An analysis of landscape characteristics of urban rivers – with the case of Chengdu

Jian Zhang, Zhongwei Shen, Hao Shen*

School of Architecture, Southwest Jiaotong University, Chengdu, Sichuan, China

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Abstract

Urban river landscape is a key ecological regulating system in cities, attracting increasing attention from people. Our research conducted a systematic and comprehensive research of landscape characteristics of main rivers in Chengdu from some new perspectives, including the city in the large, city location and Single River. This research is intended to better understand the landscape structure along main rivers in Chengdu, to facilitate the evaluation of macro-regional ecological environment, and to provide references for the study of regional ecological environment.

Keywords: urban rivers, landscape characteristic, city location, tree crown sizes, canopy contribution rate, landscape area

1 Background research

Since the birth of city, it has formed irreconcilable opposite to the natural ecosystem [1], which is rooted in the absolute destruction and demand of ecosystem during the urban development. The urban ecologicalization is an inexorable trend in urban development, as well as a new trend of world urban development [2]. Urban rivers are key constituent parts in the urban ecosystem. These urban rivers provide important water sources and material transport channels for cities, which also enhance the diversity of urban landscape and enrich the lives of residents. Urban rivers prepare a vital material foundation for the comfort, stability and sustainability of cities.

Urban rivers indicate rivers or river sections originated from urban areas or running through urban areas, including some historical canals excavated by human but now showing characteristics of natural rivers after years of evolution [3]. Human activities intensely influence the hydrological characteristics, physical structure and ecological environment of urban rivers. Besides, the socio-economic system and daily life of residents in cities depend on the benefits of urban rivers. Compared with natural rivers, the interaction between human and urban rivers is very significant [4-10]. Gallery of urban rivers are vital multi-functional service body in urban landscape. It can be defined as line and area combination zone connecting the aquatic-terrestrial ecotone at both banks in the urban area and forest cover with forest structure and functions. It includes the vegetation on the flood plain in streamside space of cities, in the protection forest of riparian zone, and in a certain area from the bunding. According to the widely accepted landscape type rating, waterfront space with natural banks, meandering shoreline, open sight, diverse space activities, and pseudo-classic architecture is relatively ideal. (1) According to the comprehensive rating of "Eight Scenes of Shahe River", from the high to low rating, Xinlv Grinding Grain (Z2)> North Lake(Z1)> Sandong Ancient Bridge (Z3)>Mashi Stones (Z5)> the Hakkas in Shahe River (Z6)>Spring in Tashan Mountain (Z7)>Cuihu Lake (Z8)>Technology Garden (Z4).

2 Research method and range

In recent years, the research of landscape characteristics of urban rivers has become a focus in the research area of landscape ecology and global change. It is hard to obtain high-resolution aerial photos so that Google Earth map was used in our research to replace aerial photos as the analysis data. From 500m at the overhead view (a comparatively optimal position in terms of the overhead view contour sharpness of canopy and river landscape patch), a total of 700 screenshots were used. These photos were processed in Photoshop, and generated the remote-sensing image of rivers in Chengdu. Next, the boundary of canopy and river landscape patch was drawn. A new file folder was created in ArcCatolog to establish personal data. In Arcmap, diagrams in Google Earth were used as base maps so as to establish canopy cover shape pictures with meter as the unit. These files were saved in the form of tables for further calculation and analysis. This research focused on the analysis of similarities and differences of landscape characteristics in the above mentioned areas. The landscape index and canopy cover rate of vegetables along rivers were used as major reference indexes. Indexes including landscape characteristics to the highest degree were selected to demonstrate the landscape condition in the research area so that the landscape structure along main rivers in Chengdu could be under-

* ***Corresponding author's*** e-mail:737006315@qq.com

stood. This could facilitate the evaluation of the macroscopic regional ecological environment, and could provide references for the ecological environment and management of the research area. Statistics of the index rating rsi are shown in Table 1:

TABLE 1 Statistics of index rating rsi

Index	Very Satisfactory (V1)	Satisfactory (V2)	Average (V3)	Unsatisfactory (V4)	Extremely Unsatisfactory (V5)
A	0.1080	0.3991	0.4554	0.0376	0.0000
B	0.1174	0.5258	0.2817	0.0751	0.0000
C	0.0845	0.3052	0.4272	0.1080	0.0751
D	0.1737	0.5070	0.2535	0.0376	0.0282
E	0.2911	0.5164	0.1268	0.0469	0.0188
F	0.1362	0.4178	0.3474	0.0986	0.0000
G	0.1502	0.4836	0.2817	0.0845	0.0000
H	0.1174	0.2441	0.4554	0.1643	0.0188
I	0.0563	0.2160	0.4554	0.2441	0.0282
J	0.0751	0.3709	0.4272	0.1174	0.0094
K	0.0798	0.4085	0.4554	0.0376	0.0188
A	0.1080	0.3991	0.4554	0.0376	0.0000

Waterfront vegetation rating was satisfactory, which was larger than 4.0. Ratings of naturalness of river banks, the breadth of vision, the degree of bending, river bank hydrophilia and river flow were also satisfactorily larger than 3.5. The ratings of other indexes were between 3.0 and 3.5.

The overall evaluation results of waterfront landscape reached a rating larger than 3.5. This was satisfactory.

