A STUDY ON SURFACE WATER RESOURCES IN CHAOBAIHE BASIN OF BEIJING BASED ON BEIJING-1 MICROSATEELITE DATA

H. Z. Zhou[a] *, Y. B. Chi[a, b], Z. Y. Wang[a], Q. Wu[a], Q. Ran[a], C. J. Wei[b]

[a]Beijing Landview Mapping Information Technology Co., Ltd, Beijing 100096 -zhouhz@21stc.com.cn
[b]Institute of Remote Sensing Applications, Chinese Academy of Sciences, Beijing

ABSTRACT:

It has become a hotspot to detect regional water resources using the technology of remote sensing. Beijing-1 microsatellite has the advantages of wide swath, high resolution and short revisit periods, and so it is excellent at dynamic detection of regional water resources. Chaobaihe basin is one of most important water source areas of Beijing. In this paper, Beijing-1 microsatellite fused images were mainly used to make a study of surface water resources in Chaobaihe Basin of Beijing. Firstly, the surface water information extracting method was studied and finally Object-Oriented classification was chosen as the main method; Secondly, the distributions of surface water both in rainless seasons and rainfall seasons of 2007 was obtained in this basin. Thirdly, with TM images of 1999 and 2001 added, its temporal and spatial distribution variations were analysed. Finally, driving forces for the variations of surface water in the basin. The results showed that: (1) It is feasible that using Beijing-1 Micro-Satellite images to study surface water in Chaobaihe Basin of Beijing. (2) The variation of total surface water area between in the rainless seasons and in the rainfall seasons is not big, but the surface water areas of rivers and ponds are smaller in rainless seasons. (3) The annual change of surface water area of the basin takes on decreasing trend from 1999 to 2007. (4) The driving forces are mainly decreasing of precipitation, increasing of annual average temperature, decreasing of vegetation cover in some regions and so on.

1. INTRODUCTION

Beijing is one of the capitals in the world, which lacks water resources. The water resources quantity of one person in the city is one thirtieth of that in the world (JING Hong-wei, 2006). For the increasing of population and the development of economy, the demands of water resources have exceeded the carrying capacity of regional water resources. Chaobaihe River is one of the two biggest rivers crossing Beijing, and it is the most important surface and ground water source area (LI De-xian, 2005). As a result, it has great significance to undertake research of water resources in Chaobaihe Basin.

For years, water resources survey of China has mainly depended on the point-based sampling data. However, remote sensing has the advantages such as large scale, quick-revisit period, high precision data, which brought hope for the study of regional water resources. Beijing-1 microsatellite has wide swath, high resolution and short revisit periods (Surry Satellite Technology, 2004), whose characteristics are suitable for the study of change detection of water resources.

In this paper, the important region of water resources in Beijing——Chaobaihe Basin of Beijing has been focus on and the multi-spectral and panchromatic images of Beijing-1 microsatellite are mainly used to undertake a study of surface water resources. Firstly, we established surface water interpretation marks for Beijing-1 microsatellite. Secondly, we undertook the research of extracting methods of surface water information. Thirdly, we had an investigation of surface water and analyzed the temporal and spatial distribution of surface water. Finally, we addressed some reasons for the variations of surface water in this basin.

2. STUDY AREA

Chaobaihe River belongs to Haihe River water system, and it is one of four biggest rivers of Haihe River northern water system. Chaobaihe River comes from the northern mountain areas of Yanshan Mountain, crosses Hebei Province, Beijing City and Tianjin City (LI De-xian, 2005). Along the way, it absorbs Huaihe River and Yanqi River and flow out of Beijing at Dashawu (ZHAO Qiang et al, 2005). In the churchyard of Beijing, Chaobai River crosses Huairou County, Miyun County, Yanqing County, and eastern Shunyi County and Tongzhou County. Its basin area in Beijing is 5688 square kilometers, among which the mountain area is 4605 square kilometers and the plain area is 1083 square kilometers.

