Can city lake recreational pressure be measured? The impacts of urbanization on Wuhan's lakes

Tittle1：Urban Lake Accessibility and Measurement of Recreational Pressure: A Case Study of Wuhan

Tittle2: Urban Lake Recreational Pressure Can Be Measured? A Case Study of Wuhan

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Abstract: Urban lakes return from production function to the life-form, recreation activities become one of the important social functions of urban lakes, but the recreational pressure has been paid not enough attention. It's not conducive to the development of lake ecological function and social function. Wuhan city was took as a study case, ArcGis10.2 network analysis function was used in the accessibility analysis of urban lakes, the research combined with Kriging Interpolation results of the population density spatial distribution in the scale of 90 center city streets, and the travel rate (TR) formula improved on the basis of Koch (1978), urban lake recreational pressures (LRP) were measured. Lake accessibility analysis (LAA) results show that the accessibility of lakes in Wuhan city is good, 15 minutes can reach 96.15% of total area, good accessibility means will lead to a higher recreational pressure, in the area of recreational pressure accounted for 99.85% of the total, and 30 minutes to urban area covering almost all. Recreational pressure measurement results show that the traffic accessibility, population density were positively correlated to lake recreational pressure. Wuhan urban lake was divided into five categories by recreational pressure index(LRPI). The highest recreational pressure lakes include 11 lakes such as Neisha, Xiaonanhu Lake(4.6336-5.8027), the higher recreational pressure lakes include 2 lakes, such as Ziyang, Tangzi lake(3.3270-4.2452), the medium recreational pressure lakes include 7 lakes such as Yue, Yangchun lake(1.6425-2.9089), the lower recreational pressure lakes 7 lakes such as Moshui, Yezhi lake(-0.0322-1.3047), the lowest recreational pressure lakes include 11 lakes such as Jinyin, Tangxun lake(-2.2806--0.3764). Based on the above lake accessibility analysis and recreational pressure measurement results, lake recreational pressure mitigation strategy is put forward, the implementation of lakes grading management and allocation of resources, the lake leisure management, urban recreation spatial structure optimization to provide guidance and advice.

Keywords: urban lake function; recreational pressure; accessibility; Wuhan

1. Introduction

China is experiencing the unprecedented process of urbanization, while the change of land utilization is one of the most intuitive performances. In order to gain construction land for social economic development, the ecological land is encroached, especially for Lake Wetland (Pienimäki and Leppäkoski, 2004; Shui and Xu, 2016; Su et al., 2010; Zhu et al., 2011). Urban lakes are one of ecological types that were intruded by human activities most seriously (Liu et al., 2007). A growing number of suburban lakes have become central urban lakes along with the advancement of urbanization, biodiversity of lakes have been damaged with varying degrees, ecological functions have increasingly degenerated (Yan et al., 2013). Lake recreational planning and development have become one of the effective ways to resolve the dilemma of lake utilization and protection (Chaudhry et al., 2013; Collins-Kreiner and Israeli, 2010; Seim, 2002). Lake recreational planning not only considers the ecological land with the active posture, but also satisfies the recreational demands of water loving (Morote et al., 2016; Zhang et al., 2016), promotes development of ecological functions and socio-economic functions in lakes, ensures safety of ecological land in lakes and embodies the ecological civilization construction requirements in lakes with “harmonious coexistence between humans and lakes”(Pitkänen, 2008). Lake recreation areas have been increased rapidly since from 1978(Fan, 2009), thus lake recreation has become one of the important social functions of urban lakes and has the important significance on constructing harmonious ecological landscape in cities (Chaudhry et al., 2013; Dan et al., 2014; Zhu et al., 2014). However, it also causes a huge recreational pressure on lakes. Serious consequences may be caused for poor management. On the one hand, lake shrinkage, weak ecological functions and lost storing and adjusting functions are easy to cause natural disasters, but it is an endless and arduous task to repair ecological functions in lakes (Gössling et al., 2012; Yan et al., 2013). On the other hand, recreational demands of water loving have no scientific guidance and reasonable satisfaction (Gössling et al., 2012), impacting development of socio-economic functions in lakes.

The article aims to measure the urban lake recreational pressure. A new measurement model of recreational pressure is applied to evaluate. The research takes all urban lakes as recreation system, through GIS visualization expression, results will show all lake recreation pressure level. The measurement model also can apply to city with multi-lakes in the middle and lower reaches of the Yangtze River and similar cities over the world with significant population and in the processing of rapid urbanization. The lake recreation pressure index has the guidance significance on allocating management and protection resources reasonably, promoting recreational functions of urban lakes, and carrying out urban recreational governance and urban recreational space structure optimization.

2. Literature Review

2.1 The relationship of urban lake and people in the process of urbanization

People presents more and more close and tense relationship with lakes (D'Souza and Nagendra, 2011). Urbanization plays important role in affecting water resources (Awais et al., 2016). Urbanization seriously encroaches on lake ecological land, resulting in deteriorating water quality and area atrophy (Kudelska, 1992; Li et al., 2012; Tandyrak et al., 2016). In Wuhan City changing from 1990 to 2013, the area of Shaihu Lake has shrunk by 77.27%(Yang and Ke, 2015). So is the Gidadakonenahalli Lake in Bangalore urban district of India, in the background of urbanization, weather, climate, atmospheric inputs, hydrology, and land use practices can all exert a strong influence on lakes (Shekar et al., 2015).

