Impacts of rapid urbanization on river network and flood hazard in Shenzhen region, China

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1. Introduction

Urbanization is one of the most typical land use process, and it affected deeply to the mechanism of water circle in city, including rainfall-runoff process [1]. This change allowed natural systems to become more volatile and the probability of extreme events (flood, drought, etc.) increased. Shenzhen has been growing rapidly from rural land to an industrial city in recent 30 years and flood has become a threat to the security of the city area [2]. In this study, the relationship between river network change and urban sprawl, the flood hazard change based on the urban land and river density change was studied.

2. Materials and methods

2.1 The study area

Shenzhen region, at the central coastal area in southern Guangdong Province (Fig. 1). It has a total area of 1948.69 km^2. There are 13 rivers with drainage basin areas larger than 10 km^2 and 5 rivers basins larger than 100 km^2. We selected Buji River Basin as the study area of the impact of rapid urbanization on flood risk (Fig. 1). The upper reach of Buji River flows through Buji Town and its lower reach flows across the downtown. The length of Buji River is 17.72 km and total area of its drainage basin is 56.88 km^2.

2.2 Data sources

Land use data were acquired from LANDSAT images in 1980(MSS), 1988(TM), 2005 (ETM+). Using topographic contour data in 1968 (1:100000), in 1986 (1:50000) and rivers general investigation in 2003, river network maps were generated. For the purpose of the spatial analysis on relationship between urban land sprawl and river density decreasing, a grid map at a resolution of 500 $\times$ 500m was also obtained. Meteorological data including annual precipitation in 1953-2005 and annual maximum rainfall in 24h (1954-1993) were obtained from local meteorological station.

2.3 Methods

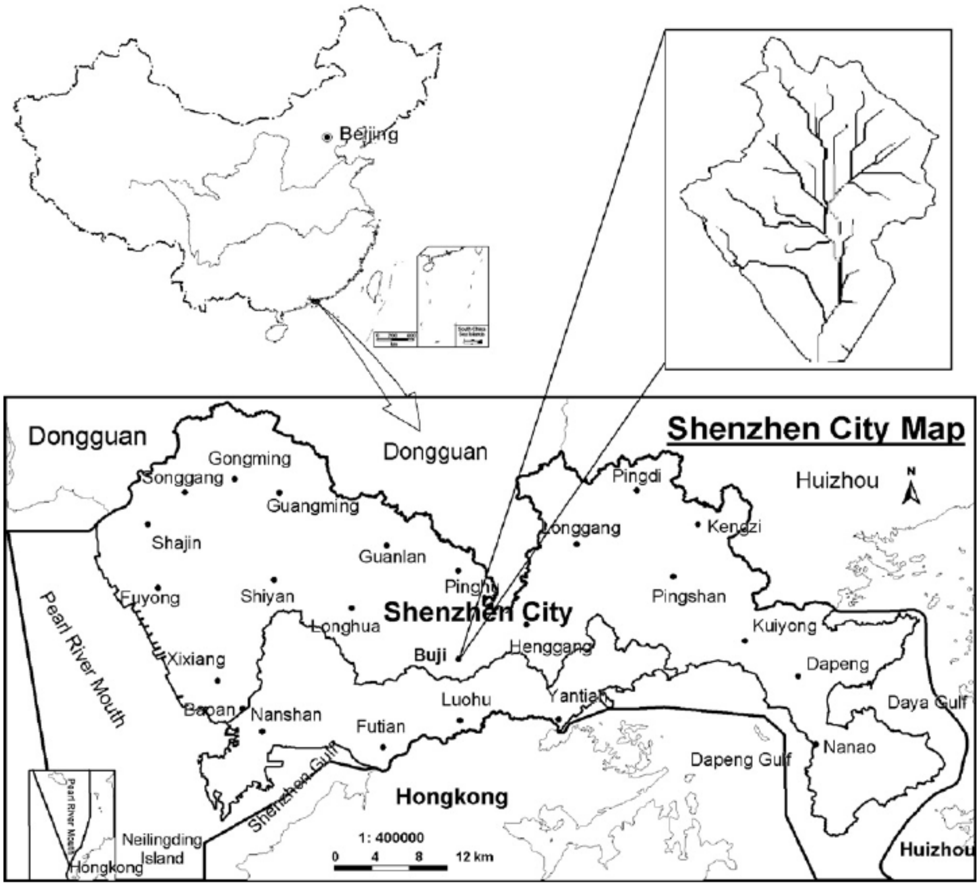

Fig.1. Location map of Shenzhen region

River network in different period generated based on the RS and GIS technology, especially the screen digital technology in MAPINFO 7.0 and image interpreter in ERDAS IMAGINE 8.4. Flood risk was studied based on comparative analysis between the flood discharge and the storage-relieving capacity of river network. The rainfall discharge ($10^4 m^3$) could obtain through SCS Model [3-4], and selected antecedent moderate moisture condition (AMCII) [5]. The storage-relieving capacity of river network was expressed by the relative quality of river density and on the assumption that the storage-relieving capacity in 1980 was 1.0.