According to the index of criterion layer, the ratings of indexes can be prioritized from high to low as: Natural Ecology>Entertainment and Ornamental Function>Social Environment. Among them, ratings of natural ecology and entertainment and ornamental function exceeded 3.5, which were satisfactory. The rating of social environment was average.

In this research, according to landscape characterristics, the entire research area were further divided into: inside 1st Ring Rd, 1st Ring Rd to 2nd Ring Rd, 2nd Ring Rd to 3rd Ring Rd, outside the 3rd Ring Rd. Besides, according to the regional relation of Chengdu, Chengdu was divided with Tianfu Square as the center into four research areas, including northeast area, northwest area, southwest and southeast areas.

The range of research areas: the east, north and west boundaries were ring roads of Chengdu. Due to the migration of city center towards the south, the south boundary was the intersection between Fuhe River and JiangAnhe River in Huayang Town, including the urban area of Chengdu. Rivers in our study were 4 main rivers with the greatest influence on the urban area of Chengdu. The average monthly designed flow in different water periods is shown in Table 2:

TABLE 2 Average monthly designed flow in different periods, Units: (m^3/s)

`	Dry Season	Prior Normal Water Period	Wet Season	Post Normal Water Period
Qingshuihe River (Supo Bridge)	1.1	12.4	35.3	19.9
Nanhe River (Baihuatan Bridge)	1.5	12.1	38.4	22.3
Shahe River (Gaoqiao Bridge)	19.6	23.5	52.3	37.2
Shahe River (Gate of Dongzikou)	15.0	14.8	17.4	16.6
Fuhe River (Branch of Dongzikou)	4.6	8.6	34.9	20.6

The river landscape model is shown in Equation (1):

$$NMSE = \frac{1}{N\sigma^2}\sum_{K=1}^{N}\left[x(k)-\hat{x}(k)\right]^2 . \quad (1)$$

3 Specific Research

This research first explored landscape characteristics of the entire research area. On this basis, the research area was divided into: inside 1st Ring Rd, 1st Ring Rd to 2nd Ring Rd, 2nd Ring Rd to 3rd Ring Rd and outside the 3rd Ring Rd. Next, with Tianfu Square as the center, Chengdu was divided into northeast area, northwest area, southwest and southeast areas. Finally, each river was systematically researched.

3.1 ANALYSIS OF THE ENTIRE RESEARCH AREA

Comparison of the canopy cover rate of each river in the research area is shown in Table 3. According to Table 3, it is known that the total canopy cover area of trees of urban river landscape in the research area was 828 hm2, and the canopy cover rate was 45.2%.Within the research area, the difference of canopy cover rates of each river in the research area was significant: Shahe River showed the highest canopy cover rate of 63.52%, which was mainly attributed to the role of Shahe River as the protected water source in Chengdu. Therefore, the ecological environment and the surrounding green space system of Shahe River are the best in Chengdu, thus generating the highest tree coverage rate of landscape around the river. It was followed by 46.8% (Fuhe River), 45.17% (Qing-

shuihe River and Modihe River), 44.36% (Dongfeng Canal) and 31.8% (JiangAnhe River). In terms of the comparison of canopy cover area, Fuhe River has the largest canopy cover area, followed by Dongfeng Canal > Shahe River > JiangAnhe River > Qingshuihe River and Modihe River.

TABLE 3 Comparison of canopy cover rates in each river of the research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of All Rivers (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in Landscape Area of All Rivers (%)
Fuhe River	635.1599	34.66	297.1229	46.8	35.87
Qingshuihe River	148.3505	8.09	67.012	45.17	8.09
Shahe River	223.4577	12.19	141.9364	63.52	17.14
JiangAnhe River	350.7365	19.14	111.5229	31.8	13.46
Dongfeng Canal	475.0198	25.92	210.7339	44.36	25.44
Total	1832.7244	100	828.3281	45.2	100

The data model is shown in Equation (2):

$$\hat{x}_{(k+1)}^{(1)} = \left(x_{(1)}^{(0)} - \frac{u}{a} \right) e^{-ak} + \frac{u}{a}. \tag{2}$$

Subsequently, the contribution level of canopy cover of each river was compared. Shahe River contributes a canopy cover rate of 17.14% with 12.19% land area, followed by the canopy cover rate of Fuhe River, Qingshuihe River and Modihe River, Dongfeng Canal (35.87%, 8.09% and 25.44%) with a land area of 34.66%, 8.09% and 25.92% respectively. Lastly, JiangAnhe River contributes a canopy cover rate of 13.46% with a land area of 19.14%. The control rate of fracture surface is shown in Table 4:

TABLE 4 Control rate of fracture surface at different periods

Fracture Surface	Dry Season	Prior Normal Water Period	Wet Season	Post Normal Water Period
Fuhe River Entry	√	√	√	√
Xibei Bridge	√	√	√	√
DaAn Bridge	√	√	√	√
Shahe River Entry	√	√	√	√
Gantachang	√	√	√	√
Shanban Bridge	√	√	√	√
Chengren Bridge	√	√	√	√
Baihua Bridge	×	√	√	√
Anshun Bridge	×	√	√	√
Hejiangting	×	√	√	√
YongAn Bridge	×	√	√	√
Zhonghe	×	×	√	√
Yuzui	×	×	×	×
Huanglongxi Brook	×	×	×	×
Control Rate of Fracture Surface	50%	79%	85.7%	85.7%

