

# Spatial-temporal Changes of Land Use/Cover and Its Impact on Evapotranspiration in Wuwei City

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**Abstract:** In order to grasp the sustainable development path of economy and ecology in Wuwei, based on GlobeLand30 land use/cover data from 2000 to 2020, we analyzed the spatial and temporal characteristics of land use/cover changes in Wuwei through single land use dynamic attitude, comprehensive land use dynamic attitude and land use transfer matrix, and combined with meteorological data and evapotranspiration data, clarified the driving mechanism of land use/cover change and its impact on evapotranspiration. The results show that during the period 2000—2020, shrublands and woodlands in Wuwei City had the highest combined motility, indicating that both were less stable. The main land use transfer direction in Wuwei City during 2000—2020 showed the transfer of cropland to man-made surface, forest land to grassland, and bare land to cropland and man-made surface. The distribution of ET in Wuwei City has strong spatial differences, which is very consistent with the land use/cover and surface vegetation coverage in Wuwei City. Conclusion: Temperature and rainfall have relatively limited effects on land use/cover changes in Wuwei, and only have some effects on land use/cover types such as wetlands, water bodies and woodlands. The main driving forces of land use/cover changes in Wuwei are socio-economic factors, among which GDP, real estate investment and government policies have significant effects on land use/cover type changes. The change of ET in Wuwei City is affected by both climate change and land use/cover change, and from 2010 to 2020, land use/cover dominates.

**Keywords:** Land use/cover, Wuwei City, Transfer matrix, Dynamic attitude, Driving force, Evapotranspiration.

## 1. Introduction

Land resources are the foundation of human survival and social development, and are one of the most precious natural resources for humanity. Land Use and Cover Change (LUCC) is an important carrier for human activities to transform the natural surface, and is the basis for studying global climate change and ecological environment issues such as carbon cycle, biodiversity, agricultural development [2-4]. Therefore, strengthening the research on the spatiotemporal dynamic changes and driving mechanisms of land use is of great significance for maintaining the balance between the natural environment and the human social system, and improving the regional ecological environment [5-6]. The main content of land use/cover change research includes two aspects: on the one hand, using long-term remote sensing images to study the spatiotemporal changes of land use/cover, and on the other hand, combining human activities and natural factors in the study area to explore the driving forces of land use/cover change [7]. Scholars both domestically and internationally have utilized different research methods and data sources to analyze the characteristics and driving forces of LUCC changes from multiple perspectives [8-9]. Wuwei City is an important node city in the central city of the Hexi Corridor in China. As the core area of the Silk Road Economic Belt, its climate is arid and there is a significant gap in water resources between the north and south. Driven by the national western development strategy, the rapid development of industry, agriculture, and urbanization, coupled with the influence of national ecological policies and local government development directions, land use/cover change is more significantly affected by human activities. Combined with the impact of climate change, its spatial pattern is constantly changing. Therefore, it is of great significance for regional

planning and the harmonious development of economy and ecology to study the spatial-temporal change characteristics and driving forces of land use/cover types in Wuwei City.

## 2. Materials and Methods

### 2.1. Data Source and Preprocessing

The main data required for this study include vector data, land use/cover grid data, meteorological data, and socio-economic data from Wuwei City. The land use/cover grid data is provided by the Ministry of Natural Resources with a 30 meter global surface cover data GlobeLand30 (<http://www.globallandcover.com/>). This data includes a total of 10 primary types, namely: cultivated land, forest land, grassland, shrub land, wetland, water body, tundra, artificial surface, bare land, glacier snow cover.

Meteorological data sourced from China Meteorological Data Network (<https://data.cma.cn/>) There are three national meteorological stations in the research area, namely Minqin Station (52681), Wuwei Station (52679), and Wushaoling Station (52787). Select daily temperature and rainfall for 20 years to obtain annual average temperature and rainfall. The socio-economic data is sourced from Wuwei Statistical Yearbook data, including population, Gross Domestic Product (GDP), highways, existing houses in villages and towns, real estate investment, freight volume, agricultural growth, and other related data.

