Dynamic Analysis of Vegetation Change in Tianzhu Tibetan Autonomous County Based on RS

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Abstract: Based on MODIS products and using ArcGIS 10, ENVI 5.0 and other data processing software, this paper studied the spatial characteristic changes of vegetation coverage in Tianzhu Tibetan Autonomous County from 2015 to 2019 by using pixel dichotomial model and dynamic spatial change model, and obtained the vegetation coverage statistical table, migration matrix and dynamic spatial change matrix. The data show that the vegetation coverage in this region is on the rise, and the vegetation in the middle and low cover areas, ground cover areas and no cover areas are all converted to higher vegetation levels. However, due to natural reasons, there are still a small number of areas with small changes in vegetation coverage or even vegetation degradation. The region should continue to strengthen ecological and environmental protection on the existing basis to maintain green development.

1. Introduction

Vegetation coverage is a concept based on the Normalized Vegetation Index (NDVI), which is defined as the percentage of the vertical projection area of the vegetation to the total surface area. It can reflect the relevant information of vegetation coverage, and to some extent, it can make up for the shortcomings that NDVI value based on the combination of red and near-infrared bands has difficulty in distinguishing low coverage vegetation and tends to saturate in the case of high coverage vegetation. Therefore, it can effectively stretch the value range of vegetation information, describe the ecosystem state, assess the degree of land degradation and desertification, reflect the spatial coverage law of vegetation growth on the earth's surface and its distribution characteristics, thus helping monitor and analyze the spatial dynamic changes of vegetation. For the important indicator in evaluating the ecological environment quality and measuring the surface vegetation status, its temporal and spatial distribution and regional area conversion play an important role in the government's regional planning and decision-making.

Tianzhu Tibetan Autonomous County is located in the central part of Gansu Province, south of Wuwei City, where the three plateaus meet. With a special ecological location, it is an important water conservation area and supply area for the Shiyang River Basin and the Yellow River Basin. The vegetation in this area assumes important roles in water conservation, soil erosion containment and biodiversity protection. However, the outstanding contradiction of agriculture, forestry and animal husbandry has increased the pressure on the ecological environment. Therefore, it seems urgent to use scientific methods to study the vegetation coverage and its change characteristics in the area, build the foundation for future environment construction based on the current situation and changes.

This paper extracts the normalized difference vegetation index NDVI from MODIS L3 products, accurately counts the vegetation coverage of Tianzhu Tibetan Autonomous County, and clarifies the conversion process of vegetation grades through the transfer matrix, aiming to reveal the law of vegetation area transfer and spatial change of vegetation coverage in Tianzhu Tibetan Autonomous County. It analyzes and evaluates the regional ecological environment of Tianzhu Tibetan Autonomous County to provide scientific basis for oasis vegetation resource management, land desertification control and sustainable development of "green water and green mountains", thus providing theoretical basis for the sustainable development of ecological economy in the region.

In recent years, many scholars at home and abroad have used the normalized vegetation index NDVI and NOVAA/AVHRR of MODIS to study the relationship between vegetation coverage and

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climate change. Wang Zhichao et al. chose Landsat 5/8 remote sensing images in Jinjiang District, Chengdu in 2002, 2009 and 2018, using vegetation coverage (FVC) and remote sensing ecological index (RSEI) to assess its ecological quality and changes from 2002 to 2018 [1]. Based on Landsat remote sensing image data, Memet Tursun· Memet used normalized vegetation index NDVI, dimidiate pixel model, center migration model to analyze the spatial and temporal evolution of vegetation cover in Shule County from 1996 to 2017 [2]. Based on the remote sensing data from 2000 to 2019 and the measured data in 2014, He Guoxing et al. used empirical regression model to construct a vegetation coverage estimation model, and studied the temporal and spatial change law, stability and variation reasons of FVC in alpine meadows in the past 20 years [3]. Wu Yingga et al. used the GIS platform to calculate the soil wind erosion modulus in Wuchuan County in 2018 and 2019 based on Landsat8 data, collected wind erosion factors, and comparatively analyzed the spatial distribution characteristics, land use methods, topography and vegetation coverage [4]. Zeng Linglin, Wardlow Brian et al. used MODIS multi-temporal synthesis data to reconstruct the new strategy of high time resolution NDVI time series. Afshar Mehdi H. et al. used microwave L-band and NDVI to evaluate the farmland drought in Central Europe. These research results all suggest that vegetation coverage can effectively reflect the spatial coverage law of vegetation growth and its distribution characteristics.

