intensified. Serious human disturbance, the overall spatial pattern, the city " Sponge " landscape distributed in a large part of the plaque area outlying border areas of the city center, connected into pieces, drainage water and powerful, and in the center of the city inside, impervious the city faces " Sponge" landscape fragmentation fragmented into small patches, almost destroyed river, a tributary of the Minjiang river runs through the northern part of the central city of Fuzhou and over, but its landscape ecological functions by the receiving water body is not strong, the city center the " Sponge " can not form a landscape ecological functions with receiving a large number of water bodies, leading to waterlogging serious harm.

For the central city of Fuzhou, the city "cavernous" Reconstruction landscape should be protected outlying cities "Sponge" landscape with ecological functions, internal governance inland, increase the "Sponge" landscape forming function band. For the City "Sponge" landscape, including not only the natural landscape of vegetation and water, there are many types of artificial landscapes, such as: green roofs, permeable pavement and so on. Based on the results of landscape ecology index analysis for the idea in the context of open data era, the use of multi-source open Internet data acquisition and access traditional data binding to waterlogging simulation inundated areas in-depth understanding and observation, the waterlogging simulate the submerged area is divided into four types (Tab. 5), according to the relevant documents and guidelines (Ministry, 2014; Zhu et al, 2015; Tang, 2010), urban planning sponge proposed regulation.

Table 5.The Planning Control of All Types of the Distributions of Submergence in Urban includes Typical Case

Waterlogging flooded zone types	Typical region	Planning regulation
City Central Business Distric（CBD）	Wuyi Square, Cangshan District People's Government nearby area	Green corridor construction (10 m)
Traffic Road Rural Development and to be	Gushan Town, New Town	A green roof pilot area, permeable pavement pilot area
Urban Residential	Near the Metro	Town gates green roof pilot area
Other sites	Cangshan District Strait	The first mountain road near

	International Convention and Exhibition Center	the river corridor construction (300 m)

5 conclusion

1) The central city of Fuzhou in 100-year storm, rainfall duration 2 h and 4 h under simulated disaster scenario, flooding elevation is 3.943 m, 4.055 m, inundated areas exposed populations were 1.259 million, 4.430 million, and mostly located in large regional activity rate, large inundated areas risk disaster.

2) The central city of Fuzhou "cavernous" Landscape in 2006-- During 2014, the number of declining spatial form was fragmented, multi-shift change landscape into urban residential land, the ratio close to 40%. The results show association rule mining, urban waterlogging region and "cavernous" area closely associated with landscape shift change. "Cavernous" landscape disappeared exacerbated urban waterlogging.

3) Landscape ecological indices analysis showed that increased central city of Fuzhou "cavernous" degree of landscape fragmentation and human disturbance serious. A large number of "cavernous" landscape is fragmented, unable to connect to become receiving water landscape and greatly reduce the drainage capacity.

4) For the type of land in the flooded areas, local conditions make relevant sponge urban planning regulation.

REFERENCES

Arnold, C. L., and Gibbons, C. J. (1996). “Impervious surface coverage: The emergence of a key environmental indication.” *Journal of the American Planning Association*, 62(2), 243-258.

Cai, X., Li, Y., Wu, W., and Wang, Y. (2013). “Cellular automaton model of flood submergence based on bulk method.” *Journal of Hydroelectric Engineering*, 32(5), 30-34.

Cao, W., Qu, C., and Wang, S. (1998). “Composition of city underlying surface and its effect on water balance factors.” *Journal of Heilongjiang Hydraulic Engineering College*, 25(3), 39-44.

Carlson, C., Barreteau, O., Kirshen, P., and Foltz, K. (2014). “Storm water management as a public good provision problem: survey to understand perspectives of low-impact development for urban storm water management practices under climate change.” *Journal of Water Resources Planning and Management*, 141(6), 0401-0408.

Chen, L., and Shi, Y. (2016). “Fuzhou was selected as the national experimental city in sponge city.” *People. cn,* http://fj.people.com.cn/n2/2016/0426/c364469-28221899.html>(Apr. 26, 2016).