3.2 ANALYSIS OF FOUR MAIN RESEARCH AREAS

The comparison of the canopy cover rate of river landscape in each ring road of the research area is shown in Table 5. According to Table 5, the areas with the canopy cover rate ranking from high to low are respectively: 2nd Ring Rd to 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd, inside 1st Ring Rd and outside the 3rd Ring Rd. Among them, the canopy cover rates of 2nd Ring Rd to 3rd Ring Rd and that of 1st Ring Rd to 2nd Ring Rd were similarly highest. This could be attributed to the distribution of dense resident complexes near rivers from 2nd Ring Rd to 3rd Ring Rd and from 1st Ring Rd to 2nd Ring Rd. Therefore, the mode of landscape was relatively stable. Besides, due to the requirements of residents on river landscape, the landscape was diverse. However, the canopy cover rate inside 1st Ring Rd was lower than the above two areas because the area inside 1st Ring Rd was the urban center. The rivers are mainly surrounded by commercial lands or lands for other purposes, with huge visitors' flow rate. Since the human activity imposes huge demand on river landscape, the area of green space was narrowed, and the canopy cover rate became smaller. Moreover, the area outside the 3rd Ring Rd was close to the nature and the density of vegetation was smaller than that of the urban area, and the cover rate of trees was the lowest.

TABLE 5 Comparison of canopy cover rate of river landscape in each ring road of our research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of All Rivers (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas (%)
Inside 1st Ring Rd	56.9955	3.11	25.0592	43.97	3.02
1st Ring Rd to 2nd Ring Rd	84.9036	4.33	45.0156	53.02	5.44
2nd Ring Rd to 3rd Ring Rd	432.8825	23.62	230.3341	53.21	27.81
Outside 3rd Ring Rd	1258.0248	68.64	527.9192	41.96	63.73
Total	1832.7244	100	828.3281	45.2	100

In terms of contribution rate: the area from 1st Ring Rd to 2nd Ring Rd had the highest contribution rate, which contributes a canopy cover rate of 5.44% with a land area of 4.33%. This was mainly caused by the contribution of large ecological gardens like Huahuaxi Park. This was followed by that from 2nd Ring Rd to 3rd Ring Rd, which contributed a canopy cover rate of 27.81% with a land area of 23.62%. This was mainly caused by the considerable number of ecological wetland parks in the flow area of Shahe River from 2nd Ring Rd to 3rd Ring Rd. The ecological wetland parks remarkably improved the tree coverage in this area.

It can be seen from the results that the ratings of evaluation indexes of landscape types prioritized from high to low are as follows: (1) river flow (A): A3 gentle slope waterfront for people to enjoy > A1 water level lower than the river bank by 0-2m > A2 water level lower than the river bank by 2 – 5m; the rating model of river landscape evaluation indexes is shown in Equation (3):

$$\hat{x}^{(0)}(k) = (x^{(0)}_{(1)} + \frac{u}{a})e^{ak} - \frac{u}{a}. \quad (3)$$

Degree of river bending (B): B3 relatively meandering > B2 slightly meandering > B1 straight;

Environmental quality of waterfront (C): C1 Waterfront vegetation width larger than 50m> C2 waterside vegetation width between 20 and 50m > C3 waterside vegetation width less than 20m;

Naturalness of River Banks (D): D3 natural and Nature-Imitated banks > D2 stacking of natural stones > D1 grass planted on artificial banks;

Waterfront vegetation (E): E3 mainly grass + shrub + tree > El mainly grass + tree > E2 mainly grass + shrub;

Hydrophily of river banks (F): F2 with fishing available along rivers > F3 with viewing platform > F1 with walking along banks allowed;

Next, the area inside 1st Ring Rd and outside the 3rd Ring Rd contributed a canopy cover rate of 3.02% and 63.73% respectively with a land area of 3.11% and 68.64%. The data model of waterside vegetation and water flow is shown in Equation (4):

$$X^{(0)}_{(t)} = \left\{x^{(0)}_{(1944)}, x^{(0)}_{(1945)}, ..., x^{(0)}_{(1990)}\right\} = \{261, 465, ..., 432\}. \quad (4)$$

3.2.1 Comparison of canopy cover rates of different rivers inside 1st Ring Rd

The comparison of canopy cover rates of different rivers inside 1st Ring Rd is shown in Table 6. According to Table 6, it can be found that the canopy cover rate of Fuhe River, Qingshuihe River and Modihe River inside 1st Ring Rd was almost identical, so was their contribution to the canopy cover rate. Fuhe River, Qingshuihe River and Modihe River inside 1st Ring Rd contributed a canopy cover rate of 56.74% and 43.26% with a land area of 55.83% and 44.17% respectively. This indicates that the establishment and operation modes of these river landscapes inside 1st Ring Rd were almost identical. Meanwhile, a limited canopy cover rate also reflects the large demand from human activity, which is closely related with the land nature of commercial space around rivers.