According to the literature, urbanization caused the dilemma of lakes utilization and protection. On the one hand, urban land use strongly restricted the availability of places where people can access nature and its services (D'Souza and Nagendra, 2011). Urbanization make people close to urban lake, which is the one piece of the natural world left in city. On the other hand, urban lake ecology system was destroyed. Recreation in lakes surrounding land layout, have active protection sense to stop the lake water quality deterioration(Jolliffe, 1988), which purpose is the plan based on the idea of sustainable development.

2.2 The urban lake function

Under the background of urbanization, the distance between people and lakes in the narrow, make lakes become the main place of people to release pressure. The urban lake function is quietly changing. A large number of researchers have discussed the functions of contemporary urban lake. Lake is one of the important factors that gave rise to city, so the city location commonly associated with lakes and rivers (Tandyrak et al., 2016). Urban lake undertook the function of supply and transportation in the old days, and now urban lakes not only provide with purify air and habitat, but also play an important role in leisure and active recreation of the inhabitants, and supply a variety of benefits derived from urban aesthetics (Burger et al., 1999; Swinnerton and Hinch, 1987), like Lake Ełk in Poland (Tandyrak et al., 2016) and the Mogan and Eymir Lakes in Turkey(Karakoç et al., 2003). For example, Agara Lake in the south Indian city of Bangalore, the landscape surrounding the lake has altered from a agricultural area, dependent on the lake for irrigation and drinking water, to a densely urbanized area where the lake is used predominantly for recreation (D'Souza and Nagendra, 2011). Lots of research effort on proving it, a novel approach for quantifying human presence by combining social media “big data” and remote sensing tools, through identifying photography hotspots(from the Flickr photo-sharing website), to find where the people going(Levin et al., 2015), the results infer that protect areas, such as Lake and Peak Districts (UK) attracted more people. As to recreational mode, Butler and Redfield (1991) gave us the results: Of those respondents indicating a preferred lake use, 48 percent chose walking or looking as most important; boating as second at 27 percent; and fishing was third, favored by only 8 percent. Citizens feel strongly (94 percent) that the lakes are valuable community assets(Butler and Redfield, 1991).

Through recreation use, urban lake has a huge range of effects on community’s health, especially the recreational services of lake received the highest weight (Shojaei et al., 2014). In addition, the urban lake system also relates to the urban ecosystem health (Zhang et al., 2005). Urban lakes are often used as a tool of shaping and spread the city’s image, such as Lake Biwa in Japan (Yamamoto and Nakamura, 2004), so is the hundreds of lakes city Wuhan.

The realization of the urban lake recreation function is based on nice water quality. The quality of the lake water is a basic factor to leisure and recreation in the city(Crase and Gillespie, 2008; Tandyrak et al., 2016), because which bring a measurable effect of improving the attractiveness and quality of life in the city and improving the tourist values (D'Souza and Nagendra, 2011), and also good water quality reduce spread of the virus in the recreation and swimming waters(Aslan et al., 2011; Roser et al., 2006). Such as Lake Hume in Australia, the recreational value to visitors is different under different water quality and water level scenarios using the contingent travel cost method (Crase and Gillespie, 2008).

2.3 Urban lake recreational pressure and measurement

Recreational pressure

Urban lakes are shallow, highly artificial, have good accessibility and perfect infrastructure, so compared with rural lakes, people will be more contact with urban lakes (Birch and McCaskie, 1999), but it also means that urban lake would be confronted with heavy recreational pressure. The recreational pressure gave a description of the relationship between recreation development, visitors and lake ecology. A number of studies have been devoted to express the relationship with tourism environmental capacity (Brown et al., 1997; Liu et al., 2001; Liu et al., 2009; Pereira et al., 2005) or tourism carrying capacity (Butler, 1997; Ding et al., 2015; Luo et al., 2008; Mccool and Lime, 2001; Saveriades, 2000) from the perspective of tourism supply.

As for the concept of tourism crowding took into account for tourists demand for the size of the leisure space(Schmidt and Keating, 1979). It was used for reference to the measurement of recreational pressure in this research. Tourism crowing refers to specific density level within a certain area of a negative evaluation(Absher and Lee, 1981; Shelby et al., 1989), density is the objective values, each unit number in the space can be directly controlled by the management. With the deepening of the crowding perception research, the study area from the wilderness area off to high-density use area, such as the festival of the scene, the urban forest, city parks, urban lakes,etc(Cheng et al., 2015). Case study and model study have shown that density is an important factor caused tourist crowded, but is not the only factor(Absher and Lee, 1981). Tourist density lead to high contact ratio, which would reduce the quality of outdoor experience(Cole and Hall, 2010), so tourist density has potential negative impact on tourist satisfaction in recreational space(Manning and Anderson, 2012; Wei and Yang, 2015), which reveal visitors density for tourist satisfaction and the scenic area management has important significance. A study shows tourist density of 6 m/or 40 m2 one person on the coast was recreational pressure cap, within the scope of this will not lead to health and safety issues, personal privacy will not be infringed(Soboleva E. and Galysheva Y., 2013).

Recreational pressure will bring impacts not only on the use of urban recreational facilities but also on the development and management of recreational resources(de Vries and Goossen, 2002; Van Herzele and Wiedemann, 2003). Recreation pressure measurement model of case study is less, most of existing researches estimated the recreational population of urban green space by distance attenuation model(H Rnsten and Fredman, 2000) and Voronoi polygon, and to evaluate existing park green space layout(Li and Zhang, 2012; Xiao-Ma et al., 2009). The disturbance range that recreational activity causes toward the environmental of tourism destination would grow with the increase of recreationists(Xiao-Ma et al., 2009). But there were two disadvantages in this way: Firstly, recreational pressure indicators expressed with the total residents number in

Voronoi polygons, not considering the realistic tourism market and the inhabitant's travel rate, overestimated the reality of park recreation pressure; Secondly, the distance from the recreationists to destination expressed in a straight line, not conforming to the actual situation.

