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Correlation analysis and threshold value research on the form and function indexes of an urban interconnected river system network

Ming Dou, Lu Yu, Meng Jin and Yan Zhang

ABSTRACT

As urbanization has accelerated, the form of river and lake systems has changed greatly in cities, which has caused variations in the functioning of the interconnected river system network (IRSN). To quantitatively evaluate the influence of the urbanization process on IRSN, the form index system and function index system were established in this study. The form index system involved eight indexes, and the function index system included 18 indexes. We also used statistical methods to analyze the correlations between the form indexes and the function indexes of the IRSN. Multiple linear regression equations were established between the variations in the IRSN form indexes and the function indexes. Finally, we determined the threshold values of the IRSN form indexes that can meet Zhengzhou City's future development demands for water function. The threshold value for the drainage network density is between 0.32 and 0.33; the threshold value for the node connection rate is between 1.54 and 2; the threshold value for the degree of connectivity between river systems ranges from 0.55 to 0.77; and the threshold value for circuitry of the river ranges from 0.40 to 0.60. Validation shows that these values are reasonable.

Key words | form and function index, future development, index threshold value, interconnected river system network

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INTRODUCTION

River and lake systems are the fundamental storage places for freshwater resources; as such, they are closely linked with the origins of human civilization. The interconnected river system network (IRSN) is the water channel with a certain functional objective, which was built under the combined influence of nature and humans to maintain the hydraulic connection and material circulation among diffident water bodies (Dou *et al.* 2011) and it can directly reflect the continuity of water flow and the connectivity of river systems. However, the rapid acceleration of urbanization and population growth have led to serious changes in the IRSN, which has become a major factor in the deterioration of the environment (Dou *et al.* 2011). As a policy of water resources management, the IRSN strategy has been brought forward by the Chinese government, and this should help meet the demands of future development and water function utilization.

Against this backdrop, studies about IRSN have drawn increasing attention. The definition of IRSN has also been interpreted in many ways. Ward put forward the concept of the degree of connectivity between river systems, and regarded IRSN as an index that could measure the mutual transmission capacity of water resources in a river landscape (Ward 1997). Subsequently, the relevant researches were booming in terms of hydrology. The IRSN has also been defined as the flowing efficiency of the runoff moving from the source area to the main stream or the water basin, or as the water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle (Western *et al.* 2001; Pringle 2003). In bioecology, IRSN is

doi: 10.2166/ws.2016.103

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defined as the transformation between substances, energy, and organisms in the hydrosphere or the transformation between elements of the hydrosphere in the water (Lane *et al.* 2004). Other specialists have applied the concept of the degree of connectivity between river systems to landscape ecology, hydrology, topography and other fields. In other words, Bracken provided an overview of how existing research relates to the concept of connectivity in both ecology and hydrology, and proposed a conceptual model of hydrological connectivity (Bracken & Croke 2007). Tetzlaff explored the utility of the connectivity concept and explained how it contributed to a more unified and interdisciplinary understanding of the influence of catchment-scale hydrological processes (Tetzlaff *et al.* 2007). Xu conceptualized an interconnected river and lake system network as the hydraulic connection between lakes and rivers established by natural forces or engineering measures (Xu & Pang 2011).

Although studies on river system structure are relatively scarce, several researchers have addressed this problem. Grvaelius proposed the earliest river classification principles, and arranged rivers in a certain order to meet the needs of quantitative analysis (Jin 2014). The self-similarity of the structure and components of natural rivers was shown by Horton and Strahler, who proposed the Horton law and the Strahler river classification method, respectively (Sun *et al.* 2013). Vannote demonstrated that river systems were not independent from each other and had common horizontal and vertical connections (Vannote *et al.* 1980). Claps found that the average river system fractal dimension was approximately 1.7 (Claps & Oliveto 1996). Other studies have investigated the quantitative relationship between the branching ratio, fractal dimension, and geomorphic development process (Chen 1980; Chen 1986; He & Zhao 1996; Jin *et al.* 2003). In addition, some researchers studied the case analysis, concept, driving factors, and theoretical basis of the IRSN (Li *et al.* 2011; Tang 2011; Wang *et al.* 2011; Cui *et al.* 2012).