3. Results and discussion

3.1 The process of urbanization

In recent 30 years the area of urban land increased fleetly, and the ratio of urban land of Guanlan river baisn in 2005 is about 375 times than its in 1980, while 271 times in Maozhou river basin (Tab. 1). Shenzhen river basin, where the Shenzhen city located, the ratio is about 24 times; and the lowest ratio is in Dayawan stream, which is about 3 times.

The area of high-density urban land changed largely, which from 0 km^2 in 1980 to 90.1 km^2 in 2005 and the low density urban land also changed rapidly from 11.5 km^2 to 568.1 km^2. The differences among 9 basins were mainly relative to the location of the basin and the phase of urbanization.

Table 1 The ratio of urban land and river density in 9 drainage basins of Shenzhen region (1980/1988/2005)

Drainage Basin		Ratio of urban land (%)			River density (km/km^2)		
ID	Name	1980	1988	2005	1980	1988	2005
1	Maozhou river	0.16	5.81	43.36	0.77	0.80	0.71
2	Guanlan river	0.12	6.19	45.03	0.98	0.71	0.69
3	Longgang river	0.37	6.82	35.55	0.83	1.04	0.66
4	Pingshan river	0.64	1.56	18.90	1.18	1.03	0.56
5	Shenzhen river	1.80	28.89	45.09	0.80	0.70	0.79
6	Zhujiangkou stream	0.62	12.24	46.72	0.52	0.70	0.56
7	Shenzhanwan stream	0.78	16.65	40.95	0.43	0.41	0.48
8	Dapengwan stream	0.58	2.80	11.11	1.09	1.10	0.52
9	Dayawan stream	1.08	1.52	3.46	1.11	1.04	0.84

3.2 The analysis of river network change

The river network structure expressed the trends from comprehension to simplicity from 1980 to 2005 (Tab.1, Fig. 2). The length of rivers shortened 355.4 km, accounting for 17% of its in 1980, and the river numbers decreased 378, accounting for 44%. The river density changed from 0.84 to 0.65 km/km^2.

The river density changed diffrently in 9 basins. From 1980 to 2005, the river density increased smoothly in Shenzhenwan stream and Zhujiangkou stream and other basins decreased in different degree. In all, the higher the basin where the ratio of urban land is, the lower of the extent of river density change is; that is to say, the river network change is relative to urbanization phase of the basin.

3.3 The impact of urbanization on the river network

Based on the correlation method, the relationship between the urban sprawl and river density decrease was analyzed and the correlation coefficient is 0.46, which is significant at the 0.02. It shows that the higher the urbanization is, the lower the river density is; and the urban sprawl is the main reason for the density of river network decreasing.

Based on 500×500m grid map, the spatial relationships between urban sprawl and river density decreasing were obtained (Fig. 3). The result shows that the contribution rate of urban sprawl to the decreasing of river network was increasing continuously with the time flowing, and it changed from 38.2% in 1980~1988 to 75.4% in 1988~2005. The spatial location changed from high-density urban land distribution areas and its circumjacent areas to its periphery areas.

3.4 The impact of urbanization on flood hazard

With urban land development, impermeable land surfaces enlarged rapidly, the capacity of rainfall detention declines sharply and runoff coefficient increases. Therefore, urbanized area would become more susceptible to flood hazard under conditions of high precipitation intensity. In recent 30 years, increase of urbanized land and decrease of farmland was the main land use change in the Buji River Basin. At the same time, the river density changed from 0.75 in 1980 to 0.95 in 1988 and to 0.78 km/km^2. According to the results of land use classification and the SCS model, taking the heavy rain (about 212mm in 24 hours) in Buji river basin on July 26 1980 as a case, the rainfall discharges and flood hazard in 1980,1988,2005 were obtained (Tab. 2).