The evapotranspiration data is a MOD16 product, which was calculated by NASA based on the Penman Monteith model. Select the MOD16A3GF dataset from 2000 to 2020 (<https://search.earthdata.nasa.gov/>) This data is a L4 level product synthesized from MOD16 products throughout the year, with a time resolution of years. Use the MRT tool of ENVI software to preprocess HDF type data through lattice

projection, cropping, and embedding.

### 2.2. Land use/cover transfer matrix

The land use transfer matrix describes the structural characteristics and direction of changes in different land use types within a region, and is currently the most widely used method in land use research. The mathematical calculation process is as follows:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1n} \\ S_{21} & S_{22} & \dots & S_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ S_{n1} & S_{n2} & \dots & S_{nn} \end{bmatrix}$$

In the formula,  $S_{ij}$  represents the area of different land use types.  $N$  is the number of land use types, and  $i$  and  $j$  are the serial numbers of land use types in the early and late stages of the study.

## 3. Result and Analysis

### 3.1. Temporal and spatial changes in land use/cover

The spatiotemporal distribution of land use/cover in Wuwei City in 2000, 2010, and 2020 is shown in Table 1. In 2020, the land use types in Wuwei City were mainly bare land, grassland, and cultivated land, with a bare land area of 17628.2 km<sup>2</sup>, accounting for 53.24% of the total area of Wuwei City, mainly distributed in the northern desert area of the research area; The grassland area is 6664.1 km<sup>2</sup>, and the cultivated land area is 6464.4 km<sup>2</sup>, accounting for 20.13% and 19.53% of the study area, respectively. Grassland is mainly distributed in the southern Qilian Mountains of Wuwei City, and cultivated land is distributed in the middle of the central plain oasis area and the northern desert area. Forest land, artificial surface, and wetlands come second, with an area of 1313.2 km<sup>2</sup>, 669.8 km<sup>2</sup>, and 237.2 km<sup>2</sup>, respectively. Forest land is distributed in the Qilian Mountains in the southern part of Wuwei City, while wetlands are concentrated in the northeast. Artificial surface is distributed in a dotted pattern in the central plain oasis area. Shrubs, water bodies, and glaciers have relatively small snow cover areas, with water bodies distributed at the junction of oasis and desert areas.

**Table 1.** Statistical table of Land use/cover area in Wuwei City land from 2000 to 2020

Year LUCC	2000	2010	2020	Changing trends
Cultivated land	6 683.7	6 753.2	6 464.4	Increase first and then decrease
Woodland	1 702.3	1 041.7	1 313.2	Reduce first and then increase
Grassland	6 019.2	7 130.4	6 664.1	Increase first and then decrease
Shrubland	62.4	63.2	54.1	Increase first and then decrease
Wetlands	209.0	224.3	237.2	Continuously increasing
Water	33.7	39.3	47.9	Continuously increasing
Artificial surface	192.3	123.8	669.8	Reduce first and then increase
Bare ground	18 177.6	17 712.5	17 628.2	Continuous reduction
Glacier snow cover	27.8	27.7	28.9	Continuously increasing

### 3.2. Land use/cover transfer matrix

Through the land use transfer matrix of different periods, it is possible to further grasp the changes in land use/cover transfer in Wuwei City. Based on the land use/cover data of Wuwei in 2000, 2010 and 2020, the ENVI density segmentation and the confusion matrix module based on the ground truth are used to make the land use transfer matrix of Wuwei in 2000-2010, 2010-2020 and 2000-2020 (Table 2), and clarify the transfer direction of land use/cover in different periods of Wuwei.

