Analysis of spatial pattern Change of LU/LC over the upper Tarim River region since 1990 using remote sensing data

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Abstract. The upper reaches of Tarim River (URTR) is an important port of trade between China and central Asia. The development of the URTR is thus significant for the SREB initiative. The LU/LC data in the URTR from 1990 to 2015 were used to quantitatively explore the dynamics of LU/LC changes, and its driving force was discussed from two aspects of nature and human. Results showed that the unused land and grassland were the main land use types in this area, accounting for more than 79%. Compared with the data of 1990, the areas of woodland, water, farmland, and building land of 2015 increased with 3.24%, 6.53%, 10.57%, and 0.40%, respectively, and the areas of unused land and grassland decreased, which accounted for 53.25% and 26.01%, respectively. The increases of the woodland and farmland areas mainly originated from grassland and unused land. The woodland increased sharply around 2000 due to the abundant water during the period between 1998 and 2000. Subsequently, part of the woodland was shifted into the farmland. The extension of building land wasn’t obvious, but showed a salient feature of population urbanization. It was essential that the LU/LC patterns of the URTR were deeply influenced by human farming and living activities.

1. Introduction

It is crucial for land use planning, utilization of regional resources and environment management that examining the processes and trends of land use change and analyzing the primary causes. The upper reaches of Tarim River (URTR), located in the land-based Silk Road Economic Belt (SREB) (i.e., which focuses on connectivity and cooperation among main countries of Eurasia) in China, is an important port of trade between China and central Asia. The development of the URTR is thus significant for the SREB initiative.
Given that URTR is an ecological sensitive area, its land-use/land-cover changes have links to both human and nature interactions, monitoring the change of land use/land cover (LU/LC) over this region is helpful to create its harmonious coexistence pattern between man and nature and maintain its sustainable development in the future[1].

There are some existing researches focuses on the land use cover change of URTR, such as: Yongliang (2010) analyzed the changes (from 1994 to 2005) of population, land use patterns and water resource based on integrated methodology of GIS and statistic data[2]. Zumrat Ebrayimland use and land cover change and trends and environmental effects of the period 1960 to 2000 were analyzed and researched quantitatively using mathematical statistical methods. Most the existing study focus on the land use cover changes before 2010[3].

In this paper the LU/LC data in the URTR from 1990 to 2015 were used to quantitatively explore the dynamics of LU/LC changes, and its driving force was discussed from two aspects of nature and human. Firstly, the LU/LC data over the URTR form 1990 to 2010 were obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn). Furthermore, the LU/LC data over the URTR in 2015 were interpreted from Landsat satellite remotely sensed images. Then, a time series of LU/LC were built, and transfer matrix and association analysis were employed to explore the driving force of the LU/LC changes. This research provides the basic data support for decision-making so as to drive local economic development and construction of the SREB.

2. Data and methodology

2.1 Study area

Study area located between 34–43°N and 76–85°E (Figure 1) and covering more than 2.7 × 105 km2, including parts of hotan and aksu river basin, most of kashghar and ogen river basin, the upper reach of tarim river basin. The 495 km long upper tarim mainstream section and its sources seldom has contribution to surface runoff generation, and only fed by precipitation in the upper tributaries and snow/glacier-melt in the mountain regions, due to the extremely arid climate[4]. The unused land and grassland were the main land use types in this area, accounting for more than 79%.

2.2 Data

A 1-km gridded database of component classifiers have been completed for five stages: the late 1980s (1990), 1995, 2000, 2005, and 2010[5-7]. The database was produced under uniform quality control and integration checking, which ensured high-quality and consistency of the database[8]. There are 6 land use classes and 25 subclasses in the database, including cropland, woodland, grassland, water body, built-up land, and unused land. Additionally, we use the human–computer interactive interpretation method and the LUC information of 2010 as reference to interpret the 2015 Landsat TM digital images covering research area. Thus, 6 stages land used cover datasets (Figure 2), from 1990 to 2015, were used to spatial pattern Change analysis.
Figure 1. Position and scope of study area.

Figure 2. Land use cover of over upper reaches of Tarim River for six stages: 1990, 1995, 2000, 2005, 2010, and 2015
2.3 Methodology
The total acreage of each land use class was calculated separately for every 5 years to analyze the quantitative land use change trend. Then transfer matrix and spatial analysis was employed to explore and mapping the dynamic transformation of land use cover. Finally, the driving force of land use transformation was discussed from two aspects of nature and human by utilizing statistics of natural resource and human society.

3. Result and discussion

3.1 Characteristics of land use acreage changes
From 1990 to 2015, land use cover in URTR indicated the significant characteristics of total acreage (figure 3) and spatiotemporal differences. Compared with the data of 1990, the areas of woodland, water, farmland, and building land of 2015 increased with 3.24%, 6.53%, 10.57%, and 0.40%, respectively, and the areas of unused land and grassland decreased, which accounted for 53.25% and 26.01%, respectively.

(1) The basic characteristics of changes in cropland can be summarized as follows. The total area of cropland increased by $11 \times 10^3$ km$^2$ during past 25 years. After 2010 the cropland increased by $6 \times 10^3$ km$^2$, with reclaimed cropland concentrated mainly in the farming–forestry or farming–pastoral ecotones of Kashghar and Ogen river basin.

(2) The basic characteristics of changes in woodland can be summarized as follows. The total area of woodland increased quickly by 2750 km$^2$ during the period from 1995 to 2000. After then the area decreased during the following 2 stages. The increased woodland mainly distributed around/near the water, which including river, lake or marsh.

(3) The basic characteristics of other land use cover changes in grassland can be summarized as follows. The total area of grassland decreased by $14 \times 10^3$ km$^2$. The total area of Unused land increased first and then decreased; the water increased in this region, and the built-up land decreased then increased.