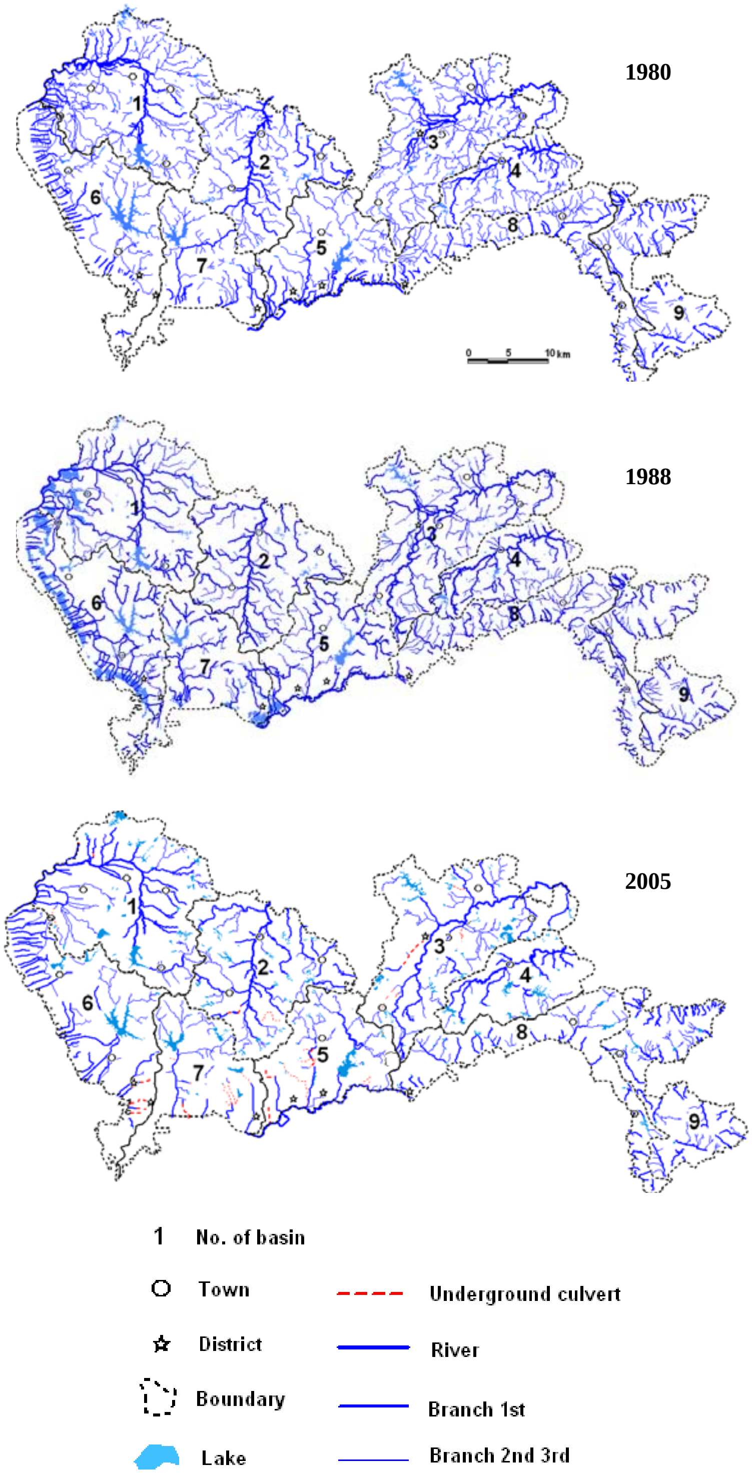

Fig.2. Map of river network change from 1980 to 2005 in Shenzhen region

The rainfall discharge changed from $832.8\times10^4m^3$ in 1980 to $862.1\times10^4m^3$ in 1988 and in 2005 $962.5\times10^4m^3$. On the assumption that the storage-relieving capacity of unit length of river network is the same in different years, the longer the length of river network was, the stronger the storage-relieving capacity. Based on flood hazard in 1988 was 0.77 in comparison with 1.00 in 1980. In 2005 it is 1.16 times of 1980's and 1.09 times of 1988's. In all, the river network could "magnify" or "dwindle" the probability of the flood hazard in some degree.