Chen, W., Chen, S., Yang, J., and Ma, J. (2014). “Reservoir flood inundation simulation based on integrated 3D scene of terrain and dam.” Geography and Geo-Information Science, 30(2), 16-19.

Chou, B. (2015). “Connotation, Path and Expectation of Eco-sponge City (LID).” *Construction Science and Technology*, (1), 11-18.

Fu, R., Luo, L., Liu, J., and Zhao, H. (2015). “The application of the drains system capability assessment based on SWMM.” *China Rural Water and Hydropower*, 3, 103-109.

Fujian Urban and Rural Planning Design Institute, Shenzhen Polytechnic. (2003). “Housing and Urban-Rural Development of Fujian approved and published local standardization of construction engineering in Fujian Province《Strom Intensity Formula in Fujian city and some county》.” *Housing and Urban-Rural Development of Fujian.* http://www.fjjs.gov.cn/xxgk/zfxxgkzl/zfxxgkml/flfg_zfxxgkml/jskj/200311/t20031107_43279.htm> (Nov. 3, 2003).

Fuzhou Planning Design and Research Institute and Fuzhou Urban and Rural Planning Bureau

(2009). “The urban master planning of central urban area in Fuzhou city.” *Fuzhou Urban and Rural Planning Bureau*, http://ghj.fuzhou.gov.cn/ghzs/ztgh/200910/t20091018_45873.htm>(Feb, 19, 2009)

Fuzhou, China 2007. (2007). “Tourist attraction.” *China Fuzhou*, http://www.fuzhou.gov.cn/zfb/xxgk/zjrc/zrdl/dlqk/200706/t20070615_13089.htm>(Jun. 15, 2007)

Geiger, W. F. (2015). Sponge City and LID Technology—Vision and Tradition. *Landscape Architecture Frontiers,* 3(2), 10-20.

Guo, D. (2006). “Prediction of land use and land cover patterns in recent yellow river delta using markov chain model.” *Soils,* 38(1), 42-47.

Guo, L., and Long, Y. (2002). “Analysis of Flood Submerging Based on DEM.” *Bulletin of Surveying and Mapping*, (11), 25-27.

Guo, N. (2012). “Dynamic analysis and prediction of vegetation landscape pattern based on 3S technology—A case study of Xi'nan peninsula in Fujian.” Fuzhou, Fujian Normal University.

Hao, J. (2012). Study on the influence factors of runoff reduction for urban impermeable underlying surface under simulated rainfall condition. Chongqing, Chongqing University.

He, B., Chen, C., and Zhou, N. (2003). “Urbanized area runoff coefficient and its application.” *Shanghai Environmental Sciences*, 22(7), 472-475.

IPCC. (2011). “Intergovernmental panel on climate change special report on managing the risks of extreme events and disasters to advance climate change adaptation.” Cambridge: Cambridge University Press.

Li, S. (2013). “Study on urban flood risk management and practical technology-a case study of Fuzhou city.” Beijing, China Institute of Water Resources and Hydropower Research.

Liu, D., Cheng, H., Huang, W., Hu, Z., and Qiu, S. (2013). “Research on water supply and drainage discipline development in Fujian Province.” *Straits Science*, (1), 24-.

Liu, W., Chen, W., Peng, C., and Qian, Y. (2015). “A water balance approach to assess rainwater availability potential in urban areas: the case of Beijing, China.” *Water Science and Technology Water Supply*, 15(3), 490-498.

Liu, X., and Huang, Y. (2005). “Analog Calculation of Submerged Area with Bulk Method.” *Bulletin of Surveying and Mapping*, (12), 47-49.

Martin-Mikle, C, J., de Beurs, K, M., Julian, J, P., and Mayerc, P, M. (2015). “Identifying priority sites for low impact development (LID) in a mixed-use watershed.” *Landscape and Urban Planning*, 140, 29-41.

Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2014). “Ministry of Housing and Urban-Rural Development of the People’s Republic of China concerning the printing and distribution of the Explanation of Sponge City Development Technical Guide.” *MOHURD*, http://www.mohurd.gov.cn/zcfg/jsbwj_0/jsbwjcsjs/201411/t20141102_219465.html>(Oct. 22, 2014).