TABLE 6 Comparison of canopy cover rate of different rivers inside 1st ring rd of the research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area Inside 1st Ring Rd (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas Inside 1st Ring Rd (%)
Fuhe River	31.8389	55.83	14.2292	44.62	56.74
Qingshuihe River and Modihe River	25.1566	44.17	10.83	43.07	43.26
Total	56.9955	100	25.0592	43.92	100

3.2.2 Comparison of canopy cover rates of different rivers inside 1st Ring Rd to 2nd Ring Rd

The comparison of canopy cover rates of different rivers from 1st Ring Rd to 2nd Ring Rd is shown in Table 7. According to Table 7, within the area from 1st Ring Rd to 2nd Ring Rd, the canopy cover rate of three rivers showed remarkable significance. Fuhe River had the highest canopy cover rate of 60.91% mainly because Fuhe River runs through some urban parks with flourishing vegetations like Wangjiang Park. These parks substantially increased the tree coverage rate of river landscape in this area. This was followed by the tree coverage rate of 50.93% of Shahe River. Compared the

overall tree coverage rate of Shahe River, the tree coverage rate of this section was reduced because it mainly flowed through the resident area of old cities. The high participation rate of citizens influenced the river landscape area of Shahe River to a certain degree. Next, the tree coverage rate of Qingshuihe River and Modihe River reached 47.84. In terms of tree coverage contribution rate, Fuhe River, Shahe River, Qingshuihe River and Modihe River contributed a tree coverage rate of 04%, 33.34% and 30.62% respectively with a land area of 31.32%, 34.74% and 33.94%.

TABLE 7 Comparison of canopy cover rate of different rivers from 1st ring rd to 2nd ring rd of the research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area from 1st Ring Rd to 2nd Ring Rd (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas from 1st Ring Rd to 2nd Ring Rd (%)
Fuhe River	26.6437	31.32	16.228	60.91	36.04
Qingshuihe River and Modihe River	28.8636	33.94	13.797	47.84	30.62
Shahe	29.3963	34.74	14.9906	50.93	33.34
Total	84.9036	100	45.0156	53.04	100

3.2.3 Comparison of canopy cover rates of different rivers inside 2nd Ring Rd to 3rdc Ring Rd

The comparison of the canopy cover rate of different rivers from 2nd Ring Rd to 3rd Ring Rd is shown in Table 8. According to Table 8, rivers with the tree coverage rate ranking from high to low are Shahe River (65.42%), Dongfeng Canal (45.47%), Qingshuihe River and Modihe River (42.07%), and Fuhe River (41.91%). The tree coverage rate of Shahe River was the highest in this section, which was mainly attributed to the large number of ecological wetland parks and urban parks at both sides of it, as well as the extensive green belts. In terms of tree coverage contribution rate, Shahe River topped by contributing a tree coverage rate of 55.11% with a land area of 44.84%, followed by that of Fuhe River, Qingshuihe River and Modihe River as well as Dongfeng Canal. They contributed a tree coverage rate of 19.84%, 6.93% and 18.12% with a land area of 25.2%, 8.76% and 21.2%.

TABLE 8 Comparison of canopy cover rate of different rivers from 2nd ring rd to 3rd ring rd of the research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area from 2nd Ring Rd to 3rd Ring Rd (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas from 2nd Ring Rd to 3rd Ring Rd (%)
Fuhe River	109.0456	25.2	45.7025	41.91	19.84
Qingshuihe River and Modihe River	37.9232	8.76	15.9572	42.07	6.93
Shahe	194.0614	44.84	126.9458	65.42	55.11
Dongfengqu Canal	91.7703	21.2	41.7286	45.47	18.12
Total	432.8005	100	230.3341	53.21	100

3.2.4 Comparison of canopy cover rates of different rivers outside 3rdc Ring Rd

The comparison of canopy cover rates of different rivers outside the 3rd Ring Rd is shown in Table 9. According to Table 9, the tree coverage rate was realized from high to low by Fuhe River, Qingshuihe River and Modihe River, Dongfeng Canal, as well as JiangAnhe River. The tree coverage contribution rate was realized from high to low by Qingshuihe River and Modihe River, Fuhe River, Dongfeng Canal and JiangAnhe River. They contributed a tree coverage rate of 5.01%, 41.86%, 32.01% and 21.12% with a land area of 4.48%, 37.17%, 30.46% and 27.89% respectively. This indicated that the urbanization level of areas near Fuhe River, Qingshuihe River and Dongfeng Canal was comparatively consistent. Meanwhile, the overall urbanization level of areas near JiangAnhe River was lower than that of the other three rivers.