The elevation in the upper stream of Chaobaihe Basin is more than 1500 meters while that in the downstream is less than 10 meters (See Figure 1). The stratum lithology in the mountain areas of Chaobaihe River is mainly volcano sedimentary series coming from the Jurassic and metamorphic rocks from Miyun Cluster. Further, there are sedimentary rocks from the Great Wall and Jixian Cluster. In the plain areas, there are mainly alluvial loam soil and sandy loam soil from the quaternary. The river bed in the upper stream of Taipingzhuang in Huairou County makes up of gravel and erratic boulder while the river bed in the downstream is composed by fine sand. From Huairou County to Tongzhou County the groundwater is abundant (The management office of Chaobaihe River in Beijing, 2004).

In Chaobaihe Basin of Beijing, the annual mean temperature in plain areas is 11^0C to 12^0C while in mountain areas 2^0C to 11^0C. Its climate is warm temperate zone semi-arid and semi-humid monsoon climate and its annual average precipitation is 610

---

* Corresponding author.

739

millimetres. The differences of runoff between in rainless seasons and that in rainfall seasons are big. The annual water evapotranspiration is 1180 millimetres, the annual evapotranspiration on land is about 400 millimetres, the annual evapotranspiration in the hilly areas is about 450 millimetres and that in the plain areas is about 500 millimetres (The management office of Chaobaihe River in Beijing, 2004).
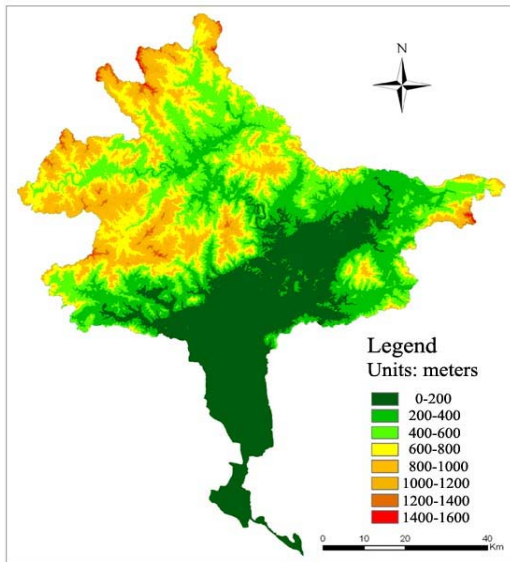

Figure 1. DEM of Chaobaihe Basin of Beijing

3. MATERIALS AND METHODS

3.1 Remote sensing data

In this paper, the multi-spectral and panchromatic images during January in 2007 and October in 2007 of Beijing-1 Micro-Satellite were used as the main data sources. Beijing-1 Micro-Satellite was launched on the October 27, 2005, whose altitude is 686 kilometers and whose orbit is sun-synchronous. The design parameters is showed in Table 1.

Sensors	Multi-spectral camera	Panchromatic camera
Spectral range	Green band: 520-600 nm	500-800nm
	Red band: 630-690 nm	
	Near – Infrared band: 760-900 nm	
Resolution	32 meter	4 meter
Swath	600kilometer	24kilometer
Revisit periods	3-5days	5-7days

Table 1. The design parameters of Beijing-1 microsatellite

3.2 Data processing

Firstly, the multi-spectral images and panchromatic images were radio-metrically and geo-metrically corrected. The reference multi-spectral images are ortho-rectifid Landsat TM

data in 2000. To undertake correction works, a scene of the image was defined as one unit, Second Order Polynomial was selected as the correcting model and Cubic Convolution was selected as the resampling method. The correction accuracy is controlled in one pixel in the plain areas and two to three pixels in the mountain areas. The reference panchromatic data is the aerial photos of Beijing in 2005. The corrected panchromatic images were all transferred to Transverse Mercator projection and the standard meridian was 117^{0}C. Secondly, the multi-spectral imaged were resized according to the boundary vector of Chaobaihe Basin. Thirdly, mosaicking panchromatic images were obtained. Finally, the Brovey Transferring Method was used to produce fused images.