Overall, many researchers have focused on the concepts and characteristics of the IRSN, but few studies have quantitatively described the internal mechanism of the IRSN, and little work has characterized the relationship between urban development and the IRSN. Thus, it is urgent to establish a quantitative relationship between the form and function of the IRSN to evaluate the influence of the urbanization process on the IRSN. Taking Zhengzhou City as a study area, first, we developed a set of index systems describing the form of the IRSN using landscape ecology and river geomorphology theories. Second, we established a set of function indexes of the IRSN, aiming to evaluate water function as well as consider the city's development needs. Third, we analyzed the correlation between the form indexes and the function indexes using statistical methods. Fourth, we established quantitative expressions for the relationship between changes in the IRSN form indexes and the function indexes. Finally, we determined the threshold values for both the future development demands of Zhengzhou City and water function. To some extent, our results could help guide reasonable construction of urban river systems and management of water function.

MATERIALS AND METHODS

Study area

Zhengzhou City (N34°16′-34°58′, E112°42′-114°14′) is located in central China between the Yellow River basin and the Huai River basin. It includes 124 rivers, and the river systems of Zhengzhou City in 2009 are shown in Figure 1. Expansion of urban areas has given rise to large changes in the river and lake systems of Zhengzhou City. For instance, some rivers have been completely filled in, and there is a growing trend toward simplification or truncation of rivers. Thus, the form and structure of rivers has changed dramatically, which has aggravated the shortage of water resources in Zhengzhou City.

Framework and methodology

Description of the IRSN form indexes

Currently, methods based in landscape ecology are generally used to describe the form of a river system and indexes which can represent the connectivity between the corridors in landscape ecology are used to characterize the connectivity of river systems (Zhao 2008; Zhao *et al.* 2011). To describe the morphological pattern of the river system, two aspects should be fully taken into account. One is from the perspective of the

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Figure 1 | The river systems of Zhengzhou City in 2009.

river system's own structure, and the other one is based on the state of connection of the river system. Thus, the characteristic form index of the IRSN is classified using structural form indexes and connectional form indexes. In this study, we construct a set of index systems describing the form of river systems (as shown in Table 1). The basic information for the indexes in Table 1 can be extracted using the multiple-band method and the decision-tree classification method.

Description of the IRSN function indexes

The various functions of river and lake systems play a leading role in offering a variety of resources and services that support urban development. From the point of natural function, the momentum and relatively stable path of water allows it to transfer material and creates an environment for living creatures. From the point of view of social function, however, the acceleration of urbanization can promote the social values of the river and lake system. Hence, the function index system of the IRSN presented in this paper includes both natural and social functions. Illustration of 18 specific indexes is given in Table 2.

Bivariate correlation analysis of the indexes

In this study, bivariate correlation analysis was conducted using the Statistical Package for the Social Sciences. The recursion formula of the correlation coefficients is given below:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

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Table 1 | The form index system of the IRSN

Type	Index name	Abbreviation	Calculation formula[a]	Effects
Structural form indexes	River length	*RL*	–	Indexes that reflect the degree of development of regional river systems
	Water area	*WA*	–	
	Storage capacity of the riverway	*SCR*	–	Indexes that reflect water storage capacity of regional river systems
	Drainage network density	*DND*	$DND = \frac{\sum_{i=1}^{m} L_i}{A_r}$	Indexes that reflect the degree of development of regional river systems
	Water surface ratio	*WSR*	$WSR = \frac{A_w}{A_r}$	Indexes that reflect the size of the regional water area
Connectional form indexes	Circuitry of the river	*CR*	$CR = \frac{n - v + 1}{2v - 5}$	Indexes that reflect the exchange capacity of material and energy at each node in the river system
	Node connection rate	*NCR*	$NCR = \frac{n}{v}$	Indexes that reflect the connectivity at each node in the river system
	Degree of connectivity between river systems	*DCBR*	$DCBR = \frac{n}{3(v-2)}$	Indexes that reflect the connectivity and water transport capacity between river systems

[a]L_i is the length of the river; A_r is the total area of the region; A_w is the area of the water; n is the number of rivers in the region; and v is the number of nodes in the region.

where x_i and y_i are the values of the two variables; $\bar{x}$ and $\bar{y}$ are the average of the two variables; r is the correlation coefficient; n is the sample size.

Determination of the index threshold

A multiple linear regression equation for the selected indexes was developed. This takes the IRSN function indexes as dependent variables and the IRSN form indexes as independent variables. Ultimately, the coefficients of the equations which had significant linear correlations were determined using the SPSS software. The equation is given as follows:

$$y_t = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} + \cdots + \beta_k x_{tk} + u_t \ (t = 1, 2, \cdots, n) \qquad (2)$$

where y_t is the dependent factor; $x_{t1}, x_{t2,\ldots}, x_{tk}$ are the independent variables; u is the random error, which expresses accidental influence by random factors that failed to be observed; k is the number of independent variables.