During the period from 2000 to 2010, the cultivated land area increased by 69.5 km<sup>2</sup>, mainly due to the interaction with artificial surfaces. The forest land is mainly turned out, with the main turning direction being grassland, covering an area of 698.4 km<sup>2</sup>, accounting for 97.8% of the total turning out area, distributed in the central part of the southern Qilian Mountains; The transferred area is 53.3 km<sup>2</sup>, mainly from grasslands, shrublands, and bare land. Between 2010 and 2020, the cultivated land area decreased by 288.7 km<sup>2</sup>, with the main turning out directions being artificial surface, grassland, and bare land. The turning out areas were 428.0 km<sup>2</sup>, 77.4 km<sup>2</sup>, and 76.1 km<sup>2</sup>, respectively; The transferred area of cultivated land mainly comes from bare land and

grassland, with 195.5 km<sup>2</sup> and 95.6 km<sup>2</sup> respectively. Overall, from 2000 to 2020, the main transfer directions of land use in Wuwei City showed the phenomenon of farmland turning into artificial surface, forest land turning into grassland, bare land turning into farmland and artificial surface.

### 3.3. Driving factors of land use/cover change

Land use/cover change is a comprehensive reflection of the impact of natural conditions, climate change, economic development, social environment, and population changes.

#### 3.3.1. Natural factors

Natural factors mainly include hydrothermal conditions, namely temperature and precipitation, which are fundamental conditions for land use/cover change. Over the past 20 years, the average annual temperature change in Wuwei City has fluctuated relatively little and showed an upward trend, but the increase was gentle; The annual rainfall fluctuates greatly and shows an overall upward trend. From 2000 to 2010, the annual rainfall showed a downward trend with a decreasing rate of 4.03 mm/a. From 2010 to 2020, the annual rainfall showed an upward trend with a rising rate of 2.79 mm/a. Overall, there has been a slight increase in temperature and precipitation in Wuwei City, which is consistent with the continuous increasing trend of wetlands and water bodies in

Wuwei City. The forest land in Wuwei City shows a trend of first decreasing and then increasing, which is similar to the trend of annual rainfall. This also indicates that in arid areas, rainfall is the main factor affecting forest land changes. From the perspective of other land use/cover changes in the

research area, the impact of temperature and rainfall on land use/cover changes in Wuwei City is relatively limited, with only a certain impact on land use/cover types such as wetlands, water bodies, and forests.

**Table 2.** Land use transfer matrix of Wuwei City from 2000 to 2020

2000 2020	Cultivated land	Woodland	Grassland	Shrubland	Wetlands	Water	Artificial surface	Bare ground	Glacier snow cover
Cultivated land	6 102.6	1.5	95.0	0.3	1.2	2.7	66.1	195.1	0.0
Woodland	8.2	949.8	303.8	26.5	0.0	0.3	0.0	24.6	0.0
Grassland	77.4	721.3	5 163.3	13.9	8.3	3.9	1.5	673.4	1.2
Shrubland	0.2	18.8	13.3	21.7	0.0	0.0	0.0	0.2	0.0
Wetlands	1.6	0.0	1.4	0.0	189.3	2.5	0.0	42.4	0.0
Water	4.5	0.4	4.7	0.0	4.9	23.4	0.3	9.6	0.1
Artificial surface	413.1	0.2	48.2	0.0	0.0	0.2	123.8	84.2	0.0
Bare ground	76.1	10.3	380.2	0.0	5.3	0.8	0.6	17 145.0	9.9
Glacier snow cover	0.0	0.0	9.3	0.0	0.0	0.0	0.0	3.0	16.6

### 3.3.2. Socio economic factors

From 2000 to 2020, the GDP of Wuwei City increased from 6428.15 million yuan in 2000 to 52641.42 million yuan in 2020. With rapid economic growth and the rapid advancement of urban modernization, real estate investment increased from 78.15 million yuan in 2000 to 5293.83 million yuan in 2020. The existing housing area in villages and towns doubled, the freight volume increased by 6.7 times, and the rapid expansion of residential land, operating land, and transportation land, Explained the reason why the artificial surface area of Wuwei City has increased by 2.5 times in 20 years. At the beginning of the 21st century, the industrial development of residents in Wuwei City was relatively backward, with agricultural development being the main focus of the people. Reclamation of arable land was the most effective way for farmers to become rich. Therefore, from 2000 to 2010, there was a pattern of increased arable land and decreased unused land. However, the ecological environment in the northwest region is relatively fragile. The national implementation of the project of returning farmland to forests and grasslands, as well as afforestation, coupled with the rapid development of urban modernization construction after 2010, has led to the occupation of a large amount of arable land, grassland, and unused land, which is consistent with the trend of increasing and then decreasing the area of arable land, grassland, and shrub land from 2000 to 2020. The population of Wuwei City decreased by 451000 people from 2000 to 2020, which did not affect the rapid development of real estate and agriculture. It also indicates that population is not the main factor affecting land use/cover type changes in Wuwei City in the past 20 years.