3.3 Surface water information extraction methods

For the fraction of the mountains and the plains in the study areas is equivalent and the differences of natural characteristics of both areas are bigger, in the process of surface water information extraction, the phenomenon of "same object with different spectrums" and "same spectrums with different objects" widely exists. In the rainless season such as winter and spring, not only the surface water area is small but also the distribution is scattered and it is always frozen. In the rainfall season such as summer and autumn, not only the surface water area is big but also its distribution is continuous. The spectrum differences of the same objects in different seasons and areas are big. Therefore, the fused images of Beijing are separated into the images of mountain areas in rainless season, that of mountain areas in rainfall season, the image of plain areas in rainless season and the image of plain areas in rainfall season.

Several extraction methods such as threshold method, unsupervised classification, NDVI method and object-oriented method were used to extract surface water information and make analysis of comparison. Considering the factors such as the influence of building shadows and mountains' shadows on surface water extraction, the accuracy of extracted surface water boundary and the continuity of extracted results and so on, finally object-oriented classification was selected as the main method and other methods as ancillary ones, See Table 2.

Different types of areas	Finally chosen methods
Plains in rainless seasons	Object-oriented classifications
Plains in rainfall seasons	Unsupervised classification or Objected-oriented classification
Mountains in rainless seasons	Objected-oriented classification
Mountains in rainfall seasons	NDVI method with Objected-oriented classification

Table 2. The List of Extraction methods

Figure 2 was the entire flow chart of technology in this study, besides using Beijing-1 microsatellite fused images, we also take use of water stream data and DEM data of Beijing as references.
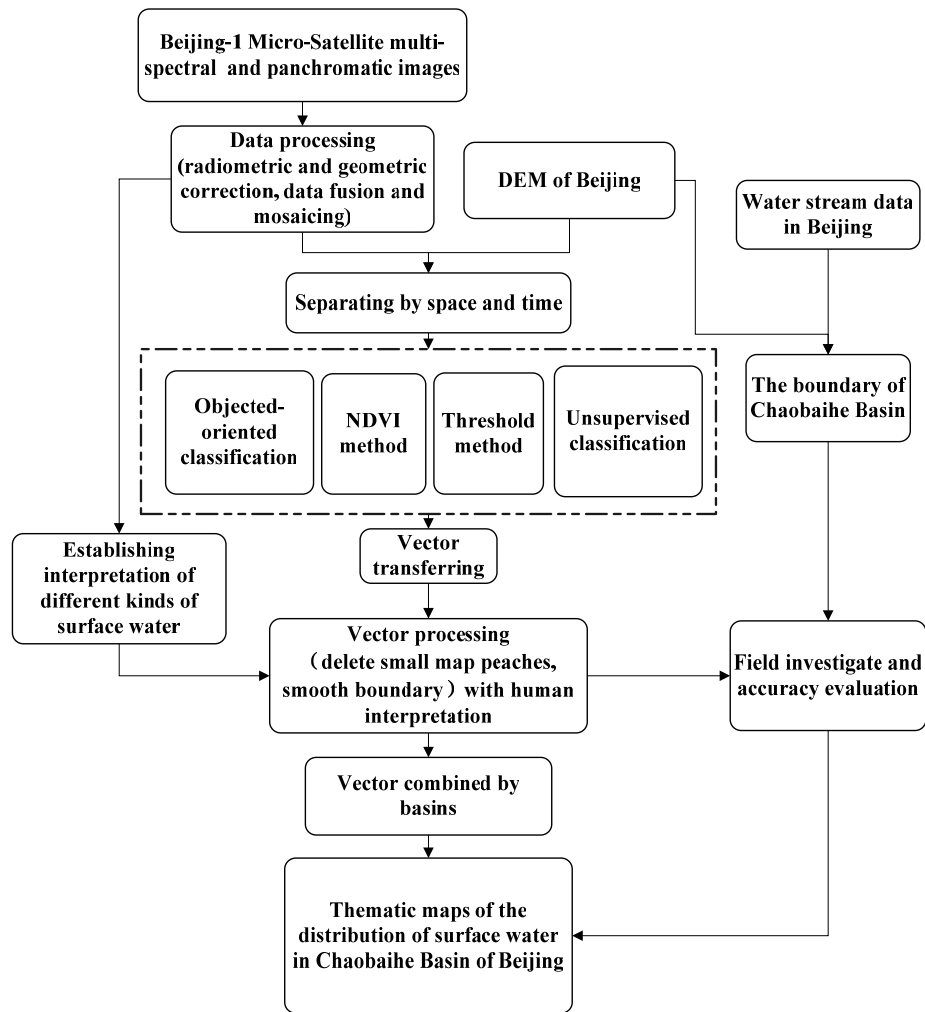
Figure 2. The entire flow chart of technology in this study