Finally, the values of the IRSN function indexes that were suited to future urban development were predicted based on comprehensive planning of urban water resources and urban master planning by 'interpolation method'. The theory of the 'interpolation method' is that specific function f(x) is developed using the function value of a given point, and the function value of other points on the interval can be worked out approximatively through f(x). When the multiple linear regression equation was qualified by the function indexes, it could be transformed into a mathematical inequality and hence inequality equations. The threshold values were fixed after solving the public area of the function graph made by the ZX Mathematical Functions Mapping software (Jin 2014).

RESULTS AND DISCUSSION

Calculation of the IRSN form indexes

Taking the year 1990 as an example, the detailed operation steps of extracting the Zhengzhou river system information through the Environment for Visualizing Images software are shown in Figure 2(a)–2(e). Figure 2(a) shows Zhengzhou's TM imagery, which was processed after downloading from the

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Table 2 | The function index system of the IRSN

Target layer	Rule layer	Index layer	Illustration of indexes
Natural functions	Function of transferring material and energy	Guarantee rate of mean annual runoff	Number of days during which runoff exceeds the average in a year/total number of days in a year
		Rate of rivers discontinuous	Number of days during which rivers are discontinuous in a year/total number of days in a year
		Sediment delivery efficiency	Measured sediment data of rivers/sediment carrying capacity of rivers
	Function of shaping river geomorphology	Change rate of wetland area	(Wetland area of evaluation year – wetland area of base year)/wetland area of base year
		River erosion modulus	River erosion thickness of unit time
	Function of sustaining ecosystem	Biodiversity index	Quantitative index, $-\sum Pi \ln Pi$, where $Pi =$ number of some kind of creature/number of all creatures
		Guarantee rate of instream ecology water demand	Number of days during which instream ecology water demand is met in a year/total number of days in a year
	Function of purifying the water environment	Standard-reaching rate of river water quality	Length of river whose water quality exceeds Class III of surface water environmental quality standard/ total length of regional river
		The period of water renew	It can be calculated through a particular formula
		Pollutant taking capacity of rivers	Guaranteeing water quality can satisfy the requirements of functional zones, the maximum quantity of pollutants that the water body can hold
Social functions	Function of allocating water resources	Percentage of urban water supply coming from surface water	Proportion of surface water accounting for the urban water supply
		Percentage of agricultural irrigation supply coming from surface water	Proportion of surface water accounting for the agricultural irrigation supply
	Function of hydropower and water transportation resource utilization	Hydroelectric power efficiency	Average annual energy output of hydropower stations
		River navigation ability	Number of days during which rivers are navigable in a year/total number of days in a year
	Function of flood defense	Reservoir regulation capacity index	Total capacity of reservoirs/annual average runoff volume
		Standard-reaching rate of flood control safety engineering	Number of engineering which can meet flood safety/ total number of engineering
	Function of landscape maintenance	Degree of comfort with water	It can be obtained by expert scoring according to appropriate criteria
		Urban water landscape emissivity	Percentage of total area taken by regions where people can arrive on foot within 15 min, the Second Ring Road in the urban area, like springs, rivers, lakes, wetlands, fountains, garden and plots

RSI data center. The RSI (Figure 2(b)) was obtained by applying the multiple-band method to the image (Figure 2(a)). Figure 2(c) was obtained by classifying Figure 2(b) via the decision-tree classification method, in which the white portion shows the water body of Zhengzhou. In addition, a clear network diagram of Zhengzhou's river system is presented in Figure 2(d), which was created by overlaying Figure 2(c) and the actual network diagram. Finally, a generalized network diagram (Figure 2(e)) of the Zhengzhou river system was created by plotting the river system and the direct nodes.

To create network diagrams of the river system in 1990, 2002, and 2006–2010 (Figure 3), the numbers of river systems and nodes between river systems were obtained following the scheme detailed above, and the values for the form indexes were calculated for the entire study area (Table 3).