Palla, A., and Gnecco, I. (2015). “Hydrologic modeling of Low Impact Development systems at the urban catchment scale”. *Journal of Hydrology*, 528, 361-368.

Peng, D., and You, J. (2006). “Application of modified SCS model into runoff simulation.” *Journal of Water Resource & Water Engineering*, 17(1), 20-24.

Rosa, D. J., Clausen, J. C., and Dietz, M. E. (2015). “Calibration and verification of SWMM for low impact development.” *JAWRA Journal of the American Water Resources Association*, 51(3), 746-757.

Shao, W., and Pan, W. (2012). “On the relationship between urban impervious surface and rainfall-runoff.” *Journal of Subtropical Resources and Environment*, 7(4), 20-27.

Shi, Y., Wan, D., Chen, L., and Zheng, J. (2014). “Simulation of rainstorm waterlogging and submergence in urban areas based on GIS and SWMM." *Water Resources and Power*, 32(6), 57-60, +12.

Sun, J., Xi, S., You, D., and Zheng, F. (2012). Analysis and 3D simulation of flood inundation based on ArcGIS system. *Urban Geology*, 7(3), 31-33, +37.

Tang, S. (2010). "Study and planning on the landscape pattern of urban green corridors in Fuzhou city." Fuzhou, Fujian Agriculture and Forestry University.

Wang, S. (2014). "Xi jinping explained 'the new normal' systematically." *Xinhua*, http://news.xinhuanet.com/world/2014-11/09/c_1113175964.htm> (Nov. 9, 2014).

Xiao, D., Li, X., Gao, J., Chang, Y., Gao, N., and Li, G. (2003). *Landscape Ecology.* Beijing, Science Press.

Xu, H. (2005). "A study on information extraction of water body with the Modified Normalized Difference Water Index (*MNDWI*)." *Journal of Remote Sensing*, 9(5), 589-595.

Xu, H. (2009). "Quantitative analysis on the relationship of urban impervious surface with other components of the urban ecosystem." *Acta Ecologica Sinica*, 29(5), 2456-2462.

Yang, D., and Liu, H. (2014). "Research on spatial planning strategy for flood control system in Fuzhou." *City Planning Review,* 38(8), 85-90.

Yang, J., Jia, P., Zhou, T., Zhang, M., and Liu, W. (2011). "DEM-based simulation analysis and virtual reality expression of flood submergence." *Journal of Southwest University (Natural Science Edition)*, 33(10), 143-148.

Yin, Z., Xu, S., Yin, J., and Wang, J. (2010). "Small-scale based scenario modeling assessment of urban rainstorm and disaster risk water-logging." *Acta Geographica Sinica*, 65(5), 553-562.

Zhang, Z., Ye, S., and Liao, C. (2013). "Research on water-related issues in urban road system" Digital Manufacturing and Automation (ICDMA), 2013 Fourth International Conference on. IEEE, 1148-1151.

Zhao, Q., Wang, J., Xu, S., Chen, Z., Liu, Y., Xie, C., and Hu, Y. (2010). "Flood risk assessment of coastal community: A case study in Longwan District of Wenzhou City." *Geographical Research*, (4), 665-674.

Zhou, C., Zhang, Y., and Huang, H. (2014). "Impacts of impervious surface area and landscape metrics on urban heat environment in Fuzhou City, China." *Geo-Information Science*, 16(3), 490-498.

Zhou, F., Cheng, X. Mo, L., Wang, W., Chang, K., Zhou, G., and Jia, S. (2014). "The City Drains System Capability Assessment Based on SWMM." *Construction Science and Technology*, (15): 94-95.

Zhu, H., Gu, H., Gui, X., and Zhu, C. (2009). "Analysis Simulation and Visualization of Flood Inundation Based on ArcGIS." *Bulletin of Surveying and Mapping*, (5), 66-68.

Zhu, Q., Yu, K., and Li, D. (2005). "The width of ecological corridor in landscape planning." *Acta Ecologica Sinica*, 25(9), 2406-2412.