4. RESULTS

4.1 Surface water variations in Chaobaihe Basin of Beijing in 2007

Figure 4 showed the distribution characteristics of surface water both in rainless season and rainfall season of 2007 in Chaobaihe Basin of Beijing, in which, the water in deep blue represents reservoirs, the water in light blue represents rivers and the water in deep green represents ponds.

Seen from the figure, the main branches of Chaobaihe River are Chaohe River and Baihe River. Baihe River and its branches mainly locate in the northwestern mountain areas of the basin whose controlling area and water quantity are relatively bigger. The phenomenon of zero flow is hardly seen. Chaohe River mainly locates in northeastern mountain areas of the basin whose controlling area and water quantity are relatively smaller and there are serious phenomenons of zero flow among the branches of Chaohe River.

There are several bigger reservoirs such as Miyun Reservoir, Baihebu Reservoir, Yunzhou Reservoir, Huairou Reservoir and so on mainly locating in the middle-stream and upper-stream of the basin. In the down-stream, there are many ponds mainly

distributing along the rivers. The reason for that distribution is that the groundwater table along rivers is higher than other places where it is good to make use of groundwater. The ponds are mainly used for fishing culture. Compared two distribution figures in different temporal periods, it is indicated that the distributions of Baihe River with its branches and Chaohe River with its branches in rainless season are similar to those in rainfall season. However, the surface area of Huaihe River with its branches in rainfall season is bigger than that in rainless season.

After calculating, we can conclude that in the rainless season of 2007, the surface water area of Chaobaihe Basin in Beijing is about 12120 ha., which takes account of 2.19% of the total basin area. Among the area of all types of surface water, the surface water area of reservoirs is about 9847 ha., the area of rivers is about 1741 ha., and the area of ponds is about 532 ha. In the rainfall season of 2007, the total surface water area of Chabaihe Basin is about 12478 ha., which is 2.26% of the total basin area. Among the area of all types of surface water, the surface water area of reservoirs, the area of rivers and the area of ponds are respectively 9582ha., 2064ha., and 832ha.. Compared to the results of rainless season, the surface water area of rivers in rainfall season increases by 323ha., the area of

reservoirs decreases by 265ha., and the area of ponds increases by 300 ha..