2. Overview of the study area

Tianzhu Tibetan Autonomous County is located between 36°31' to 37°55' north latitude and 102°07' to 103°46' east longitude. Located at the eastern end of the Hexi Corridor, it is adjacent to Yongdeng County in the south, Jingtai County in the east, and Liangzhou District and Gulang County of Wuwei city in the north, bordering Sunan County to the northwest and Menyuan, Huzhu and Ledu County of Qinghai Province to the west. The territory is high in the northwest and low in the southeast, with an altitude between 2040-4874 meters. The landform is mainly mountainous, with Wushaoling located in the middle of the county and stretching from east to west. The middle part is a plain oasis area, and the south part is the Qilian Mountains. It has a plateau monsoon climate, with four distinct seasons, little precipitation, and cold winters. As shown in Figure 1. Tianzhu Tibetan Autonomous County is located in a national nature reserve. The annual precipitation is about 160mm and the average annual temperature is about 7°C.

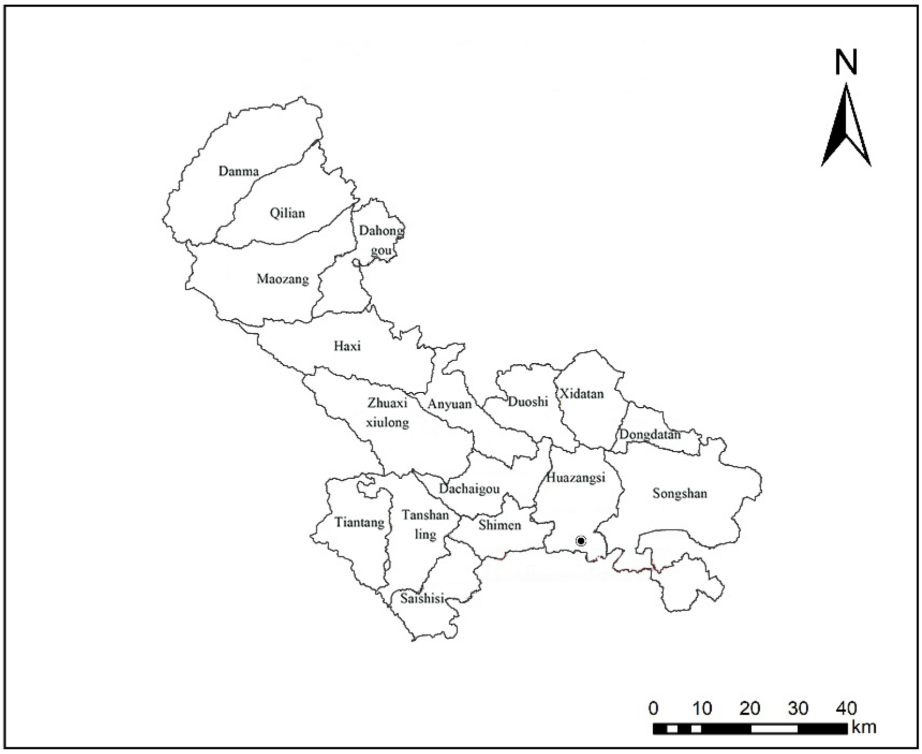


Figure 1 Administrative division map of Tianzhu Tibetan Autonomous County

3. Data sources and research methods

3.1 Data sources

This paper selects the monthly vegetation index L3 product of public data MOD13A3-1km on geospatial data cloud (http://www.gscloud.cn/). The data product includes two types of vegetation index data: the normalized vegetation index (NDVI) and the enhanced vegetation index (EVI). The spatial resolution is 1000m×1000m, and the time resolution is 1 month. The spatial resolution and timeliness of this data product meets the vegetation coverage research requirement of the county.

The fine vegetation growth status in August in the study area can represent the vegetation growth status in the area. In order to analyze the changes in vegetation coverage year by year, the inter-annual NDVI products used in this paper during the four-year period from 2015 to 2019 are all MODIS remote sensing images taken in August.

3.2 Data processing

According to the processing route of MODIS terrestrial product data, the product data has undergone basic image processing such as radiation correction, geometric correction, atmospheric correction, and cloud mask. Therefore, we directly converted the downloaded image format from HDF format to Ttiff format. The map projection was converted from global sinusoidal projection SIN to Albers Equal Area projection, and resampled. Then, ArcGIS 10 was used for raster cropping and image splicing to gather NDVI image data of Tianzhu Tibetan Autonomous County at different time scales. Where, the NDVI value range is [-1, 1].