TABLE 9 Comparison of canopy cover rate of different rivers outside the 3rd ring rd of the research area

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area outside 3rd Ring Rd (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas outside 3rd Ring Rd (%)
Fuhe River	467.6317	37.17	220.9632	47.25	41.86
Qingshuihe River and Modihe River	56.4071	4.48	26.4278	46.85	5.01
Shahe	0	0	0	0	0
Dongfengqu Canal	383.2495	30.46	169.0053	44.1	32.01
JiangAnhe River	350.7365	27.89	111.5229	31.8	21.12
Total	1258.0248	100	527.9192	41.96	100

3.3 ANALYSIS OF REGIONAL LOCATION OF CHENGDU

In this research, Chengdu was divided with Tianfu Square as the center into four research areas, including northeast area, northwest area, southwest and southeast areas. Besides, this division was integrated with 1st Ring Rd, 2nd Ring Rd, 3rd Ring Rd, outside the 3rd Ring Rd to analyze the river landscape of Chengdu. The comparison of the canopy cover rate of river landscapes at different locations is shown in Table 10. According to Table 10, the changing patterns of canopy cover rates in northwest area, northeast area and southeast area are: the canopy cover rate was the highest from 2nd Ring Rd to 3rd Ring Rd, followed by that in the area from 1st Ring Rd to 2nd Ring Rd, and that inside 1st Ring Rd and outside the 3rd Ring Rd. This was consistent with the previous conclusion without the division of directions. The southwest area, however, was an exception. In this area, the canopy cover rate was highest in the area from 1st Ring Rd to 2nd Ring Rd, followed by that inside 1st Ring Rd, the area from 2nd Ring Rd to 3rd Ring Rd and finally the area outside the 3rd Ring Rd. This was mainly attributed to the Huanhuaxi park in the section of Qingshuihe River and Modihe River. Huanhuaxi Park is located in the area between 1st Ring Rd and 2nd Ring Rd in the southwest, thus substantially increasing the canopy cover rate of the area. Around the rivers from 2nd Ring Rd to 3rd Ring Rd in this area, there were the main resident complexes of Chengdu, with large density of populations. Residents present strong demand on the activities in the river landscape. Hence, the river landscape area was comparatively narrow, and the canopy cover rate was lower than other areas. Variance analysis of location difference rating is shown in Table 11.

TABLE 10 Comparison of canopy cover rate of river landscape in different regions

Type	Within 1st Ring Rd		1st Ring Rd to 2nd Ring Rd		2nd Ring Rd to 3rd Ring Rd		Outside 3rd Ring Rd	
	Area (hm2)	Canopy Cover Rate (%)	Area (hm2)	Canopy Cover Rate (%)	Area (hm2)	Canopy Cover Rate (%)	Area (hm2)	Canopy Cover Rate (%)
Northwest Area	4.4298	43.91	18.6901	47.75	94.3988	49.84	362.419	42.83
Northeast Area	18.3359	44.01	29.3963	50.99	165.0332	55.46	150.9815	43.52
Southwest Area	14.9724	43.52	23.4515	62.55	18.0612	41.52	383.791	39.95
Southeast Area	19.2574	44.28	13.3657	48.13	155.3073	54.26	360.8333	42.58
Total	56.9965		84.9036		432.8825		1258.0248	

TABLE 11 Variance analysis of location difference rating

Evaluation Index	Near Shahe River	Urban Area of Chengdu	Other Cities	F Value	Significance Probability	Multiple Comparison Appraisal
River Flow	3.56	3.57	3.63	0.332	0.717	(n,s)
Bending Degree of River	3.71	3.68	3.66	0.128	0.880	(n,s)
Waterside Environment Quality	2.95	3.35	3.41	10.017	0.000 ¨	(1,2)(1,3)
Hydrophily of Banks	3.80	3.73	3.73	0.330	0.719	(n,s)
Breath of Vision	3.92	4.08	4.08	1.701	0.184	(n,s)
Waterside Architectural Style	3.49	3.66	3.67	2.329	0.099	(n,s)
Waterside Land Utilization	3.63	3.76	3.72	1.020	0.362	(n,s)
Traffic	3.15	3.38	3.33	2.477	0.085	(1,2)
Safety	2.85	3.09	3.19	6.005	0.003 ¨	(1,2)(1,3)
Total Average	3.13	3.52	3.59	14.971	0.000 ¨	(1,2)(1,3)

As can be drawn from Table 11, with different distances from the river, significant differences were observed among the waterside environment quality, waterside land utilization and traffic indexes, showing a small degree of influence (3/12 = 25%). Our assumption that the difference of resident locations would influence the overall evaluation of waterside landscape was partially established. We conducted multiple comparisons through the L.S.D least significant difference method, and obtained that differences of the three indexes were mainly reflected between areas near river, urban area of Chengdu and other cities. According to the above indexes, the rating of population living near the river was the lowest. It was because overall the waterside landscape had a width smaller than 50m, except the large width of vegetation buffer area. A large part of the river sections between 2nd Ring Rd and 1st Ring Rd was less than 20m wide. Its inner relation can be expressed by Equation (5):

$$\bar{A} = \sum_{i=1}^{M} \left| q^{(0)}(j) \right| M , \tag{5}$$

In terms of changes in the river patch area, changes at four directions were different. In the northwest, the river patch area increased successively from inside the city to outside the city, which was consistent with our previous conclusion without the division of directions. In the northeast, the river patch area increased successively from 1st Ring Rd to 3rd Ring Rd. However, compared with the patch area from 2nd Ring Rd to 3rd Ring Rd, the patch area outside the 3rd Ring Rd decreased again. This could be attributed to the main drainage basin of Shahe River that is located in the area from 2nd Ring Rd to 3rd Ring Rd. This substantially increased the river landscape area of the

area. In the southwest, the overall trend is consistent with our previous findings. This was because the river flew through the main resident complexes of Chengdu in the area from 2nd Ring Rd to 3rd Ring Rd. Residents' demand on activities dominated so that the river landscape area was limited and the changes in the trend were produced. In the southeast, in addition to a decreasing trend in the area from 1st Ring Rd to 2nd Ring Rd, trends in other sections were increasing. The declining trend from 1st Ring Rd to 2nd Ring Rd was attributed to the geological location of the river section, which is close to key roads of Chengdu and the campus of Sichuan University. In order to ensure the smooth traffic and sufficient campus area, the river landscape area was greatly reduced.