Seen from the variation in the year, the change of total surface water area in the basin is not big. However, seen from every type of surface water, the change is becoming much bigger. The rivers surface water area increases in the rainfall season, mainly due to the increasing of precipitation in that period. The reservoirs surface water area decreases in the rainfall season, whose reason is mainly human water transfer among reservoirs in different basins. The ponds surface water area increases for some reasons. The ponds' water comes from groundwater and also the precipitation can increase the amount of ponds water in some extent.
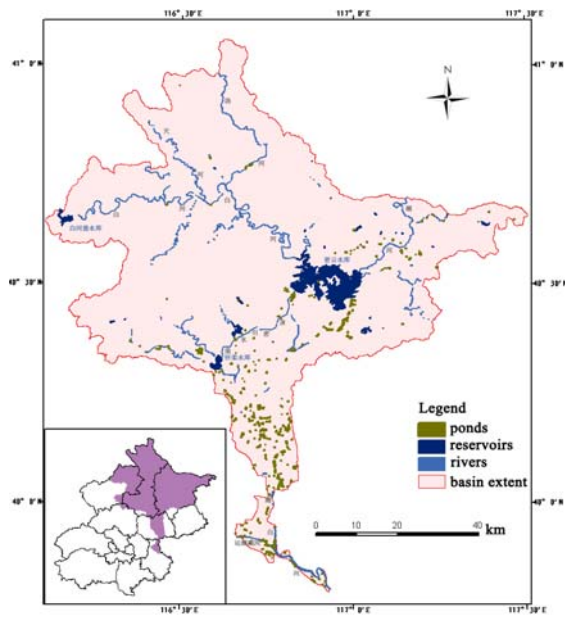
A.
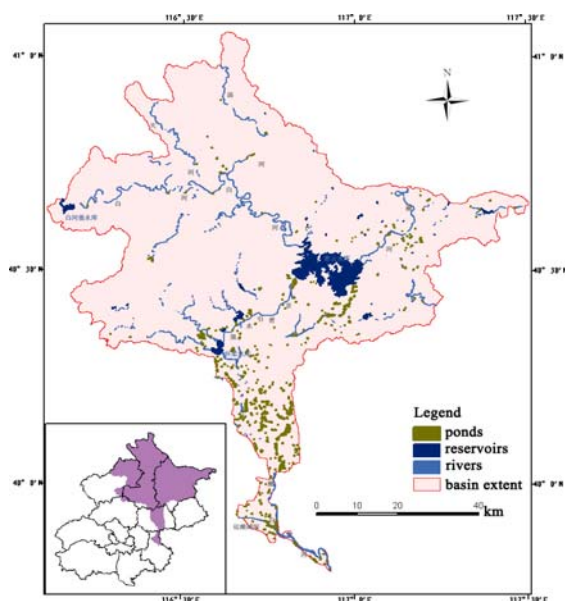
B.

Figure 4. The diagraph of surface water distribution in Chaobaihe Basin of Beijing (A. in the rainless seasons of 2007; B. in the rainfall seasons of 2007)

4.2 The inter-annual variations of Surface water in Chaobaihe Basin

Using Landsat TM images of the summer of 1999 and 2001 in Chaobaihe Basin of Beijing, we extracted surface water information and estimated the results. The surface water area in 1999 is 19430 ha. and the area in 2001 is 13044 ha. Because the surface information extraction of TM images mainly compose of rivers surface water and reservoirs surface water while that of Beijing-1 Micro-Satellite not only includes rivers and reservoirs but also includes ponds. Therefore, in order to compare in the same rules, the total surface area of 2007 minus the ponds surface water area can be compared to that of 1999 and 2001. As a result, the surface water area of 2007 is 7784 ha., smaller than that of 1999 and 2001, that is to say, the surface water area in 2007 is respectively 40% smaller than the area in 1999 and 11% smaller than the area in 2001. Accordingly, the fraction of surface water to the total basin area is from 3.42 percent of 1999 and 2.29 percent of 2001 to 2.05 percent of 2007. The change curve of surface water area of Chaobaihe Basin in Beijing from 1999 to 2007 is showed in figure 5.
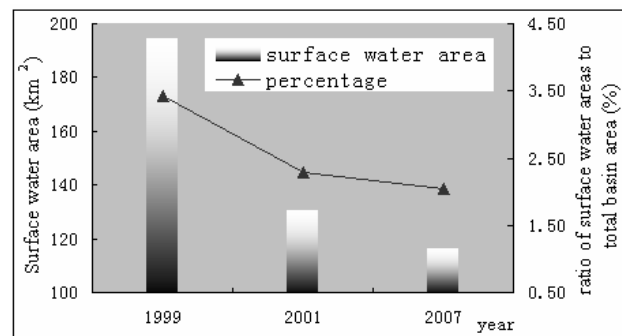

