The influence of LUCC on water demand in the north slope of Tianshan Mountain

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Abstract: This paper analyzes the spatial distribution and change of domestic water in the economic belt of the northern slope of Tianshan Mountains, understands the influence of LUCC process on domestic water, and provides a scientific basis for sustainable utilization and management of domestic water in arid areas. In this paper, the conventional linear fitting method is used to analyze the temporal and spatial change trend of domestic water use and the impact of land use change on it in 1989-2017 in the northern slope of Tianshan economic belt. The results show that from 1990 to 2018, the area of urban and rural industrial and mining residential areas increased by 1734km², the population increased by 158.58 × 10⁴, the total domestic water consumption increased from 125 × 10⁶m³ in 1989 to 398 × 10⁶m³ in 2017, and the per capita domestic water consumption also increased rapidly, especially in urban areas. The spatial difference between per capita domestic water consumption and total domestic water consumption in the whole year is obvious. It can be seen that the LUCC process has an important impact on the change of domestic water consumption.

1. Introduction

LUCC process is the main cause of the disturbance of the earth's natural system [1- 2]. Therefore, the research on LUCC has increased in different disciplines. The research on the dynamic change of climate shows that the disturbance of hydrological cycle and climate model will have a great impact on water supply. When human activities are involved, the impact will be more serious. It is more obvious when considering LUCC changes because it has an impact on water resources. Domestic water is largely dependent on the water supply from the ecosystem [3]. In the land use change, the change of construction land is the most important factor in the process of LUCC [4-5]. Therefore, the expansion of built-up area leads to the increase of population and the demand for domestic water consumption [6].

China's per capita water resources are very low, but they have considerable temporal and spatial variability [7-8]. In recent years, many scholars have made different research on different directions of water resources. Some scholars have analyzed the per capita water resource availability of major cities in the tropical Andes in the future, and indicated that the future population change may exceed the impact of climate change on water resource availability [9, 13]. Some scholars also calculated the change of domestic water demand by simulating the use of domestic water appliances [10], and...
discussed the supply and demand prospect of water resources by combining the population growth trend and climate change scenario with the use of (WEAP) hydrological model [11]. In the direction of combining remote sensing with water resources, some scholars use remote sensing data to evaluate the change of oasis scale and water resource utilization rate in combination with different water resource management practices [12]. In addition, according to the water demand and land use situation, aiming at the climate warming in the arid areas, the economic optimal operation change and adaptability of the water supply system are studied [13-15]. Some scholars also use multiple linear regression, principal component analysis, analytic hierarchy process and cluster analysis to analyze the spatial changes of influencing factors [16-18]. To sum up, most of the research on water demand are on the total amount of water resources, which focus on a year or a quarter, and more factors are considered as climate, population and economy. There are few research on long-term sequence of domestic water demand, especially in arid and semi-arid areas.

The economic belt on the northern slope of Tianshan Mountain is the key area of Xinjiang's economic, technological and social development, as well as an important hub of the silk road facing central Asia and Europe. With the rapid development of economy, resource development, urbanization and the rapid increase of population, the land use structure has changed in recent years, while the domestic water consumption has also increased sharply, resulting in limited water consumption. In view of the contradiction between the supply of water resources and the increasing demand for water, it is very important to further understand the law of the change of domestic water supply. The main purpose of this study is to explore the land use change and its impact on the spatial and temporal distribution of domestic water in the Northern Tianshan economic belt in recent 30 years. This paper uses a model considering the impact of land use change on domestic water demand, and simulates domestic water demand by considering land use change and per capita GDP. This study provides a reference for sustainable utilization and management of domestic water.

2. Study area
The Northern Slope Economic Belt of Tianshan is located in the hinterland of Eurasia, Northwest China, the southern margin of Jungar basin, and the middle part of the northern foot of Tianshan Mountain (Fig. 1). It covers an area of 9.53 × 10^4 square kilometers, accounting for 5.9% of the total area of Xinjiang. It is a dry continental climate. In this arid area, mountains and plains alternate. The Tianshan Mountains block the atmospheric circulation and form a huge Junggar Basin in the leeward direction[19]. This area is one of the 19 national key development areas, which concentrates 83% of the heavy industry and 62% of the light industry in Xinjiang. Its GDP over the years accounts for more than 40% of the whole Xinjiang. It has good basic conditions such as town, transportation and energy, which plays an important role in driving, radiating and demonstrating the economy of Xinjiang. However, the Northern Slope Economic Belt of Tianshan is a typical arid oasis economic zone, with only 11% of the total water resources in Xinjiang. The shortage of water resources and the fragility of ecological environment make the sustainable development ability of the whole regional economy relatively low.
3. Data and methodology