Accessibility

Standing on the shoulders of giants(Comber et al., 2008; Reyes et al., 2014; Talen, 2001; Talen and Anselin, 1998; Tsou et al., 2005; Vries and Boer, 2008), this research defined lake recreation pressure refers to the quantitative expression of recreation demand based on the accessibility of urban lake. Accessibility can be viewed as the ease of reaching destinations by transportation. How to get the accessibility of quantified? Academics have disputed how the term "ease" should be defined and measured. People who are in places that are highly accessible can reach destinations in short times, people in inaccessible places can reach fewer places in the same amount of time. This research will evaluate the accessibility of urban lakes quantitatively based on transportation network in drive mode, combining the population spatial distribution and residents travel rate, to establish urban lake recreational pressure index of each lake.

3. Research Area Overview

Wuhan is the provincial capital in Hubei which is the province of thousands of lakes and it is a comprehensive reform pilot area in national resource-economical and environment-friendly society—a central city in Wuhan urban circle. It is located in east longitude 113°41′-115°05′ and northern latitude 29°58′-31°22′. Wuhan is one of rapidly growing China city, which has 13 areas under administration with the overall area of 8494km^2. The central urban administrative region include Jiang’an District, Jianghan District, Qiaokou District, Hanyang District, Wuchang District, Qingshan District and Hongshan District. The area of central urban areas defined in the research is 955km^2. Permanent resident population in the whole city has been 10.22 million until the end of 2013.

Wuhan City is praised as *“Hundreds of Lake City”*. According to the *“Three-line and One-road” Planning in Wuhan Lakes（TAOP, 2012）* issued by Wuhan Government, there are a total of 166 lakes, including 40 urban lakes. In the beginning of 2015, TAOP for 166 lakes has been finished completely. Wuhan urban lakes represent an especially important context for studying the consequences of urbanization in China. With the urban expansion, Tangxun Lake and Jinyin Lake in Wuhan distant suburban area have already become urban lakes. Replaced by Tangxun Lake, East Lake isn’t the biggest urban lake in Wuhan any more. For convenient statistics and analysis, West Lake and North Lake in the research have been called as Northwest Lake, Jin Lake and Yin Lake has been named as Jinyin Lake. There are a total of 38 lakes. The urban lake directory in Wuhan is shown in Table 1.

Tab.1 A Profile of Wuhan Urban Lakes

Lake Name	Recreational Area(km^2)	ID	Administrative Division	Lake Name	Recreational Area(km^2)	ID	Administrative Division
Northwest	0.2440	1	Jianghan	Yangchun	0.8180	12	Hongshan
Huanzi	0.1409	2		South Lake	9.5930	24	

Houxiang	0.1415	3		Huangjia	11.9180	28	
Lingjiao	0.1664	4		Yezhi	3.2840	30	
Xiaonanhu	0.0800	5		Yandong	22.9350	31	
Jiqidangzi	0.1340	6		Qingling	16.2970	32	
Tazi	0.4696	7	Jiang’an	Ye Lake	13.0940	33	
Zhangbi	1.2470	8	Qiaokou	Chedun	4.0200	35	
Zhuyehai	0.6330	9		Zhuzi	6.4660	36	
Ziyang	0.3050	11	Wuchang	Qingtan		37	
Simeitang	0.1620	17		East Lake	88.0000	38	
Shuiguo	0.1410	13		Wujia	0.3060	16	
Shai Lake	0.1438	14		Lianhua	0.1660	10	Hanyang
Sha Lake	3.9790	27		Moshui	4.9140	18	
Neisha	0.0760	15		Yue Lake	1.3080	19	
Yanxi	32.4603	34	Qingshan	Sanjiao	4.0310	20	
Qingshanbei	4.9031	25		South Taizi	5.9500	21	
Tangxun	63.8790	29	Jiangxia	North Taizi	0.7180	22	
Jinyin Lake	12.4900	26	Dongxihu	Longyang	4.7570	23	

Data source: “Three-line and One-road” Protection Planning(2012) in Wuhan Urban Lakes

As shown in Tab.1, recreational area in urban lake is the sum between control area and water surface area of green line in TAOP. East Lake’s recreational area covered East Lake Scenic Area. Zhuzi Lake is extremely closed to Qingtan Lake, so their recreational area is calculated as one in TAOP. The spatial distribution of Wuhan urban lakes is shown in Fig.1. The number of lakes in the center is obviously more than peripheral lakes, but its area is less than peripheral areas, due to erosion effect of urbanization on lakes.