3.3 Construction of vegetation coverage model

3.3.1 Normalized vegetation index

The normalized vegetation index (NDVI) is the best indicator of vegetation growth status, and there is a strong correlation between NDVI and vegetation coverage. Since the spectral characteristics of vegetation have a large contrast in the red and near-infrared bands, NDVI can be obtained by combining the red and near-infrared bands [5-10].

The calculation formula of NDVI is:

$$NDVI = (NIR - Red)/(NIR + Red) \tag{1}$$

Where, *NIR* and *Red* are respectively the ground reflectivity of infrared band and red band after atmospheric correction.

3.3.2 Dimidiate pixel model

The theory of dimidiate pixel model (DPM) believes that vegetation information and soil information constitute pixel information P. The vegetation information is recorded as P_v, and the soil information is recorded as P_s. The reflectance value of any pixel can be indicated as the linear weighted sum of the vegetation coverage part and the non-vegetation coverage part. The formula is as follows:

$$P = P_v + P_s \tag{2}$$

For the mixed pixel composed of two parts of soil information and vegetation information, the vegetation coverage of the pixel (denoted as f_c) is equal to the ratio of the area covered by vegetation in the pixel. From the knowledge of linear algebra, we can know that the ratio of the area covered by soil is 1-f_c. Assume that the pure vegetation coverage information is P_{veg} and the pure soil coverage information is P_{soil}, then there is:

$$P_v = f_c \times P_{veg} \tag{3}$$

$$P_s = (1 - f_c) \times P_{soil} \tag{4}$$

The above three formulas can be solved jointly to obtain the mathematical expression formula of vegetation coverage f_c:

$$f_c = (P - P_{soil})/(P_{veg} - P_{soil}) \tag{5}$$

Where, P_{veg} and P_{soil} are the two parameters of the model. As long as the parameter values are known, formula (5) can be used to calculate the vegetation coverage of the pixel.

3.3.3 Use NDVI to estimate vegetation coverage

By substituting NDVI into the dimidiate pixel model to calculate vegetation coverage, it is possible to effectively reduce the influence of shadows, terrain, solar radiation, and atmospheric noise on the estimation results, thereby obtaining more accurate vegetation coverage. Based on the band combination characteristics of NDVI, a dimidiate pixel model can be established to calculate vegetation coverage. The NDVI gray value information of a single pixel can be understood as a combination of $NDVI_{veg}$, which represents vegetation coverage information, and $NDVI_{soil}$, which represents non-vegetation coverage information. The condition of formula (5) is met, so NDVI is substituted into formula (5) to obtain the vegetation coverage expression based on NDVI:

$$f_c = (NDVI - NDVI_{soil})/(NDVI_{veg} - NDVI_{soil}) \tag{6}$$

Where, $NDVI_{soil}$ is the NDVI value of the soil pixel, $NDVI_{veg}$ is the NDVI value of the green vegetation pixel, f_c is the vegetation coverage, and NDVI is the normalized vegetation index of the pixel.

3.3.4 Values of NDVIsoil and NDVIveg

$NDVI_{soil}$ represents the minimum value of the pure soil coverage pixel, which is theoretically infinitely close to zero. Actually, however, due to the influence of the atmosphere and the different soil type, surface moisture, roughness, soil color, etc., its value varies with time and space, generally between -0.1-0.2. $NDVI_{veg}$ is the maximum value of the pure vegetation coverage pixel, which is equal to 1 under ideal conditions. Different vegetation types, coverage effects and seasonal changes render $NDVI_{veg}$ value to present strong spatio-temporal heterogeneity characteristics, so its true value is difficult to determine. The value of $NDVI_{veg}$ is usually determined according to the expert method, but the empirical value will vary with changes in atmospheric conditions and different initial numerical data. Therefore, when estimating vegetation coverage, atmospheric conditions will cause accidental errors, which will eventually lead to decreased accuracy in vegetation coverage estimation. Therefore, it is more accurate to calculate the values of $NDVI_{soil}$ and $NDVI_{veg}$ from images based on probability statistics. If the $NDVI_{veg}$ value and $NDVI_{soil}$ value are then taken as the maximum and minimum values within a given confidence interval, the influence of errors caused by remote sensing image noise can be eliminated to a certain extent [11-15].