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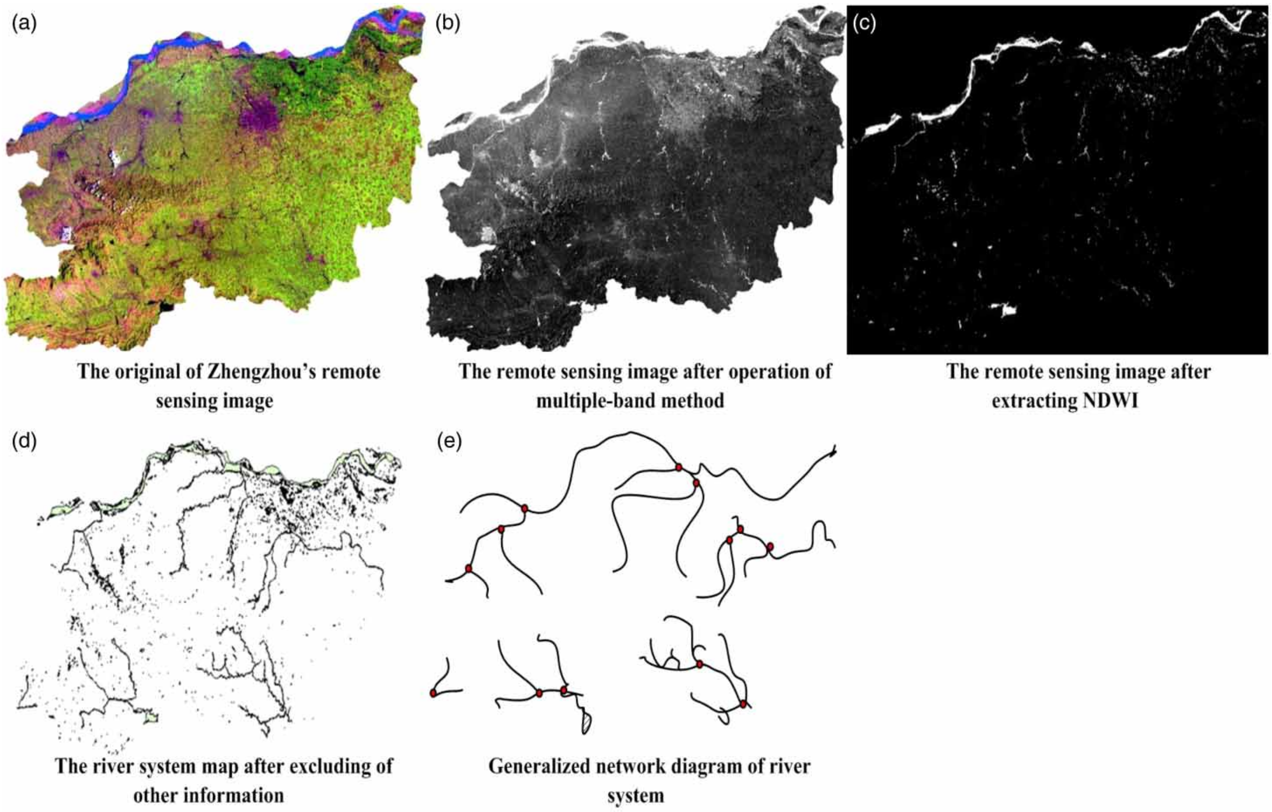

Figure 2 | Extraction process of river system information using the ENVI software.