The comparison of river landscape patch number in different directions and the average patch area is shown in Table 12. According to Table 12, in northwest, the patch number decreased from the area outside the 3rd Ring Rd, from 2nd Ring Rd to 3rd Ring Rd, from 1st Ring Rd to 2nd Ring Rd and the area inside 1st Ring Rd. The average area of patch decreased successively from the area outside the 3rd Ring Rd, the area inside 1st Ring Rd, from 2nd Ring Rd to 3rd Ring Rd, and from 1st Ring Rd to 2nd Ring Rd. In northwest, the patch number and patch area fell from the area outside the 3rd Ring Rd, from 2nd Ring Rd to 3rd Ring Rd, inside 1st Ring Rd, and from 1st Ring Rd to 2nd Ring Rd; from 2nd Ring Rd to 3rd Ring Rd, outside the 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd, inside 1st Ring Rd; In southwest, the patch number and patch area fell from the area outside the 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd, inside 1st Ring Rd, 2nd Ring Rd to 3rd Ring Rd; outside the 3rd Ring Rd, 2nd Ring Rd to 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd, inside 1st Ring Rd; In southeast, the patch number and patch area fell from the area outside the 3rd Ring Rd, 2nd Ring Rd to 3rd Ring Rd, inside 1st Ring Rd, 1st Ring Rd to 2nd Ring Rd; outside the 3rd Ring Rd, 2nd Ring Rd to 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd and the area inside 1st Ring Rd. Thus, it can be concluded that the patch number in northwest progressively increased from the urban area to external areas. In northwest, the patch area was smallest in the urban area and larger in external areas. In northeast, the patch number progressively increased from 1st Ring Rd and the urban area to external areas. The patch area progressively increased from the area inside 1st Ring Rd to 3rd Ring Rd. Area outside the 3rd Ring Rd had smaller patch area than that from 2nd Ring Rd to 3rd Ring Rd. Compared with the situation in southeast, these trends were similar in southwest. They both presented a smallest number of patches in urban area, which was smaller than external areas. The changing trend of patch areas was the progresssive increase from the urban center to the external.

TABLE 12 Comparison of patch number and average patch area in different regions of the research area

Type	Within 1st Ring Rd		1st Ring Rd to 2nd Ring Rd		2nd Ring Rd to 3rd Ring Rd		Outside 3rd Ring Rd	
	Average Patch Area (hm2)	Patch Number	Average Patch Area (hm2)	Patch Number	Average Patch Area (hm2)	Patch Number	Average Patch Area (hm2)	Patch Number
Northwest Area	1.4766	3	0.49	38	1.15	82	2.88	126
Northeast Area	0.87	21	1.55	19	3.93	42	2.8	54
Southwest Area	1.07	14	1.15	21	3.01	6	4.41	87
Southeast Area	0.71	27	1.34	10	4.85	32	10.31	35

Comparison of patch density in different regions of the research area is shown in Table 13. According to Table 13, through the calculation of the river landscape area in per square kilometer, we obtained the size of river landscape in different locations of Chengdu and their trend of variation. In northwest, the patch density decreased from the area from 2nd Ring Rd to 3rd Ring Rd, outside the 3rd Ring Rd, 1st Ring Rd to 2nd Ring Rd and the area inside 1st Ring Rd. In northeast, the patch density decreased from the area from 1st Ring Rd to 2nd Ring Rd, 2nd Ring Rd to 3rd Ring Rd, inside 1st Ring Rd and outside the 3rd Ring Rd. In southwest, the patch density decreased from the area from 1st Ring Rd to 2nd Ring Rd, outside the 3rd Ring Rd, inside 1st Ring Rd and from 2nd Ring Rd to 3rd Ring Rd. In southeast, the patch density decreased successively from the area outside the 3rd Ring Rd, from 2nd Ring Rd to 3rd Ring Rd, inside 1st Ring Rd, and from 1st Ring Rd to 2nd Ring Rd. It can be concluded that only the patch density in the area outside the 3rd Ring Rd in northwest declined. In other areas, the patch density generally increased from the urban area to the external areas. In northeast, the patch density was high in the middle and lower at both ends. The patch density of the inner city area was higher than that of the external areas. In southwest, the patch density was lower in the area from 2nd Ring Rd to 3rd Ring Rd, and the patch density of other sections remained similar. In southeast, the patch density in the area from 1st Ring Rd to 2nd Ring Rd was slightly lower but presented an increasing trend from urban area to external areas.