In summary, the main driving force of land use/cover change in Wuwei City is socio-economic factors, with GDP, real estate investment, and government policies having a significant impact on the changes in land use/cover types.

Therefore, socio-economic factors such as economic growth and real estate investment, as well as national macroeconomic policies, are the main driving forces for the adjustment and change of land use structure in Wuwei City from 2000 to 2020.

### 3.3.3. The impact of LUCC on evapotranspiration

Table 3 shows the distribution range and proportion of ET in Wuwei City in 2000, 2010 and 2020 respectively. It can be seen from the figure that the distribution of ET in Wuwei City has a strong spatial difference, and the overall pattern is spatial analysis that the southern mountain area and the central plain area are high, and the northern desert area is low. This feature is very consistent with the land use/cover and surface vegetation coverage in Wuwei City, which also shows that land use/cover is the most important factor affecting evapotranspiration. There were significant changes in ET in Wuwei City from 2000 to 2020, with a significant growth trend in ET in the southern Qilian Mountains, which is related to climate change in Wuwei City; The significant increase in ET in the oasis area of the central plain is related to changes in arable land area and agricultural production methods in the study area; The increase in evapotranspiration in the northern region is mainly in the central region, which is consistent with the changing characteristics of the increase in arable land area in the northern region. Over the past 20 years, ET in the research area has been continuously increasing, with a significantly faster rate of change from 2000 to 2010 than from 2010 to 2020. This is also related to the changes in bare land and arable land areas in Wuwei City. From 2010 to 2020, the arable land area in Wuwei City decreased by 288.7 km<sup>2</sup>, mainly towards construction land. This land use/cover change significantly reduced evapotranspiration, and the rate of bare land cultivation slowed down over the past decade, further weakening the changes in evapotranspiration.

**Table 3.** Distribution range and proportion of ET in Wuwei City in 2000, 2010 and 2020

ET/mm	Proportion/%		
	2000	2010	2020
< 200	81.97	77.50	76.85
200~250	4.90	2.64	2.10
250~300	3.44	4.01	3.56
300~350	2.53	3.31	3.50
350~400	2.90	2.79	3.31
400~450	3.10	2.22	2.84
450~500	1.02	2.47	2.01
500~550	0.13	3.11	2.83
550~600	0.01	1.75	2.74
> 600	0.00	0.20	0.25

#### 4. Summary

In 2020, the land use type of Wuwei City was mainly bare land, with a bare land area of 17628.2 km<sup>2</sup>, accounting for 53.24% of the total area of Wuwei City. It is mainly distributed in the northern desert area of the research area. The absolute change in land use/cover area in Wuwei City is as follows: grassland>bare land>artificial surface>forest land>cultivated land>wetland>water body>shrub land>glacier snow cover. Among them, the area of cultivated land, grassland, and shrubland increased first and then decreased, the area of forest land and artificial surface decreased first and then increased, the area of wetlands and water bodies continued to increase, and the area of bare land continued to decrease. The impact of temperature and rainfall on land use/cover change in Wuwei City is relatively limited, and only has a certain impact on land use/cover types such as wetlands, water bodies, and forests. The main driving force of land use/cover change in Wuwei City is socio-economic factors, among which GDP, real estate investment, and government policies have a significant impact on the changes in land use/cover types. Therefore, socio-economic factors such as economic growth and real estate investment, as well as national macroeconomic policies, are the main driving forces for the adjustment and change of land use structure in Wuwei City from 2000 to 2020. The distribution of ET in Wuwei City has a strong spatial difference, showing a spatial analysis pattern of high mountains in the south and plains in the middle and low desert areas in the north, which is very consistent with the land use/cover and surface vegetation coverage in Wuwei City.

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