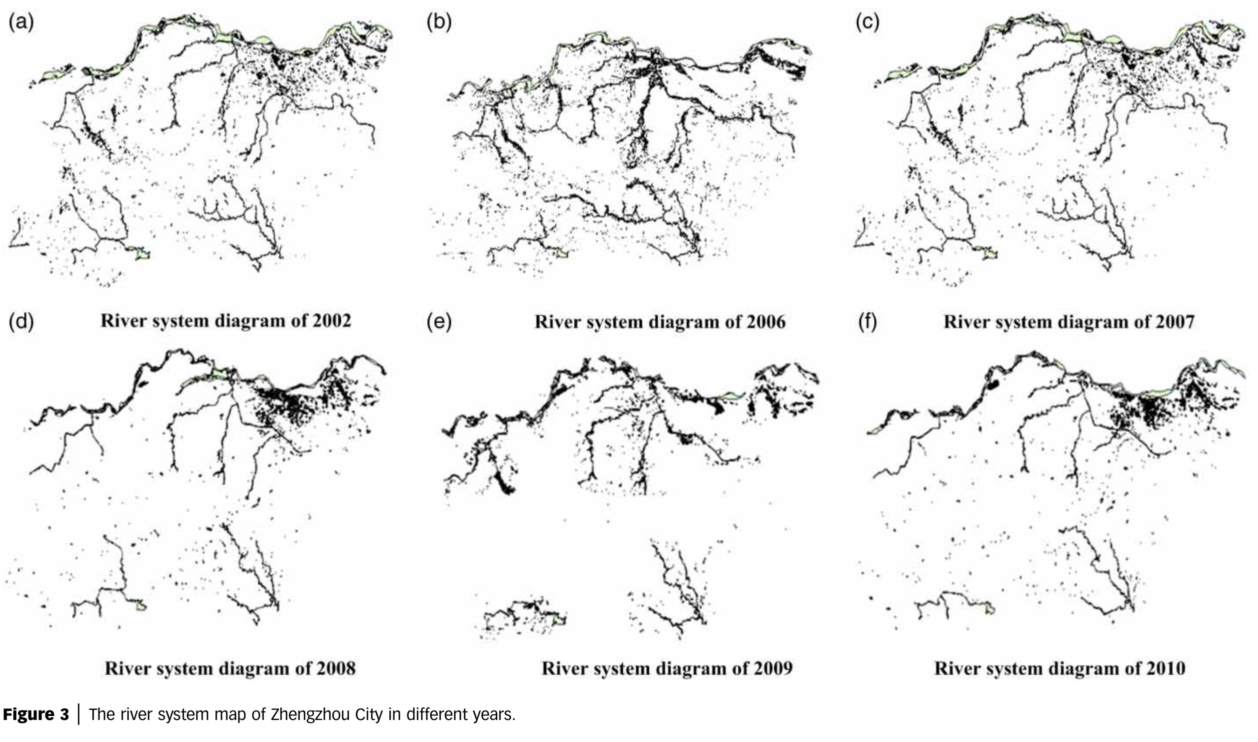

Figure 3 | The river system map of Zhengzhou City in different years.

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Table 3 | Values of the form indexes of the IRSN in Zhengzhou City

Index	Year 1990	2002	2006	2007	2008	2009	2010
RL/km	2365.02	2049.72	2089.93	1877.76	1781.93	1680.42	1787.65
WA/km^2	336.05	315.41	248.18	187.14	186.93	180.17	190.76
SCR/km^3	141.90	102.49	96.14	84.50	78.41	75.62	75.08
DND/km/km^2	0.32	0.28	0.28	0.25	0.24	0.23	0.24
WSR/–	0.05	0.04	0.03	0.03	0.03	0.02	0.03
CR/–	0.43	0.22	0.27	0.18	0.31	0.31	0.36
NCR/–	1.62	1.31	1.30	1.18	1.33	1.33	1.38
DCBR/–	0.64	0.50	0.54	0.48	0.57	0.57	0.61

Calculation of the IRSN function indexes

Considering the situation of Zhengzhou City, the eight most adequate indexes as shown in Table 4 were selected to characterize the natural and social function of the IRSN. Next, the IRSN's function was evaluated based on data for the river and lake system and ecological water quality of Zhengzhou City for different years (1990, 2002 and 2006–2010) in accordance with the *Water Resources Comprehensive Plan of Zhengzhou City* (2007) and the *Ecological Water System Planning of Zhengzhou City* (2007) (as shown in Table 4). More information on the selected indexes and evaluation results is available in the literature (Jin & Dou 2013).

Bivariate correlation analysis of IRSN form indexes and IRSN function indexes

Eight function indexes and eight form indexes were analyzed by bivariate correlation analysis, as shown in Table 5.

Table 5 shows that the significance level of *SRWQ* with *NCR* is 0.006 (less than 0.01), and the next three indexes (*SCR, RL,* and *DND*) have significance levels above 0.01 but below 0.05, which pass the significance test. The *UWSW* is correlated to *SCR* at a significance below 0.05, and the significance with *NCR* is below 0.01. There are three form indexes (*NCR*, *CR*, and *DCBR*) which have a significant relationship with *BI*. The relationship between *BI* and *NCR* is less than 0.01, while the significance level of