TABLE 13 Comparison of patch density in different regions of the research area

Type	Within 1st Ring Rd		1st Ring Rd to 2nd Ring Rd		2nd Ring Rd to 3rd Ring Rd		Outside 3rd Ring Rd	
	Average Patch Area (hm2)	Patch Density (hm2/km2)	Average Patch Area (hm2)	Patch Density (hm2/km2)	Average Patch Area (hm2)	Patch Density (hm2/km2)	Average Patch Area (hm2)	Patch Density (hm2/km2)
Northwest Area	4.4298	0.65	18.6901	2.46	94.3988	3.46	362.419	3.01
Northeast Area	18.3359	2.19	29.3963	4.39	165.033	3.81	150.982	1.5
Southwest Area	14.9724	2.52	23.4515	3.07	18.0612	0.74	383.791	3.01
Southeast Area	19.2574	2.91	13.3657	1.43	155.307	4.28	360.833	4.43

3.4 ANALYSIS OF THE TEGIONAL LOCATION OF UNDIVIDUAL RIVER

The comparison of canopy cover rate in each section of Fuhe River landscape is shown in Table 14. In Table 14, the variation patterns of river patch area and canopy cover area were identically increasing from center area to the external areas. The area outside 3rd Ring Rd in the direction of southwest had the highest canopy cover rate, which was mainly caused by the Fuhe River that flew through the new city area of Chengdu. The river banks of the new city area were larger than those of old city areas. Besides, the vegetable types were greatly diverse. Therefore, this area had the highest canopy cover rate, followed by that from 1st Ring Rd to 2nd Ring Rd in southeast, from 3rd Ring Rd to 2nd Ring Rd in northwest, from 2nd Ring Rd to 1st Ring Rd in northwest, inside 1st Ring Rd in southeast, inside 1st Ring Rd in northwest, expressway to 3rd Ring Rd in northwest, outside the 3rd Ring Rd in southeast and the area inside 1st Ring Rd in northeast. We could come up with a conclusion that the area of Fuhe River in southeast had the highest canopy cover rate, followed by that in northwest. Their variation pattern was constant increase of canopy cover rate from the urban center to areas outside the city. The variation pattern of canopy cover rate in another two directions was larger canopy cover rate in external areas than urban areas.

TABLE 14 Comparison of canopy cover rate in the landscape of each section of Fuhe River

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of Fuhe River (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas of Fuhe River (%)
Expressway to 3rd Ring Rd (Northwest)	221.4725	34.87	93.9964	42.44	31.63
3rd Ring Rd to 2nd Ring Rd (Northwest)	54.9638	8.65	28.1191	51.16	9.46
2nd Ring Rd to 1st Ring Rd (Northwest)	3.1922	0.5	1.5598	48.86	0.52
Inside 1st Ring Rd (Northwest)	4.4298	0.6	1.9452	43.91	0.65
Inside 1st Ring Rd (Northeast)	18.3359	2.89	8.0705	40.15	2.71
Inside 1st Ring Rd (Southeast)	9.0732	1.43	4.2135	46.44	1.41
1st Ring Rd to 2nd Ring Rd (Southeast)	23.4515	3.69	14.6682	62.55	4.93
2nd Ring Rd to 3rd Ring Rd (Southeast)	54.0818	8.52	17.5834	32.51	5.91
Outside 3rd Ring Rd (Southeast)	169.7264	26.72	69.0292	40.67	23.23
Outside 3rd Ring Rd (Southwest)	76.4328	12.03	57.9376	75.8	19.5
Total	635.1599	100	297.1229	46.78	100

Comparison of canopy cover rate in the landscape of each section of Shahe River is shown in Table 15. It can be drawn from Table 15 that river patch area and canopy cover area presented a pattern of increasing from urban center to the area outside the city. The highest canopy cover rate and canopy contribution rate occurred in areas from 3rd Ring Rd to 2nd Ring Rd in northeast and southeast. Both presented a pattern of larger canopy cover rate and canopy contribution rate in external areas than those in urban center.

TABLE 15 Comparison of canopy cover rate in the landscape of each section of Shahe River

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of Shahe River (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas of Shahe River (%)
3rd Ring Rd to 2nd Ring Rd (Northwest)	19.573	8.76	10.471	53.5	7.34
3rd Ring Rd to 2nd Ring Rd (Northeast)	55.7578	24.95	40.6303	72.87	28.63
2nd Ring Rd to 1st Ring Rd (Northeast)	29.3963	13.16	14.9906	50.99	10.56
2nd Ring Rd to 3rd Ring Rd (Northeast)	31.0193	13.88	14.3813	46.36	10.13
2nd Ring Rd to 3rd Ring Rd (Southeast)	87.7113	39.25	61.4632	70.07	43.34
Total	223.4577	100	141.9364	63.52	100

Comparison of canopy cover rate in the landscape of each section of Dongfeng Canal is shown in Table 16. In Table 16, river patch area and canopy cover area of Dongfeng Canal presented a pattern of successively increasing from urban center to the area outside the city. The canopy cover rate from 3rd Ring Rd to 2nd Ring Rd in northeast was highest, and that from 2nd Ring Rd to 3rd Ring Rd in southeast was lowest. Generally, the canopy cover rate of each section was similar, which could mainly be attributed to the artificial excavation of Dongfeng Canal with basically consistent channel width and river landscape width. Therefore, the canopy cover rate was basically identical.