Figure 5. The inter-annual change of surface water area in Chaobaihe Basin of Beijing

4.3 Field investigate and accuracy calibration

According to the geographical characteristics, acquisition time and imaging areas of the satellite images, sixteen in-situ sample points were chosen. These sampling areas include one pond, three reservoirs and rivers with twelve sampling points. Among them, there was one misjudged point, the accuracy therefore gets up to 92 percent. The reason for that is that the river with small width is hard to interpret and trees or shrubs or terrain along each side of them shadow surface water.

5. ANALYSIS OF DRIVING FORCES

Seen from the results above, the variation of the surface water area of Chaobaihe Basin in Beijing in 2007 is not big, however its distribution is fairly uneven. The annual change of the surface water takes decreasing trend from 1999 to 2007 especially the phenomenon of zero flow of rivers. In this paper, the reasons for the change were addressed from some factors like precipitation variation, temperature change, vegetation cover change and human activities

5.1 Precipitation variation

The decreasing of precipitation can lead to the increase of evaporation and the decrease of runoff. Figure 6 showed the

dynamic change of the inter-annual precipitation of the basin from the year of 1970 to the year of 2007. It showed that the inter-annual change of precipitation in Chaobaihe Basin of Beijing is severe, the difference of the precipitation quantity between in the rainless year and in the rainfall year is about 450 millimetres which leads to flood and arid. Seen from the change trend, the annual precipitation takes on decreasing trend.
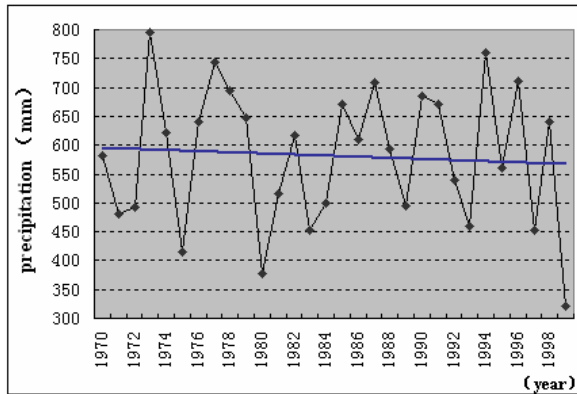

Figure 6. Precipitation inter-annual change in Chaobaihe Basin of Beijing

5.2 Temperature change

In the recent sixty years, the yearly frequency of severe hot weather has been up to 80% (XIE Zhuang et al, 1999), the multiyear annual mean temperature is 11.8^0C. The growth rate of the annual mean temperature of Beijing has been about 0.0115^0C to 0.02^0C per year since the year of 1940. If the temperature increases 1^0C, the evaportransperation will increase by 10% to 15%. About 60% to 70% of precipitation of Beijing is evaporated. The average water evaportransperation each year is 1800 to 2000 millimetres while the land evaportransperation is about 450 to 500 millimetres in Beijing (Chen Peijun, 1999).