Table 4 | Values of the function indexes of the IRSN in Zhengzhou City

Index	Abbreviation	Year 1990	2002	2006	2007	2008	2009	2010
Standard-reaching rate of river water quality/%	*SRWQ*	0.50	0.06	0.06	0.06	0.06	0.07	0.07
Percentage of urban water supply coming from surface water/%	*UWSW*	0.49	0.46	0.46	0.46	0.46	0.46	0.46
Change rate of wetland area/%	*RWAC*	0.00	−0.13	−0.16	−0.13	−0.07	0.07	0.09
Biodiversity index/–	*BI*	0.65	0.51	0.54	0.51	0.53	0.54	0.55
Reservoir regulation capacity index/s	*RRCI*	0.76	0.75	0.73	0.84	0.84	0.85	0.93
River navigation ability/%	*RNA*	0.10	0.09	0.09	0.08	0.09	0.09	0.09
Degree of comfort with water/–	*HCD*	140	145	140	145	146	148	160
Rate of rivers discontinuous/%	*DFR*	0.50	0.81	0.91	0.92	0.89	0.87	0.81

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Table 5 | Correlation analysis between the function indexes and the form indexes of the IRSN

		Form index							
Function index		***RL***	***WA***	***SCR***	***DND***	***WSR***	***CR***	***NCR***	***DCBR***
SRWQ	*r*	0.765*	0.659	0.793*	0.765*	0.657	0.708	0.898**	0.630
	a	0.045	0.108	0.033	0.045	0.109	0.075	0.006	0.130
UWSW	*r*	0.734	0.631	0.769*	0.734	0.630	0.743	0.914**	0.668
	a	0.060	0.129	0.043	0.061	0.130	0.056	0.004	0.101
RWAC	*r*	−0.333	−0.267	−0.164	−0.334	−0.267	0.711	0.474	0.754
	a	0.465	0.562	0.726	0.465	0.562	0.073	0.283	0.050
BI	*r*	0.660	0.540	0.673	0.660	0.538	0.872*	0.957**	0.819*
	a	0.107	0.211	0.098	0.107	0.212	0.011	0.001	0.024
RRCI	*r*	−0.744	−0.752	−0.690	−0.744	−0.752	0.161	−0.168	0.253
	a	0.055	0.051	0.086	0.055	0.051	0.730	0.719	0.585
RNA	*r*	0.666	0.584	0.703	0.666	0.583	0.891**	0.982**	0.834*
	a	0.102	0.169	0.078	0.102	0.170	0.007	0.000	0.020
HCD	*r*	−0.645	−0.538	−0.559	−0.645	−0.538	0.158	−0.145	0.234
	a	0.118	0.213	0.192	0.118	0.213	0.735	0.757	0.614
DFR	*r*	−0.742	−0.731	−0.836	−0.742	−0.730	−0.746	−0.636	−0.660
	a	0.056	0.062	0.069	0.056	0.063	0.054	0.072	0.107

r is the Pearson correlation coefficient between the two indexes; *a* is the significance level between the two indexes (two-tailed).
*Denotes a significance level between the two indexes below 0.05.
**Denotes a significance level between the two indexes below 0.01.

BI for *CR* and *DCBR* is significant below 0.05. The *RNA* is related to *NCR* and *CR* with a significance level less than 0.01, and with *DCBR* below 0.05, which indicates that both *BI* and *RNA* are affected strongly by the three form indexes (*CR*, *DCBR* and *NCR*). In addition, the bivariate correlation analysis shows that there are high Pearson correlation coefficients between the four function indexes (*SRWQ*, *UWSW*, *BI*, and *RNA*) and *NCR*; all relationships have a significance level below 0.01, and the coefficient between *RNA* and *NCR* is greatest (0.982).

River bed formation and pollutant levels change constantly due to the transportation of water and sediment, while water flow and river bed formation create a good living environment for creatures, so *SRWQ*, *BI* and form indexes of IRSN (*SCR*, *RL*, *DND*, *NCR*, *CR* and *DCBR*) are more closely connected. At the same time, the navigation benefit is directly related to the connectivity between river system and water transportation capability, so *RNA* is significantly associated with IRSN form indexes. Besides, river is one of the surface water supply resources in Zhengzhou, so there is a strong correlation between *UWSW* and *SCR*. The rest of the function indexes (*RWAC, RRCI, HCD,* and *DFR*) correlate poorly with the form indexes, and their significance levels do not pass the significance test. These four indexes are probably related to rainfall, economic activities, the decision-making of the local government, and have little relationship with form indexes.

Determination of the threshold of the IRSN form indexes

According to the correlation analysis results above, multiple linear regression equations for linear correlation indexes which were evaluated by mapping the variation charts through SPSS were established. The significance of the linear equations was tested using SPSS, and then the coefficients of the equations were ascertained (Table 6).