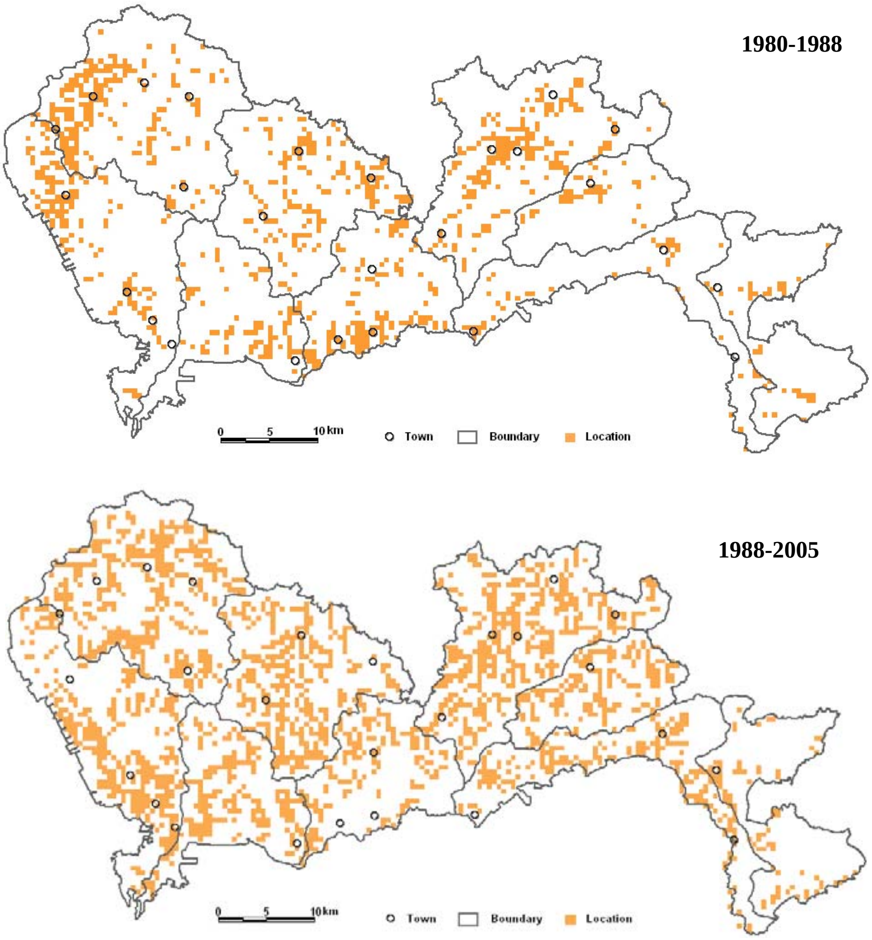

Fig.3. Spatial location of both urban sprawl and river density decreasing

Table 2 Land use types in Buji River Basin and rainfall discharge ($10^4 m^3$)

Year	LSIC	Urban land with high density	Urban land with low density	Farmland	Orchard	Forest	Grassland	Water	Wetland	Unused land	Rainfall discharge
	B	0	0.26	4.57	0	4.45	2.18	0.09	0.01	0.98	144.9
1980	C	0	0.65	14.78	0	22.59	6.41	0.57	0.06	1.5	653.9
	D	0	0.77	0.35	0	0	0.11	0.28	0.19	0.25	33.9
	B	0.38	5.29	1.18	2.05	2.67	0.06	0.17	0.004	0.72	152.0
1988	C	0.05	15.42	3.74	8.07	15.86	0.73	0.48	0.003	2.2	675.5
	D	0.48	1.3	0	0.1	0	0	0.08	0	0	34.6
	B	3.52	4.32	0.23	1.14	2.21	0	0.09	0.03	0.99	177.6
2005	C	9.79	16.2	0.77	3.89	10.89	0	0.22	0.05	4.74	749.2
	D	1.29	0.42	0.003	0.05	0.09	0	0.001	0.005	0.04	35.7

Land surface infiltration categories (LSIC): B, moderate infiltration rate; C, low infiltration rate; D, no infiltration.

4. Conclusions

In the past three decades, Shenzhen region experienced a rapid urbanization process characterized by sharp decrease in farmland and increases in urban land. Human activities and land-use change have dramatically affected the regional river network and flood hazard. The contribution rate of urban sprawl to the decreasing of river network increased continuously with the time flowing, and it changed from 38.2% in 1980~1988 to 75.4% in 1988~2005. River network structure appears as a trend from comprehension to simplicity as a result of urbanization, and the storage-relieving capacity of river network fell down greatly, which lead to the increase of urban flood hazard. Taking the heavy rain in Buji river basin on July 26 1980 as a case, flood hazard in 1988 was 0.77 in comparison with 1.00 in 1980. In 2005 it is 1.16 times of 1980’s and 1.09 times of 1988’s.

Acknowledgements

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References

[1] Goudie A. The Human Impacts on the Natural Environment [M]. 3rd Cambridge, Massachusetts. The MIT Press, 1990.

[2] HAO Minglong, YANG Geng. On the economic evaluation of planning project for urbanized soil and water conservation [J]. RESEARCH OF SOIL AND WATER CONSERVATION, 1997, 4(1):11-15

[3] U.S. Soil Conservation Service. National Engineering Handbook Section 4, Hydrology [M]. USA：U. S. Government Printing Office, 1972

[4] Pei-jun Shi, Yi Yuan, Jing Zheng. The effect of land use/cover change on surface runoff in Shenzhen region, China [J]. CATENA, 2007,69:31-35

[5] SHI Pei-jun, CHEN Jin, PAN Yao-zhong. Land Use Change Mechanism in Shenzhen City [J]. ACTA GEOGRAPHICA SINICA, 2000,55(2):151-160.