So, the increasing of temperature also picks up the evaporation and meanwhile speeds zero flow of rivers.
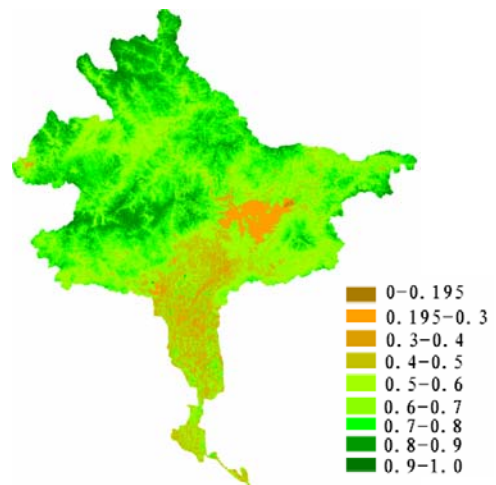
5.3 Vegetation cover variation

Vegetation cover " f " is the ratio of the vertical projection area of the canopy to the total soil area. The calculation is as follows:

$$f = (NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min}) \quad (1)$$

where, NDVI=vegetation index, $NDVI_{min}$ = Maximum NDVI in study area, $NDVI_{max}$ = Minimum NDVI in study area. Using Landsat TM images on July 1 of 1999 and Beijing-1 Micro-Satellite multi-spectral image on June 26 2007 to calculate the vegetation cover of the basin, the results are showed in Figure 7. and Figure 8.

From the year of 1999 to 2007, the vegetation cover variation of Chaobaihe Basin is different in spatial distribution and structure. Seen from the spatial distribution, in the middle of the basin, in the river valleys of upper reaches of the basin and at the north and northeast of Miyun Reservoir the vegetation cover decreased while at the west and northwest of Miyun Reservoir the vegetation cover increased. Seen from the structure variation, the fraction of areas where the vegetation cover is

between 60 percents and 80 percents decreased from 63.8% to 58.21%. While that of areas where the vegetation cover is between 80 percents and 100 percents increased from 16.68% to 21.81%.
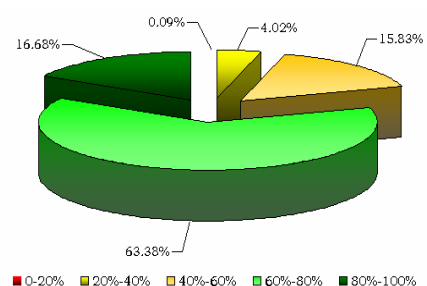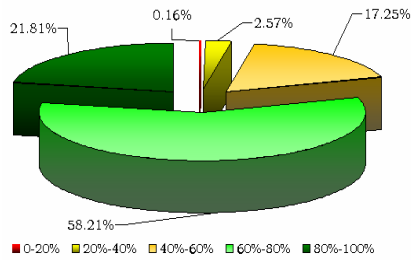

A.
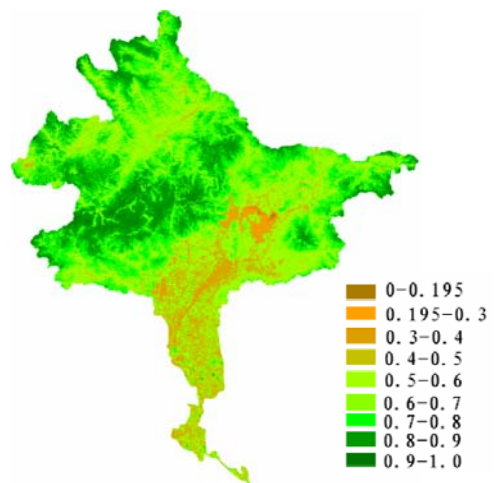
B.

Figure 7. The vegetation cover in Chaobaihe Basin of Beijing (A. vegetation cover in 1999; B. vegetation cover in 2007)

A.

21.81%   0.16%   2.57%   17.25%

58.21%

■ 0-20% ■ 20%-40% ■ 40%-60% ■ 60%-80% ■ 80%-100%

B.

Figure 8. The structure chart of vegetation cover of Chaobaihe Basin of Beijing (A. in 1999; B. in 2007)

The severe vegetation degeneration leads to the decreasing of vegetation cover. As a result, the intercepting sewage flow of surface water has decreased, the infiltration ability of soil moisture has strengthened and meanwhile the surface evaporation has speeded. Then it speeded zero flow of rivers.