A multiple linear regression equation was derived from the first line of Table 6, which takes *SRWQ* as a dependent variable and *SCR*, *DND*, and *NCR* as independent variables; multiple linear regression equations for *BI*, *UWSW*, and *RNA* were obtained in the same way. The four relationships are expressed as follows:

$$SRWQ = -1.555 - 0.002SCR + 2.278DND + 0.824NCR \quad (3)$$

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Table 6 | Coefficients of the multivariate linear equations

	Form indexes						
Function indexes	***RL***	***SCR***	***DND***	***NCR***	***DCBR***	***CR***	**Constant term**
SRWQ	0.000	−0.002	2.278	0.824	–	–	−1.555
P		0.705	−0.458	0.708			
BI	–	–	–	1.635	9.805	−8.241	−4.703
P				0.853	0.792	−0.792	
UWSW	–	0.001	–	0.069	–	–	0.363
P		0.673		0.804			
RNA	–	–	–	0.129	0.704	−0.593	−0.302
P				−0.789	−0.746	0.760	

p is the partial correlation coefficient between the two indexes.

$$BI = -4.703 - 8.241CR + 1.635NCR + 9.805DCBR \quad (4)$$

$$UWSW = 0.363 + 0.001SCR + 0.069NCR \quad (5)$$

$$RNA = -0.302 - 0.593CR + 0.129NCR + 0.704DCBR \quad (6)$$

There are five independent variables in four equations, which cannot be solved directly. While *UWSW* is a target value based on the future development of water demand, which can be calculated using data from planning and reports, and the threshold value of *SCR* was obtained on the basis of historical data. So the threshold value of *NCR* was calculated by inversely solving Equation (5). The equation is as follows:

$$NCR = -\frac{1}{69SCR} - \frac{0.363 - UWSW}{0.069} \quad (7)$$

Figure 4(a) is drawn based on the interval value of the function index *UWSW*, the form index *SCR* and Equation (7) obtained using the ZX software. Similarly, the expressions for *DCBR*, *CR* and *DND* (Equations (8–10)) were obtained based on Equations (4), (6) and (3) and the results are plotted in Figure 4(b)–4(d). The threshold values of the form indexes were obtained by solving the public area of Figure 4, which shows the relationships between every two form indexes.

$$DCBR = \frac{8.241}{9.805}CR + \frac{BI + 4.703 - 1.635NCR}{9.805} \quad (8)$$

$$CR = \frac{0.704}{0.593}DCRR + \frac{0.129NCR - 0.302 - RNA}{0.593} \quad (9)$$

$$DND = \frac{0.002}{2.278}SCR + \frac{SRWQ + 1.555 - 0.824NCR}{2.278} \quad (10)$$

Using historical data from the *Zhengzhou Statistical Yearbook* (1990–2010) and *Water Resources Bulletin of Zhengzhou City* (1990–2010) as a reference, as well as using planning data from the *Zhengzhou* City Master Plan (2008) and *Integrated Water Resources Planning of Zhengzhou* (2007), target values that would meet the need for water function in 2020 were ascertained by interpolation method. The target values are as follows: the value of *SRWQ* will reach 80%; the value of *BI* will exceed 0.65; the value of *RNA* will exceed 0.10; and the value of *UWSW* will exceed 49%. Based on Equations (7)–(10) and Figure 4, the theoretical threshold values of the form indexes of the river system in Zhengzhou were obtained: (1) the threshold value of *DND* is between 0.32 and 0.33; (2) the threshold value of *NCR* is between 1.54 and 2; (3) the threshold value of *DCBR* is between 0.55 and 0.77; and (4) the threshold value of *CR* is between 0.40 and 0.60.

Using the implementation effect diagram from *Ecological water system planning of Zhengzhou City* (2007), the node connection rate and other indexes were calculated, and the planning values of the IRSN form indexes in Zhengzhou City were determined: the planning value of *NCR* can reach 1.42 and *DCBR* can reach 0.53 by 2020. This planning value of *NCR* is close to the theoretical value of *NCR* (between