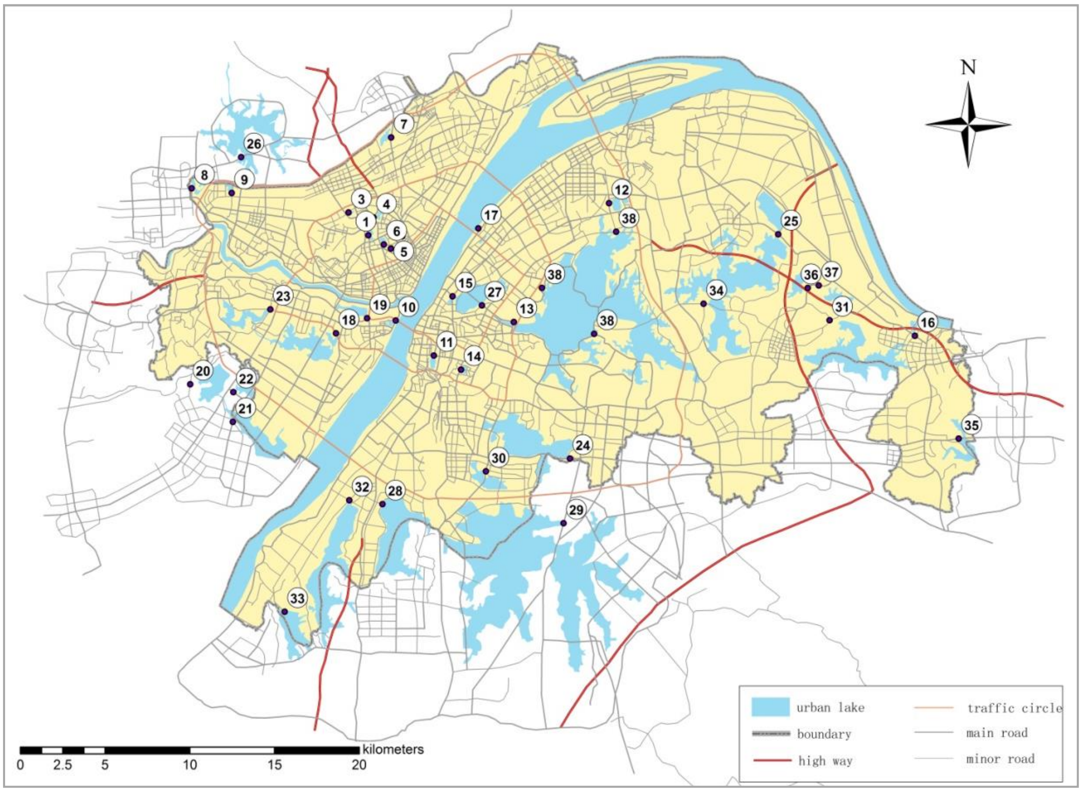

Fig. 1 Spatial Distribution of Wuhan Urban Lakes

According to TAOP, functional orientation of urban lakes can be divided into three categories: lakes in landscape park type, urban park type and ecological park type. A “park” stands for the recreational function of lakes, meaning that urban lakes return from production function to the life-form. It is the open space integrating with urban ecosystem conservation, recreation, residence life and landscape, etc(Zhu et al., 2014). It should be noticed that the aspect of lake recreation development in Wuhan city is a priority, as it evidenced by the development of infrastructure related to recreation and active leisure. This exactly displays the significance on measuring recreational pressure in lakes in the research.

4. Methodology

4.1 Research Approaches

Based on lake accessibility analysis, the research combines with population density data and travel rate in the reachable area to measure lake recreational pressures. The research approach is shown in Figure 2.

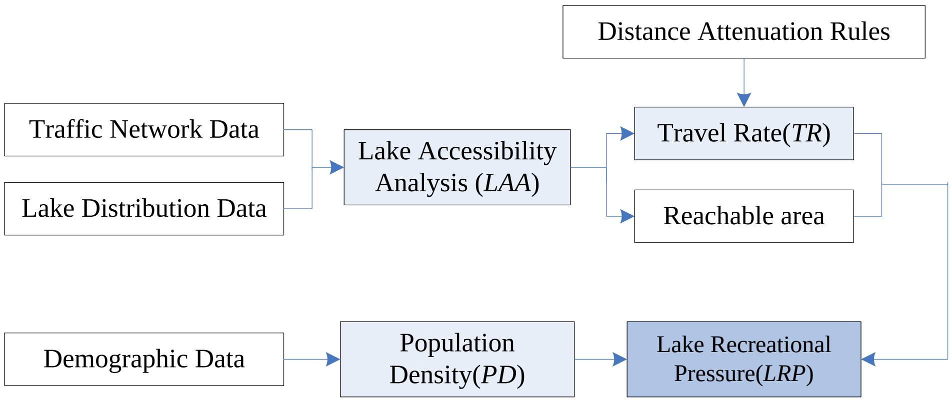

Fig.2 The Research Technical Roadmap

$$LRP = \sum_{i=5}^{n} LAA_i \times PD_i \times TR_i \qquad (1)$$

Where:

LRP : Lake recreational pressure;

i : The arrival time. {5 min, 15 min, 30 min, 45 min, 60 min, 75 min, 90 min };

LAA_i : The urban area with i min of arriving in a lake;

PD_i : Population density in the urban area with i min of arriving in a lake;

TR_i : Residents travel rate in the urban area with i min of arriving in a lake.

$$LRPI = \ln \frac{LRP}{LA} \qquad (2)$$

Where:

$LRPI$: Lake recreational pressure index.

LA : Lake area.

The Distance Attenuation Rules shows that interaction between two objects is reduced with the increase of distance (Cooper et al., 1993). The function expression of Distance-decay Regularity is various, such as Gauss distribution and Exponential distribution, etc(Jin-Feng and Bao, 2005). In practice, Logistic function(Sun et al., 2012) is widely applied, but such a method is too experienced for the judgment of Logistic function inflexion and the third feature point. Moreover, it shows that distance-decay relation between park attraction and travel time. The travel rate was proposed by Koch in 1978 and has been applied in urban recreational accessibility(H Rnsten and Fredman, 2000; Li and Zhang, 2012).

$$TR = \frac{1}{5.826426\times10^{-3} + 1.27859\times10^{-5}\times l + 8.9\times10^{-10} l^2} \qquad (3)$$

Where:

TR : Inhabitant travel rate;

l : Distance between lakes and fountain.