TABLE 16 Comparison of canopy cover rate in the landscape of each section of Dongfeng Canal

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of Dongfengqu Canal (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas of Dongfengqu Canal (%)
Expressway to 3rd Ring Rd (Northwest)	41.1611	8.67	18.6568	45.33	8.85
Expressway to 3rd Ring Rd (Northeast)	150.9815	31.78	65.7182	43.53	31.16
3rd Ring Rd to 2nd Ring Rd (Northeast)	78.2561	16.47	36.5122	46.66	17.33
2nd Ring Rd to 3rd Ring Rd (Southeast)	13.5142	2.84	5.2164	38.6	2.48
3rd Ring Rd to Expressway (Southeast)	191.1069	40.22	84.6303	44.28	40.18
Total	475.0198	100	210.7339	44.36	100

Comparison of canopy cover rate in the landscape of each section of Jianganhe River is shown in Table 17. According to Table 17, although the main drainage basin of JiangAnhe River was outside 3rd Ring Rd, its canopy cover rate showed significant difference. This was mainly because Jianganhe River flew through farmlands outside the 3rd Ring Rd, then the towns. Since the tree density of towns is much larger than that in farmlands, this difference has been formed.

TABLE 17 Comparison of canopy cover rate in the landscape of each section of Jianganhe River

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of JiangAnhe River (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas of JiangAnhe River (%)
Outside 3rd Ring Rd (Northwest)	43.3783	12.38	16. 138	37.2	14.17
Outside 3rd Ring Rd (Southwest)	307.3582	87.62	95.3849	31.03	85.53
Total	350.7365	100	111.5229	31.8	100

Comparison of canopy cover rate in the landscape of each section of Qingshuihe River and Modihe River is shown in Table 18. According to Table 18, river patch area and canopy cover area of Qingshuihe and Modihe River presented a pattern of successively increasing from urban center to the area outside the city. The canopy cover rate was highest in the area from 2nd Ring Rd to 1st Ring Rd in southwest, generally performing the feature of high in the middle but low at both ends.

TABLE 18 Comparison of canopy cover rate in the landscape of each section of Qingshuihe and Modihe Rivers

Type	Floor Area and Ratio		Canopy Cover Characteristics		
	Area (hm2)	Percentage in Landscape Area of Qingshuihe and Modihe River (%)	Canopy Cover Area (hm2)	Canopy Cover Rate (%)	Percentage in All the Canopy Areas of Qingshuihe and Modihe River (%)
Expressway to 3rd Ring Rd (Northwest)	56.4071	38.02	26.4278	46.85	39.44
3rd Ring Rd to 2nd Ring Rd (Northwest)	19.862	13.39	8.4574	42.58	12.62
3rd Ring Rd to 2nd Ring Rd (Southwest)	18.0612	12.18	7.4998	41.52	11.19
2ndRing Rd to 1st Ring Rd (Northwest)	15.4979	10.45	7.3647	47.52	10.99
2nd Ring Rd to 1st Ring Rd (Southwest)	13.3657	9.01	6.4323	48.12	9.6
Inside 1st Ring Rd (Southwest)	14.9724	10.09	6.5162	43.52	9.72
Inside 1st Ring Rd (Southeast)	10.1842	6.86	4.3138	42.36	6.44
Total	148.3505	100	67.012	45.17	100

To sum up, the patch number, average patch area and the total patch area of urban river landscape generally presented a trend of successively increasing from urban center to areas outside the city. This can be attributed to the fact that most river landscapes were artificial landscapes in the city, showing substantial interference from human. Besides, the degree of landscape fragmentation was high. In cities, when rivers flow through old resident areas, the patch area and canopy cover rate of river landscape become minimal. However, when rivers flow through new resident areas, the patch area and canopy cover rate of river landscape become maximum. The patch area of river landscape in different regions should be balanced to the greatest extent so as to realize the maximum balance of river ecosystems in different regions of a city. In this way, the urban ecosystem can be regulated to the largest extent.

4 Conclusions

Urban river landscape is a vital ecological regulating system for cities. In our research, from perspectives of the overall urban, city location and single river, a systematic and comprehensive research of landscape characteristics of main rivers in Chengdu was conducted so that the landscape characteristics of major rivers in Chengdu could be perceived. This research is intended to provide references for evaluating the macro-regional ecological environment of Chengdu, the ecological environment and management.

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Authors

Jian Zhang, born in October 1987, Chengdu, Sichuan Province, P.R. China.

Current position, grades: Doctor at the School of Architecture, Southwest Jiaotong University, China.
University studies: master's degree in architecture at Southwest Jiaotong University in China.
Scientific interests: human settlement and river landscape.
Publications: 3 papers.
Experience: participated 4 scientific research projects.

Zhongwei Shen, born in October 1965, Chengdu, Sichuan Province, P.R. China.

Current position, grades: professor at the School of Architecture, Southwest Jiaotong University, China.
University studies: master's degree in Logistical Engineering University of PLA in China.
Scientific interests: human settlement and traffic building.
Publications: more than 20 papers.
Experience: teaching experience of more than 20 years, completed 6 scientific research projects.

Hao Shen, born in June 1988, Chengdu, Sichuan Province, P.R. China.

Current position, grades: master at the School of Architecture, Southwest Jiaotong University, China.
University studies: bachelor's degree in architecture from Southwest Jiaotong University in China.
Scientific interests: human settlement and river landscape.
Publications: 1 paper.
Experience: 1 scientific research project.