3.1. Data
The statistical data are from Xinjiang Statistical Yearbook (1989-2017), China Urban Statistical Yearbook (1989-2017) and China Urban Construction Statistical Yearbook (2000-2017) (cities in this study refer to urban areas). Land use data with resolution of 1km × 1km in 1990, 2000, 2010 and 2018 are from the resource and environment science data center of the Chinese Academy of Sciences (http://www.resdc.cn/lds.aspx).

3.2. Land use transfer matrix
Land use transfer matrix is a matrix to express the amount and direction of conversion among different classes in the study area, which can quantitatively reflect the conversion between land classes. Expression is

\[
P = \begin{bmatrix}
    p_{11} & \cdots & p_{1n} \\
    \vdots & \ddots & \vdots \\
    p_{n1} & \cdots & p_{nn}
\end{bmatrix}
\]

Where, \( p_{ij} \) is the land area converted from land type \( i \) to land type \( j \), and \( n \) is the number of land types.

3.3. Estimation of domestic water demand
Due to the different living standards in urban and rural areas, the living water demand is estimated by urban and rural areas respectively [19]. The calculation model of urban per capita living water demand is as follows:

\[
y_u = a \ln x - b
\]

Where, \( y_u \) refers to the per capita living water demand of the city (L / cap d), \( x \) is GDP per capita, \( a \) and \( b \) are coefficients.

The larger the city is, the larger the population and the larger the water consumption. In this study, K-means clustering method is used to divide the per capita domestic water consumption and per capita GDP of the study area into three categories in 2017. The results show that cities with per capita GDP less than 5 × 104 yuan belong to the first category, and their models are as follows:

\[
y_u = 32.64 \ln x - 136.25
\]
The GDP per capita between $5 \times 10^4$-$10 \times 10^4$ falls into the second category, which is estimated as follows:

$$y_u = 34.33 \ln x - 143.94$$  \hspace{1cm} (4)

Other cities with per capita GDP more than $10 \times 10^4$ yuan belong to the third category, and the specific calculation formula is as follows:

$$y_u = 40.56 \ln x - 230.75$$

According to field survey data and China water resources bulletin, rural domestic water consumption is considered to be one quarter of its geographical location closest to that of the city due to incomplete information on rural domestic water consumption. Therefore, the following model is adopted for rural per capita domestic water use:

$$y_r = 1/4 y_u$$  \hspace{1cm} (5)

Among them, $y_r$ is the per capita domestic water in rural areas (L / cap d).

The annual total amount of domestic water in urban and rural areas is allocated to the grid map of land use with the resolution of $1 \text{km} \times 1\text{km}$, and the formula is as follows:

$$Y_u = 365 y_u p_u / 1000$$  \hspace{1cm} (6)

$$Y_r = 365 y_r p_r / 1000$$  \hspace{1cm} (7)

$$Y = Y_u + Y_r$$  \hspace{1cm} (8)

3.4. Simulation accuracy test

In order to evaluate the model efficiency, the model efficiency (me) which reflects the deviation between the estimated value and the actual value is calculated as follows [20]

$$\text{ME} = 1 - \frac{\sum_{i=1}^{n} (\bar{Y}_{\text{mod},i} - \bar{Y}_{\text{stat},i})^2}{\sum_{i=1}^{n} (\bar{Y}_{\text{stat},i})^2}$$  \hspace{1cm} (9)

In the formula, $\bar{Y}_{\text{mod},i}$ refers to the total domestic water demand ($10^6$ m$^3$ / year) of city i in the simulated year; $\bar{Y}_{\text{stat},i}$ is the total domestic water consumption ($10^6$ m$^3$ / year) of city I in the statistical year; $\bar{Y}_{\text{stat}}$ is the average domestic water consumption ($10^6$ m$^3$ / year) of city i in the statistical year; n is the number of city.