Eq.(3) elaborates the Distance Attenuation Rules more objectively. In the research, l is expressed by the product between arrival time and driving velocity. Such a way means actual route distance is the distance between lakes and fountain and is often measured by straight line distance and can't match with physical truth objectively. Under the condition of constant driving velocity, Eq. (3) actually indicates that travel rate is reduced with the increase of tourism time which has improved the travel rate formula of Koch(1978)(Koch, 1978; Ode and Fry, 2006).

4.2 Research Methods

4.2.1 Network Analyst

Network analyst is an important constituent part in GIS spatial analysis. Based on road network, the research solves the areal extent arriving in urban lakes in different time period. The analysis results can be used to deduce lake accessibility in the entire Wuhan central urban areas. Though accessibility study has simple buffer method, weighted expense distance method(Song et al., 2012), etc. These methods have lots of defects. For example, the former simply measures the spatial positional relationship with straight line distance, but gives no consideration to realistic resistance of entry points of urban lakes. On the other hand, the latter considers realistic resistance, but the realistic resistance comes from different landscape types. Resistance values have some subjectivity by endowing different resistance values and calculate accumulated resistance of entry points(Liu and Xiaoma, 2010). Based on traffic network and different trip modes(walking, driving and public transportation), network analyst is more objective and fitting to realistic situation(Kuta et al., 2014; Li and Liu, 2009), so it is the more excellent accessibility method in the research.

In the research, after checking traffic data topology in Wuhan correctly, Wuhan traffic database is established. The road is divided into three levels, including the main road, secondary road and regional road. According to actual traffic situation in Wuhan, it is assigned at 45km/h of average driving velocity. According to the road intersection in physical situation, splitting lines at intersections with Planarize Lines for identifying the heading direction. With feature dataset of traffic data, a network dataset has been built. Time cost property and road grade property of network dataset are set up. Evaluators of network dataset are applied to construct the expression for time cost property and is the quotient value between line length and driving velocity. Road grade property will give priority to the high-level road as driving.

The lake accessibility evaluation model has been constructed based on creating network analyst layers. The network analyst layer is a key part in ArcGIS network analyst and is mainly used for data input and output, parameter settings and result demonstrating, including route analysis, closest facility analysis, service area analysis and OD cost matrix analysis, etc.

In the research, the service area analysis has been used, lakes and road intersection points as facilities, which is confirmed by field investigation, “Three-line” planning of Wuhan urban lakes, and Google Earth aerial photo.

4.2.2 Kriging Interpolation

Spatial prediction of population density generally applies the ordinary kriging interpolation(Kukush and Fazekas, 2005). The interpolation process is similar to the weighted sliding average. The weighted value comes from spatial analysis. Kriging interpolation has two steps: to generate the variation function and covariance function, which are used for estimating statistical correlation (spatial autocorrelation) between sample point values. Variation function and covariance function depend on autocorrelation model (fitting model) to predict unknown points.

Kriging uses statistical models that allow a variety of output surfaces including predictions, prediction standard errors, probability and quantile. The flexibility of kriging can require a lot of decision-making. Kriging assumes the data come from a stationary stochastic process, and some methods assume normally-distributed data.

According to previous researches, the research implemented the spatial expression of population distribution in the block unit. In the research, population density data in 90 city streets in Wuhan were collected. According to the street position, they were changed into dot files to establish a spatial distribution database of population density. The spatial data were conducted explosive analysis. On the one hand, whether data conform to normal distribution can be verified. In theory, kriging interpolation requires that data should abide by normal distribution. On the other hand, it is convenient for selecting more suitable method and parameters in Kriging Interpolation process. In this way, subsequent population density distribution prediction will be matched with objective situation. The results also have the large reliability. In the research, Kriging Interpolation is applied to predict population density distribution in Wuhan.

4.3 Data Source and Processing

Data in the research were classified into three major categories: population distribution data, transportation network data and lake located data. Population distribution data came from Wuhan demographic census in 2010. There were a total of 90 streets in the central urban area. Population density of these 90 streets was located in the Sub-district Administration to generate population density distribution scatter diagram in Wuhan central urban area. The transportation network data were vectorized based on Wuhan road map(2015). Lake located data were vectorized according to Wuhan lake distribution (2013), as shown in Fig. 1.

5. Results

5.1 Population Density in the Central urban area

In the research, population density distribution data in Wuhan central urban area were analyzed through explosive spatial data of geostatistical analyst in Arcgis 10.2, whichwas normally distributed after logarithmic transformation. With the cross validation of predicted errors, the ordinary kriging interpolation and data transformation type log are confirmed. The tendency removal order is second order. The geostatistical analyst of ArcGis10.2 is used to carry out kriging interpolation. The interpolation results are derived as the raster data format with the pixel of 100.

After population density interpolation grids are transformed into dot files to draw a conclusion that the permanent resident population in Wuhan in 2010 was 5.8958 million with interpolation prediction. According to Wuhan statistical yearbook(2011), the population in Wuhan central urban area was 5.8618 million in the end of 2010. It shows that estimation of Wuhan population density was basically consistent with physical/actual situation. The interpolation results of Wuhan population density with the kriging interpolation are reliable.