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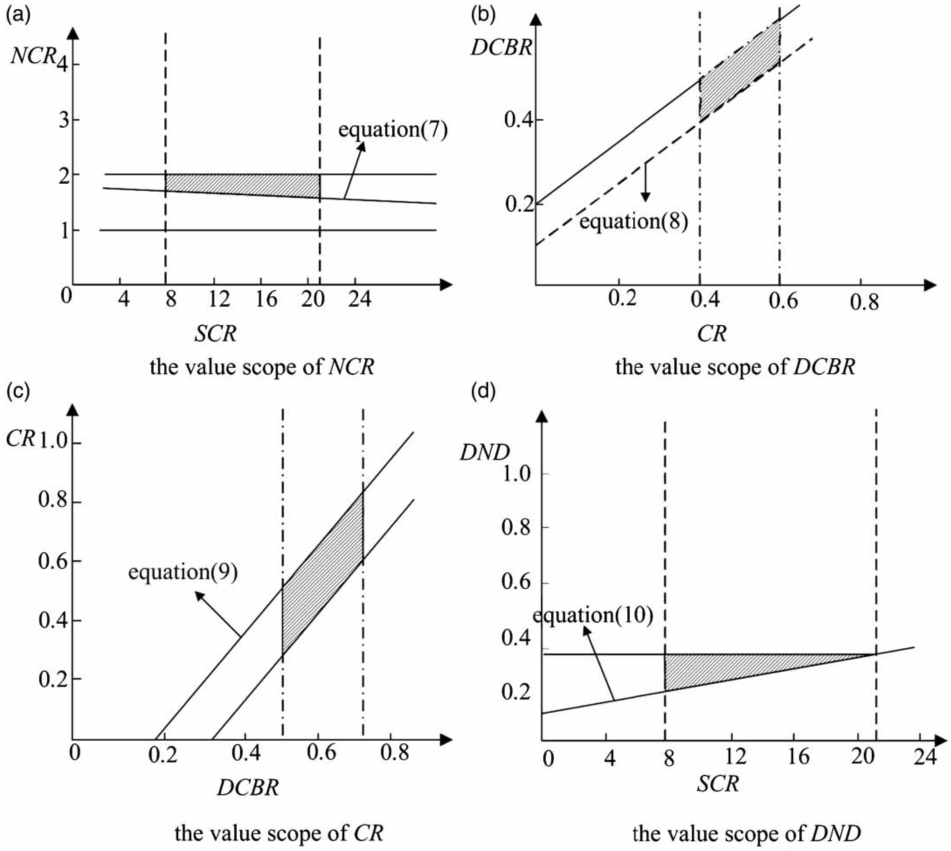

Figure 4 | Threshold values of the form indexes of the IRSN.

1.54 and 2), and the calculated planning value of *DCBR* is also close to the theoretical (between 0.55 and 0.77). On the whole, the equations and results in this study suggest that the threshold values of the IRSN form indexes are reasonable and reliable considering the future development demands of Zhengzhou City. However, due to the constraint resulting from limited number of sample and rationality of the results verified only according to implementation effect diagram, there are some shortcomings in the research work. So the feasibility of the method remains to be further verified by exploring the length of the sample data and the rationality of the quantitative relationship in the future, which would improve the accuracy and practical value of the results.

CONCLUSIONS

Research investigating the IRSN under conditions of urbanization is an important issue in the field of water science. This study developed two index systems for the form and function of the IRSN, which were used to describe the influence of city development on the form and function of the river and lake system. Eight specific indexes (*RL*, *WA*, *SCR*, *DND*, *WSR*, *CR*, *NCR* and *DCBR*) from the form index system and eight indexes (*SRWQ*, *UWSW*, *RWAC*, *BI*, *RRCI*, *RNA*, *HCD* and *DFR*) from the function index system were selected to create an index system for the IRSN in Zhengzhou City. Next, the correlations of the form indexes and the function indexes were analyzed, showing that *SRWQ* had a significant relationship with *RL*, *SCR*, *DND* and *NCR*; *UWSW* was closely related to *SCR* and *NCR*; and *BI* and *RNA* were related to *CR*, *DCBR* and *NCR*. Finally, quantitative equations that describe the relationship between the form and function indexes were established, and the threshold values of the IRSN form indexes were determined to ascertain whether they would meet the future development demand. These values can provide a reference for water resources management and the

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construction of water connectivity projects in Zhengzhou City.

ACKNOWLEDGEMENTS

The research was supported by the Natural Sciences Foundation of China (No. U1304509) and the Development Foundation for Outstanding Young Teachers of Zhengzhou University, China (No. 1521323001).

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First received 21 January 2016; accepted in revised form 6 June 2016. Available online 20 June 2016

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