The simulation result ME = 0.84, the relationship between the simulated domestic water consumption and the statistical domestic water consumption is evenly distributed along a 1:1 straight line (Figure 2), which represents that the model can better fit the actual domestic water consumption in the study area, and the simulation results show that most of the municipal domestic water simulation results are in good agreement with the domestic water statistics in 2007 and 2017. In 2017, the total demand for domestic water in Urumqi was $182.7 \times 10^6$ m$^3$, with a statistical value of $182 \times 10^6$ m$^3$ and a high degree of fit.
Figure. 2 Comparison of simulated and statistical values of total domestic water consumption in cities and counties in 2007 and 2017

Because the total amount of simulated domestic water in Urumqi is the sum of simulated domestic water consumption in each district, the value is larger than that of other cities and counties. In this paper, the rural domestic water is calculated according to its close to one quarter of the city, so the difference between the simulated value and the statistical value of some cities and counties is due to overestimation or underestimation of rural domestic water.

4. Result and analysis

4.1. Land use change analysis

The increase of domestic water consumption is directly related to the rapid growth of population, so this paper mainly considers the change of construction land. As shown in Table 1, from 1990 to 2018, the land use types converted to construction land are: cultivated land, grassland, unused land, forest land and water area, with an area of 1143 km², 767 km², 458 km², 81 km² and 21 km² respectively, of which the conversion range of cultivated land is 7.3%. The main areas of land conversion from cultivated land to construction land are Urumqi, Wujiaqu, Changji, Shihezi, Kuitun and bole, and some areas are mainly from grassland conversion, including Midong District, Dushanzi district and Mulei Kazak Autonomous County. The construction land in jimusar county and Qitai County is mainly converted from unused land. Only a small part of the construction land area in Hutubi County is converted from water body. As shown in Figure 3.

Table 1 land use transfer matrix of Northern Tianshan economic belt in 1990-2018 Company : Km²

|       | 2018          | 1990           | 
|-------|---------------|----------------|
|       | Cultivatedland | woodland       |
|       | grassland     | waters         |
|       | Construction  | Unused land    |
|       | land          |                |
| Cultivatedland | 11945         | 709            |
| woodland       | 46            | 1449           |
| grassland      | 2081          | 3667           |
| waters         | 132           | 39             |
| construction land | 1143         | 81             |
| Unused land    | 129           | 294            |
| total          | 15476         | 6239           |

Table 1: Land use transfer matrix of Northern Tianshan economic belt in 1990-2018 Company: Km²
4.2. Trend of water demand per capita

Since 1989, the per capita domestic water consumption in Northern Tianshan economic belt has increased from 55.02 L/cap d in 1989 to 136 L/cap d in 2010 and 151 L/cap d in 2017. The per capita domestic water consumption in this area has increased from 117.2 L/cap d in 1989 to 242 L/cap d in 2017. Figure 4 shows the evolution law of per capita domestic water consumption and per capita GDP of some cities in the study area during 1989-2017.
It can be seen from Figure 4 that before the urban per capita domestic water consumption reaches a certain value, with the growth of GDP, it shows a trend of rapid growth first and then slow growth. The possible reasons are the gradual improvement of people's living standards and the increase of urban water use. Since then, the per capita domestic water consumption has increased slowly, even decreased, mainly due to the use of water-saving appliances and the improvement of water-saving awareness. The per capita domestic water consumption in rural areas is increasing as a whole, but it is far lower than that in urban areas, which is directly related to the low living standards in rural areas. Figure 5 shows the spatial change of per capita domestic water in the study area.

In 1989, Urumqi City, Shihezi City, Karamay City and other regions had relatively developed economy, so the per capita domestic water consumption was generally high. From 1989 to 2000, in addition to Wenquan County, Jinghe county and jimusar County, the per capita domestic water consumption of other 14 regions increased significantly; Urumqi, Wusu city, Karamay, Shawan County and Manas County saw the fastest growth in domestic water consumption. By 2017, the domestic water consumption of rural residents in Mulei Kazak Autonomous County was 51L / cap d, and that of urban residents was 202 L / cap d, which was the lowest per capita daily domestic water consumption in urban and rural areas. With the rapid development of economy, after 2000, the per capita domestic water consumption in most areas has increased significantly, especially in the new urban area, Shuimogou District and shaibak District of Urumqi, Baijianian district and Dushanzi District of Karamay, Bole City, Kuitun city, Shihezi city and Changji City.