5.2 Lake Accessibility

The service area analysis in network analyst of ArcGis10.2 was used to obtain the Wuhan urban lake accessibility in driving situations, as shown in Figure 3 and Table 2.The network dataset was constructed with traffic network data. Facilities was closest to the lake of the intersection of road and lakes. The area within 5min reachable lakes in Wuhan central urban area is 452.301km^2. The service population is 4.35 million. The area within 15 min reachable lakes is 918.42km^2. The service population is 5.8869 million, accounting for 99.85% of total population in the central urban area. The area within 15min reachable lakes in Wuhan central urban area by car is up to 96.15% and population in the service area is up to 99.85%. Within 60min, any lake can be arrived from Wuhan central urban area. The area that can be arrived within 5 min by car basically can be arrived by walking and this is the daily recreational activity range. The area that can be arrived within 15 min by car is the recreational activity range for weekends, holidays and festivals.

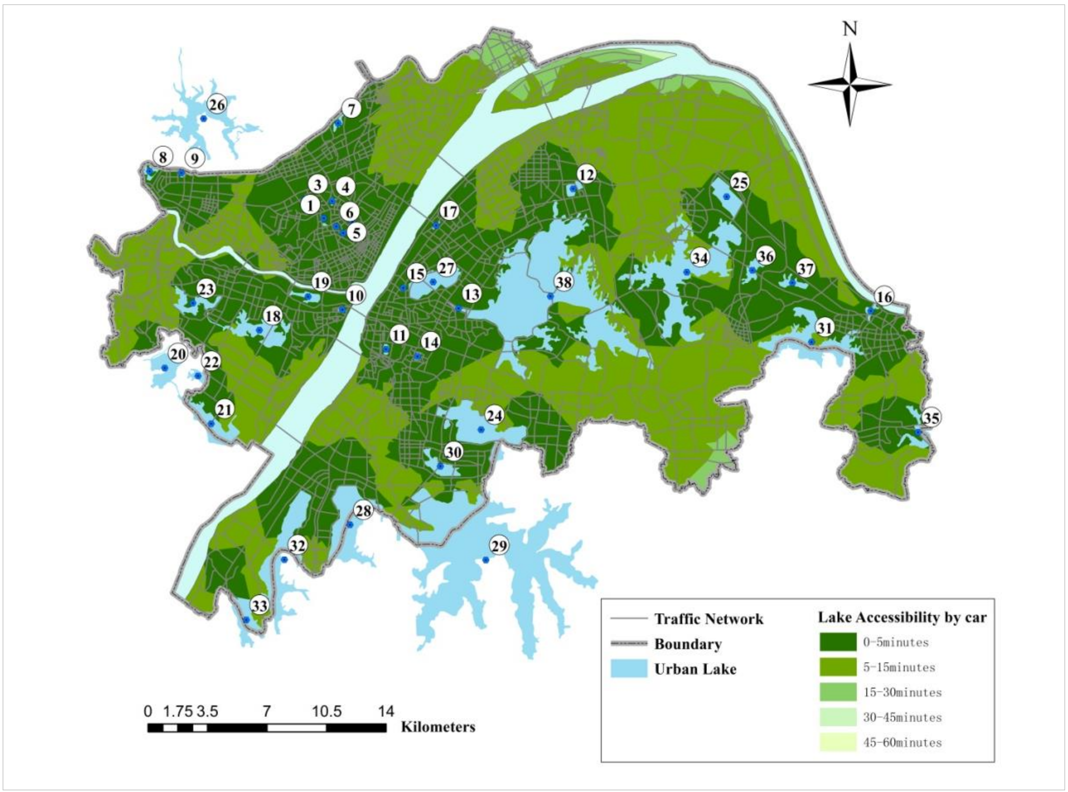

Fig.3 The Accessibility of Lakes in Wuhan Central Urban Area by Car

Thus it can be observed that Wuhan lake accessibility is good. There were the large service area and wide coverage of service population, but accessibility is the quantification expression of human activities. Lake ecology and accessibility degree are complementary. The good accessibility means the larger recreational pressure faced by urban lakes.

Tab.2 The statistics results of accessibility by car

Time	Area(km^2)	Percentage	Served Population (ten thousands)	Percentage
0-5min	452.301	47.35%	434.9098	73.7669%
5-15min	466.116	48.80%	153.7827	26.0837%
15-30min	29.1289	3.05%	0.8419	0.1428%
30-45min	4.9549	0.52%	0.0356	0.0060%
45-60min	0.7602	0.08%	0.0031	0.0005%
Total	953.261	99.80%	589.5731	100.0000%

5.3 Measurement of Recreational Pressures in Urban Lake

In order to know about the recreational pressures faced by 38 urban lakes in Wuhan and to do classification management and utilization in urban lakes, recreational service area of 38 urban lakes and population in the area are analyzed and recorded. Meanwhile, according to formula (3) of travel rate, the travel rate of different driving time is calculated, so as to calculate recreational pressure index of 38 urban lakes. The interruption value of driving time is set up as 5, 15, 30, 45, 60, 75 and 90min. the smaller driving time step is, the precision of travel rate will be. All lakes can be arrived within 90min. According to recreational pressure index, lakes are divided into 5 categories, including the highest recreational pressures, the higher recreational pressures, the medium recreational pressures, the lower recreational pressures, and the lowest recreational pressures, as shown in Figure 4.