3.2 The mainly transfer characteristics of landuse cover in URTR
The land use cover transfer matrix (table 1 to 5) of the five period, 1990 to 1995, 1995 to 2000, 2000 to 2005, 2005 to 2010, and 2010 to 2015 and the distribution of the land use change from 1990 to 2015 in URTR (figure 5) were used to primary analysis the transfer processing and its driving force. The increases of the woodlands area mainly were originated from grassland and unused land, and the transfers mainly occurred before 2005. The woodland increased sharply around 2000 due to the abundant water during the period between 1998 and 2000 (Figure 5). Subsequently, part of the woodland was shifted into the farmland. The decreases of grassland area mainly were shifted into woodland, unused land, and cropland. During the first period most of the decreased grassland shifted into unused land or cropland. After then, also large area of grassland transfer to woodland. During 2000 to 2010 farming is the only main cause of grassland shrink. During the last period the transformation of grassland has similar characteristics with the first period. About the area of water, the increases and decreases approximately equal before 2010. However, during the last period, large
area of unused land transferred into water land. The extension of building land wasn’t obvious, but showed a salient feature of population urbanization. Most of the built-up lands originated from cropland.

Figure 3. Acreage change trend of each land use class over upper reaches of Tarim River from 1990 to 2015

The characteristics of spatial distribution of land use cover conversions can be summarized as follows. The large area of grassland and woodland shift into cropland, meanwhile many croplands convert to built-up land, due to human activities. However, the degradations of grassland or woodland often distributed far from built-up land and water. The primary driving force is water.

Table 1. The land use cover transfer matrix from 1990 to 1995.

|        | 1995  | 1990  | Woodland | Grassland | Water | Built-up land | Unused Land | Cropland |
|--------|-------|-------|----------|-----------|-------|---------------|-------------|----------|
| Woodland | 4003  | 1854  | 108      | 14        | 370   | 164           |             |          |
| Grassland | 1847  | 74732 | 796      | 76        | 5983  | 2804          |             |          |
| Water   | 103   | 797   | 8558     | 5         | 1879  | 128           |             |          |
| Built-up land | 3     | 71    | 5        | 262       | 36    | 550           |             |          |
| Unused Land | 335   | 6076  | 1919     | 45        | 145079 | 712           |             |          |
| Cropland | 152   | 2625  | 139      | 518       | 714   | 13790         |             |          |

Table 2. The land use cover transfer matrix from 1995 to 2000.

|        | 2000  | 1995  | Woodland | Grassland | Water | Built-up land | Unused Land | Cropland |
|--------|-------|-------|----------|-----------|-------|---------------|-------------|----------|
| Woodland | 4073  | 1653  | 111      | 10        | 346   | 255           |             |          |

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|                | Grassland | Water | Built-up land | Unused Land | Cropland |
|----------------|-----------|-------|---------------|-------------|----------|
| Woodland       | 3779      | 6819  | 981           | 52          | 9037     |
| Water          | 115       | 560   | 8681          | 1           | 1873     |
| Built-up land  | 11        | 51    | 4             | 290         | 29       |
| Unused Land    | 858       | 7714  | 1804          | 19          | 142576   |
| Cropland       | 345       | 2481  | 186           | 505         | 608      |

Table 3. The land use cover transfer matrix from 2000 to 2005.

|                | Woodland | Grassland | Water | Built-up land | Unused Land | Cropland |
|----------------|----------|-----------|-------|---------------|-------------|----------|
| Woodland       | 8703     | 34        | 16    | 1             | 5           | 439      |
| Grassland      | 25       | 78940     | 35    | 8             | 12          | 1866     |
| Water          | 10       | 151       | 11836 | 0             | 46          | 34       |
| Built-up land  | 0        | 0         | 0     | 871           | 0           | 6        |
| Unused Land    | 20       | 98        | 63    | 15            | 155067      | 369      |
| Cropland       | 1        | 65        | 3     | 35            | 0           | 19619    |

Table 4. The land use cover transfer matrix from 2005 to 2010.

|                | Woodland | Grassland | Water | Built-up land | Unused Land | Cropland |
|----------------|----------|-----------|-------|---------------|-------------|----------|
| Woodland       | 8503     | 95        | 3     | 1             | 7           | 150      |
| Grassland      | 11       | 78727     | 6     | 0             | 88          | 456      |
| Water          | 2        | 201       | 11625 | 0             | 86          | 39       |
| Built-up land  | 0        | 0         | 0     | 929           | 0           | 1        |
| Unused Land    | 20       | 103       | 2     | 10            | 154748      | 247      |
| Cropland       | 13       | 72        | 1     | 6             | 6           | 22235    |

Table 5. The land use cover transfer matrix from 2010 to 2015.
4. Conclusion

The LU/LC data in the URTR from 1990 to 2015 were used to quantitatively explore the dynamics of LU/LC changes, and its driving force was discussed from two aspects of nature and human. Results showed that the unused land and grassland were the main land use types in this area, accounting for more than 79%. Compared with the data of 1990, the areas of woodland, water, farmland, and building land of 2015 increased with 3.24%, 6.53%, 10.57%, and 0.40%, respectively, and the areas of unused land and grassland decreased, which accounted for 53.25% and 26.01%, respectively. The increases of the woodland and farmland areas mainly is originated from grassland and unused land. The woodland increased sharply around 2000 due to the abundant water during the period between 1998 and 2000. Subsequently, part of the woodland was shifted into the farmland. The extension of building land wasn’t obvious, but showed a salient feature of population urbanization.

Figure 4. Annual run-off of Tarim River from 1998 to 2010.

Figure 5. Distribution of the land-use change from 1990 to 2015.
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