5.4 Human activities

With the increasing of population and the development of economy, the influence of human activities on the surface water is becoming much more obvious.

Firstly, there have been many types of intercepting dams to intercept basic flow of rivers, which speed up the rivers' dryness in the down-stream areas.

Secondly, there are many tap water well groups to mine groundwater along rivers to satisfy water-supply demand. As a result, the groundwater table along rivers has decreased severely which causes downward infiltration of surface water. The fact had affected the water resources balance in Chaobaihe Basin and speeded up of zero flow. For example, the groundwater before the mountains of Huairou County has always an important supply source for the runoff of Chaobaihe River, However, there are many wells along rivers which results in no groundwater supply (Li De-xian, 2006).

Besides, there has been the phenomenon of a lot of mining sand stones along river channels so that the river channels were severely damaged. The surface water began to infiltrate into ground and finally that caused speeding up of rivers' dryness.

6. CONCLUSIONS

This research focused on surface water information extraction method of different temporal Beijig-1 Micro-Satellite fused images in Chaobaihe Basin, then the analysis of the surface water temporal and spatial distribution laws in Chaobaihe Basin, and finally the driving force analysis. The results showed:

(1) It is feasible to use object-oriented classification as main method and other information extraction methods as ancillary methods extract different temporal and spatial surface water in

Chaobaihe Basin based on Beijing-1 Micro-Satellite fused images.

(2) The spatial distribution of surface water in the basin is not even. The reservoirs mainly locate in the middle-stream and upper-stream of the basin. The ponds are mainly distributed in the middle-stream and down-stream of the basin along rivers, where there are plain areas. The rivers locate all over the basin, but the phenomenon of zero flow is often.

(3) Seen from the variation in 2007 in Chaobaihe Basin, the total surface water area in rainless season is about 12120 ha., of which the surface water area fractions of rivers, reservoirs and ponds are respectively 14.4%, 81.2% and 4.4%; In rainfall season, the total surface water area is about 12478 ha., compared to that in rainless season, the surface water area of rivers increased by 323 ha., the area of reservoirs decreased by 265ha., and the area of ponds increased by 300 ha..

(4) Seen from the annual change of the basin, the surface water area takes on decreasing trend from 1999 to 2007. The ratio of surface water area to total basin area is decreasing from 3.42% in 1999 to 2.29% in 2001 and to 2.05% in 2007.

(5) The reasons for rivers' dryness in the basin are the decreasing of precipitation, increasing of annual mean temperature, decreasing of vegetation cover in some regions, interception of river channels and a lot of mining sad stones in river channels and so on.

REFERENCES

JING Hong-wei, et al. 2006. The Main Problem and Control Methods for the Surface Water in Beijing. Environmental Monitoring in China, 22(6), pp. 81-85.

LI De-xian, 2005. Review and reflection over the sustainable development of Chaobaihe River Area. Beijing Water Resources, (3), pp. 37-40.

Surry Satellite Technology Limited, 2004. Detailed Design Description for BLMIT Enhanced Earth Observation Microsatellite, Version 8.

ZHAO Qiang et al. 2005. A Study on the Vegetation Cover Change in Chaobaihe Riverbasin based on Landsat TM Images. Information of Remote Sensing, (3), pp. 21-23.

The management office of Chaobaihe River in Beijing, 2004. Flood and disasters of Chaobaihe River, Chapter One.

XIE Zhuang et al, 1999. Severe hot weather in North China and Beijing 1 Introduction of history and case analysis. Climate and environment research, 4(4), pp. 323-333.

Chen Peijun, Lu Xiaojian, Xie Zhenhua, 1999. Groundwater resources in Beijing related to the capital's development. Beijing Geology, (4), pp. 1-6.