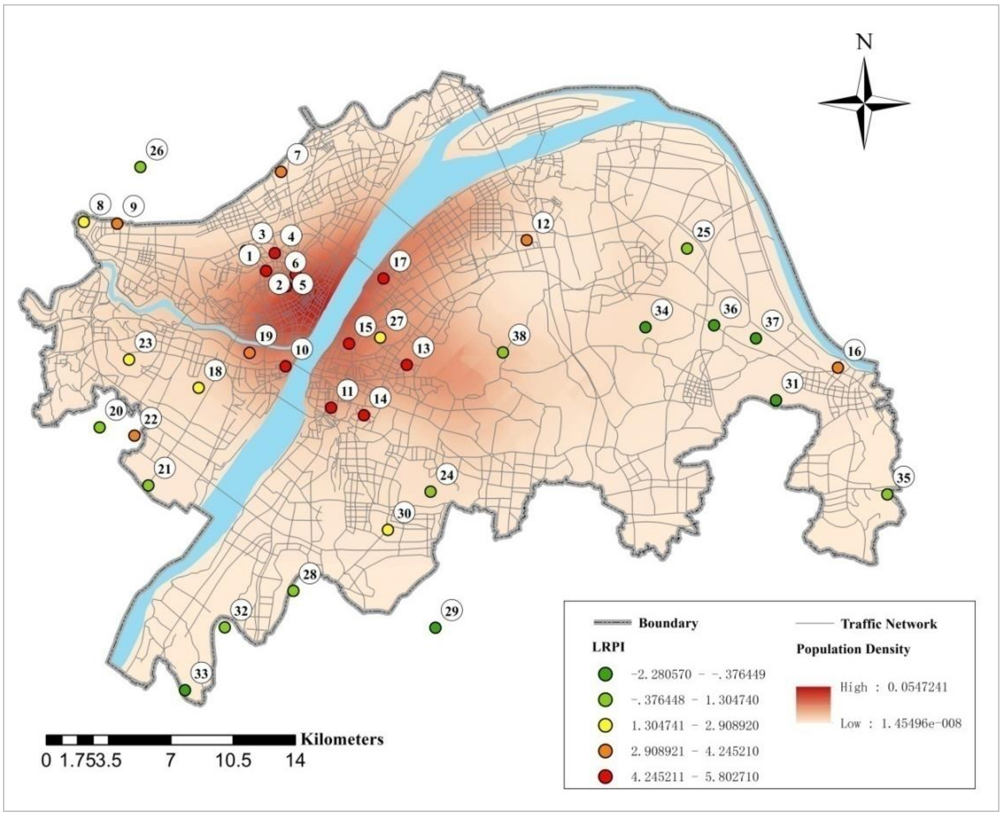

Fig.4 The classification of Wuhan urban lake recreational pressure index(LRPI)

Urban lakes are sorted according to high-low recreational pressure index. The highest recreational pressure lakes included Neisha Lake, Xiaonanhu Lake, Jiqidangzi, Huanzi Lake Simei Lake, Simei Pond, Lianhua Lake, Shuiguo Lake, Shai Lake, Lingjiao Lake, Houxiang Lake, and Northwest Lake, for a total of 11 lakes with the recreational pressure index range of 4.6336-5.8027; the larger recreational pressure lakes included Ziyang Lake and Tazi Lake, for a total of 2 lakes with the recreational pressure index range of 3.3270-4.2452; the medium recreational pressure lakes included Yue Lake, Yangchun Lake, Zhuye Lake, Wujia Lake, Beitaizi Lake, Sha Lake and Zhangbi Lake, for a total of 7 lakes with the recreational pressure index range of 1.6425-2.9089. The lower recreational pressure lakes included Moshui Lake, Yezhi Lake, Longyang Lake, Sanjiao Lake, QingshanNorth Lake, Nantaizi Lake and South Lake, for a total of 7 lakes with the recreational pressure index range of -0.0322-1.3047. The lowest recreational pressure lakes included Chedun Lake, Huangjia Lake, Jinyin Lake, Qingling Lake, Ye Lake, Zhuzi Lake, Qingtan Lake, East Lake, Yanxi Lake, Yandong Lake and Tangxun Lake, for a total of 11 lakes with the recreational pressure index range of -2.2806--0.3764.

According to the above analysis , the lakes that were located in the areas with the higher population density, such as Qiaokou District, Jiang’an District, Jianghan District and Wuchang District, etc., have the higher recreational pressures, but the lakes that were located in the areas with the lower population density, such as Hongshan District, Hanyang District and Qingshan District have the lower recreational pressures. Besides population density in areas, lake recreational pressure was also greatly influenced by transport. Population dense region is the old city with convenient traffic routes. The population sparse region also has the sparse traffic network. As a result, the poor traffic accessibility may bring about small amount of tourism flow and created a favorable for lake ecological environment conservation.

6. Conclusions

6.1 Contribution to Literature

This study contributes to the literature in several ways. First, the research focused on the recreational pressure of urban lake while the existing literatures kept a watchful eye on urban lake recreation activity or how to improve urban lake function. Second, the study offered a new and reasonable measurement model of urban lake recreational pressure. Moreover, in this paper, the research aimed at multiple urban lakes recreation pressures, the results provided a spatial distribution of recreational pressures which contributes to an understanding of urban lake recreation pressures and provides the basis of the governance. Last, the research chose typical case Wuhan, which possessed many lakes. In the process of urbanization, urban lakes faced higher pressure, how to release or management recreation stress is a problem to be solved urgently. Wuhan case is reference significance for other similar cities in the world.

6.2 Traffic Accessibility, Population Density Were Positively Correlated to Lake Recreational Pressure

The good accessibility in Wuhan urban lakes means bringing higher recreational pressure. Traffic accessibility and population density are one of characteristic indexes in urbanization. According to Environmental Kuznets Curve (EKC)(Ping et al., 2014), the higher urbanization degree is, the higher recreational pressures in lakes will be. When exceeding bearing capacity of lakes and making recreationists have negative feelings, such as being crowd, travel flow may flow to the peripheral lakes with the lower recreational pressures, showing the three-level diffusion phenomenon of the core area—edge area—suburban(Fan, 2009).