4.3. Total annual domestic water demand trend
From 1989 to 2017, the total annual domestic water consumption in the Northern Tianshan economic belt gradually increased. The total domestic water consumption increased from 125 × 106m3 in 1989 to 398 × 106m3 in 2017. From 1989 to 2017, the rural household water consumption in the Northern Tianshan economic belt increased by about two times, while the urban domestic water consumption exceeded three times, which was inseparable from the rapid growth of population in urban areas. Figure 6 shows the spatial distribution of total domestic water consumption in the Northern Tianshan economic belt in recent 30 years.
The results show that with the continuous expansion of urban and rural construction land area, the total amount of domestic water is also increasing. In 1989, the annual domestic water consumption per unit grid in some cities (Urumqi, Changji, Shihezi, Karamay, Bole) and County cities (jimusar county) in the Northern Tianshan economic belt was the highest (more than $1 \times 10^6 \text{m}^3$/year). In 1989, the total annual domestic water consumption of each 1km $\times$ 1km unit was less than $0.075 \times 10^6 \text{m}^3$/year, which was composed of grid units with high proportion of rural residential areas and low per capita domestic water consumption. From 1989 to 2000, during the 11 years, the total amount of domestic water in Shihezi, Karamay, Urumqi, Changji, Bole and many other residential areas with rapid urbanization grew rapidly. The total annual domestic water consumption in Shihezi City in 2000 is about 9 times of that in 1989. At the same time, with the expansion of urban scale, the proportion of urban population is also increasing. From 2000 to 2017, in addition to the Mulei Kazak Autonomous County, the scope of urban and rural residential areas in most areas continued to expand, and the domestic water consumption also increased rapidly, because of the continuous introduction of talents in Xinjiang, which led to the increase of foreign population.

5. Conclusion and discussion
The expansion of construction land is mainly driven by population growth and migration. From 1989 to 2017, the population of the Northern Tianshan economic belt increased from $423.75 \times 10^4$ people to $582.33 \times 10^4$ people, of which the urban population of Urumqi increased from $106 \times 10^4$ people in 1989 to $121 \times 10^4$ people in 2017, the rural population increased from $53 \times 10^4$ people to $67 \times 10^4$ people, the corresponding urban settlements expanded to 411km$^2$, and the rural settlements increased from $21 \times 10^4 \text{km}^2$ to $58 \times 10^4 \text{km}^2$. In the study area, Urumqi, Karamay, Shihezi, Changji, Bole, Fukang and other areas with high urbanization development level, with the rapid expansion of population growth and urban construction land area, the growth area is respectively 255 km$^2$, 64 km$^2$, 60 km$^2$, 78 km$^2$, 51 km$^2$, 28 km$^2$. In some areas with small population and low economic development level, the growth of rural residential areas is the main one. The most obvious ones are Wusu city, Shawan County, Manas County, Hutubi County and Qitai County. The growth areas are 62 km$^2$, 59 km$^2$, 33 km$^2$, 22 km$^2$ and 41 km$^2$ in turn.

In this paper, the influence of the change of built-up area on the domestic water consumption in the land use change is considered. The research shows that from 1989 to 2017, with the expansion of built-up area, the population increased rapidly, the per capita daily domestic water consumption increased rapidly, the total domestic water consumption showed an upward trend, and the spatial difference between the per capita and the annual total domestic water consumption was obvious. Land use change has great influence on domestic water use.

In this paper, the impact of the change of construction land area on domestic water consumption is considered. From 1989 to 2017, with the expansion of construction land area, the population increased rapidly, and the daily domestic water consumption per capita increased rapidly, resulting in the gradual increase of the total domestic water consumption. In this paper, land use transfer matrix is used to analyze land use change in the study area, especially the impact of construction land change on domestic water use. Due to the incomplete years of Lucc data, the data of daily domestic water consumption per capita and annual total domestic water consumption in 1989 and 2017 are gridded, which results in the lower domestic water consumption in 1989 than that in the actual year, while the
domestic water consumption in 2017 is higher than that in the actual year. Moreover, due to the incomplete data of domestic water consumption of rural households, it is assumed that the per capita domestic water consumption in rural areas is one quarter of the corresponding cities and counties. There are many uncertainties in this assumption, but the simulation results are helpful to understand the domestic water use pattern and its influencing factors in the study area, and to formulate appropriate ecological management and sustainable water resource management strategies.

Only by understanding the impact of LUCC on domestic water and mastering the temporal and spatial variation law of domestic water in arid areas, can we further provide a reference for the decision-making of water resources management of the government. In the future, more in-depth research will be carried out on the estimation technology of domestic water consumption, and at the same time, more influencing factors on domestic water consumption will be discussed.

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