Convenient traffic has adverse impact on lake ecology and is one of the main driving factors causing lake fragility. Besides direct occupancy of ecological landscape, the land utilization may be driven by improving land accessibility in the area, so as to impact ecological safety pattern of landscapes. The latter has the larger and wider influence range and degree than the former (Seim, 2002). Traffic is an important condition to enter into lake recreation areas and also is a part to constitute comprehensive attraction of lakes. Under the circumstance of homogenous lake resources, lakes with the good traffic are the first choice of visitors, thus ecological protection and traffic improvement in lakes form the contradiction in promoting regional development and fall into the dilemma. It is necessary to pay attention to visitor management and flow guidance, while improving recreational functions in lakes by more complete traffic conditions.

Main beneficiaries of lake recreational function were surrounding residents. In the lakes with the higher population density, such as Qiaokou District, Hanjiang District and Jiang’an District, the recreational pressures are obviously higher than peripheral lakes. High-density population is concentrated on the surrounding areas, forming recreational pressure lakes for aggregation effects. The urbanization degree of peripheral areas is lower. These areas have the lower population density. This is one of reasons for the lower recreational pressures in peripheral lakes. However, with the development of urbanization process, population in high-density areas approaches to saturation. Real estate development guides an increasing number of people to peripheral areas to drive the recreational development in peripheral lakes. It can be observed from Figure 4 that the recreational pressures in high population density areas are the higher. The peripheral lakes with the lower population density will become the main recreational areas in the future. The land utilization costs in edge zones are lower to offer possibility to establish the large-scale lake parks.

7. Applications

LRPI clearly offer important information to recreation governance of Wuhan urban lake system. In the LRPIs classification map， Wuhan lakes are divided into five grades, the lakes with higher LRPI should be pay more attention, including allocation the resources of protect and management and optimization of key regional transportation. Different grade of lakes are different in management system and resource configuration. The LRPI can provide the guidance to establish different lake management administrations with resource allocation and financial support.

According to the LRPIs, there were 13 lakes with high LRPI, which located in center urban district, including whole districts of Qiaokou, Jianghan, Jiangan and partial region of Wuchang, Hongshan and Hanyang. Firstly, the traffic to these areas should be optimized, not only the carriageway, but also walk way to lakes. Secondly, administrative department should increase the recreation infrastructure of these lakes. Due to the dense population distribution, the community can deprive from the lake parks. As to the 18 lakes with low LRPI, involved most region of Dongxihu, Qingshan, Jiangxia and partial Hanyang. It’s also necessary to improve the accessibility, adding more public transport lines to meet the disadvantaged groups, relief lake recreational pressure in the heart of the city.

LRP measurement is based on lake accessibility. The spatial accessibility is one of methods to evaluate reasonable layout of public facilities(Higgs et al., 2015; Morrill, 2015). As shown in Fig.3, though the lake accessibility in Wuhan central urban area is good, there are some areas where can’t arrive in lake creation areas within 30 min by car. These areas are equipped with the suitable recreational facilities to embody fairness of social public resource configuration.

In addition, as one of the public resource, lakes should be optimized spatial configuration to improve public service ability. Due to natural resources, lakes are restricted by natural geographical location and can’t realize spatial layout optimization of lake recreation areas. However, according to the degree of lake recreational pressures, lakes with the higher recreational pressures are equipped with green space, small-scale parks and recreational facilities, etc., to relieve recreational pressures. This should combine with surrounding configuration of lakes to optimize configuration. Measurement of lake recreational pressures provides an idea for optimization of recreational spatial structure and plays a role on relieving lake pressure and promotion ecological protection in lakes.

8. Limitations

In the research, the drawback that straight line was applied to measure the distance between fountain and lakes was overcome in research methods. The actual travel distance was used describe the spatial relation between fountain and lakes. Based on street scale, the common kriging interpolation was used to highly fit with spatial distribution of population density and to improve travel rate of Koch(1978), as well as to elaborate the distance-decay regularity between travel rate and actual driving distance. Now it is the relatively ideal and optimal research method, but the research also has some shortcomings, hoping to be perfected in the future.

First of all, in calculation of travel rate, it only considered the actual travel distance, but travel distance in reality is not the only preference of visitors. Lake attraction also will result in changes of travel rate. It will be more reasonable by combining with lake quality. For example, Ode et al(2006) combined with the forest attraction to measure forest recreational pressures(Ode and Fry, 2006), but forest property has the essential difference with lakes. Thus, it might be inappropriate to select quality factor in the research. The lake recreational pressure index constructed in the research was only applied to Wuhan urban lakes, but there was no other case comparison in other urban applications in landscape orientation. Due to data limit, it couldn't live up to time node comparison in longitudinal orientation. As a result, measurement of lake recreational pressures is limited, hoping to be perfected and promoted in the future. At last, the research was based on accessibility of lake landscapes to measure recreational demands in urban population, but didn't involve in recreational demands of urban residents in different subdivided market, time-space factors impacting lake accessibility, economic and social factors. The subsequent research may measure lake recreational pressures based on traffic modes arriving in lakes and population needs, such as children, the aged, white-collar workers, and low-income groups. Reyes et al(2014) studied walking accessibility of Canadian children in the City Park(Reyes et al., 2014).

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