In this paper, the cumulative probability distribution table of vegetation types and soil types in Tianzhu Tibetan Autonomous County is obtained through ENVI software statistics. Then, the probability distribution characteristics of the gray values corresponding to various types of pixels in the distribution table are analyzed. Based on the actual situation of vegetation coverage in the watershed, we determine gray value of NDVI pixel with a confidence interval [0.5%, 99.5%] and a confidence of 0.5% as the value of $NDVI_{min}$, while the gray value of NDVI pixel with a confidence of 99.5% is taken as the value of $NDVI_{max}$, so that $NDVI_{soil}$ equals to $NDVI_{min}$, $NDVI_{veg}$ equals to $NDVI_{max}$. $NDVI_{soil}$ and $NDVI_{veg}$ parameter table is formulated and formula (6) is used to calculate vegetation coverage in ArcGIS [15-20].

3.3.5 Calculation and classification of vegetation coverage

In ENVI 5.0, mask files of different vegetation types are created, and the cumulative probability distribution of NDVI is calculated using the mask files and the Compute Statistics tool. Using formula (6), we calculate vegetation coverage in ArcGIS 10 through the Raster Calculator tool.

It is stipulated that area with vegetation coverage less than or equal to 15% is non-covered area, and that with 15%-30% vegetation is low coverage area, which belong to the inferior coverage type. It is stipulated that area with vegetation coverage of 30% to 45% is a medium-low coverage area, which belongs to poor coverage. It is stipulated that area with vegetation coverage of 45% to 60% is medium coverage area, and the coverage is moderate. It is stipulated that area with vegetation coverage between 60% and 80% is a medium-high coverage area. It is stipulated that area with vegetation coverage greater than or equal to 80% is high coverage area [21-24].

Table 1 Coverage level threshold

Vegetation coverage index	≤0.15	0.15-0.3	0.3-0.45	0.45-0.6	0.6-0.8	≥0.8
Vegetation coverage level	non-covered area	low-coverage area	medium-low coverage area	medium coverage area	medium-high coverage area	high coverage area

3.4 Dynamic change spatial model of vegetation coverage

According to the three kinds of spatial analysis model and annual change rate (*K*) model on land use dynamic change: new rate (*IRL*), transfer rate (*TRL*) and rate of change (*CCL*) proposed by Liu Shenghe [23], we analyze spatial process of vegetation coverage change of Tianzhu Tibetan Autonomous County in 5 years. The calculation formula of the model is as follows:

$$TRL_i = (LA(i,t_1) - ULA_i)/LA(i,t_1)/T \times 100\% \quad (7)$$

$$IRL_i = (LA(i,t_2) - ULA_I)/LA(i,t_1)/T \times 100\% \quad (8)$$

$$CCL_i = (LA(i,t_2) + LA(i,t_1) - 2ULA_i)/LA(i,t_1)/T \times 100\% \quad (9)$$

$$K_i = (LA(i,t_2) - LA(i,t_1))/LA(i,t_1)/T \times 100\% \quad (10)$$

Where, $LA(i,t_l)$ is the area of land with type *i* vegetation coverage in the initial monitoring period, ULA_i is the unconverted area of land with type *i* vegetation coverage during the monitoring period, *T* is the monitoring time interval, expressed in years, $LA(i,t_2)$ is the area of land with type *i* vegetation coverage at the end of the monitoring period. Therefore, the rate of change is equal to the sum of the transfer rate and addition rate. The characteristic of the model is that it can simultaneously identify and consider changes of type *i* vegetation coverage land in the two opposite directions of transfer and addition [15].

4. Analysis on the Dynamic Characteristics of Vegetation Coverage in Tianzhu Tibetan Autonomous County

4.1 Analysis of interannual characteristics of vegetation coverage in the study area

Using the vegetation coverage of August in Tianzhu Tibetan Autonomous County with good vegetation growth from 2015 to 2019 as interannual data, the reclassification experiment of vegetation coverage in Tianzhu Tibetan Autonomous County was carried out according to the classification standards in Table 1, and the results are shown in Table 2 and Figure 2.

Table 2 2015-2019 Vegetation coverage classification statistics (Unit: km²)

Category	Year 2015	Year 2016	Year 2017	Year 2018	Year 2019
non-covered area	83.31	54.44	69.69	65.63	65.19
low-coverage area	564.69	837.19	825.25	443.25	240.13
medium-low coverage area	1277.63	1063.44	1193.94	1228.56	598.50
medium coverage area	1014.31	932.38	1001.38	980.00	1256.81
medium-high coverage area	3255.43	3142.75	2922.43	2635.69	3324.31
high coverage area	359.13	524.31	541.81	1201.37	1069.57

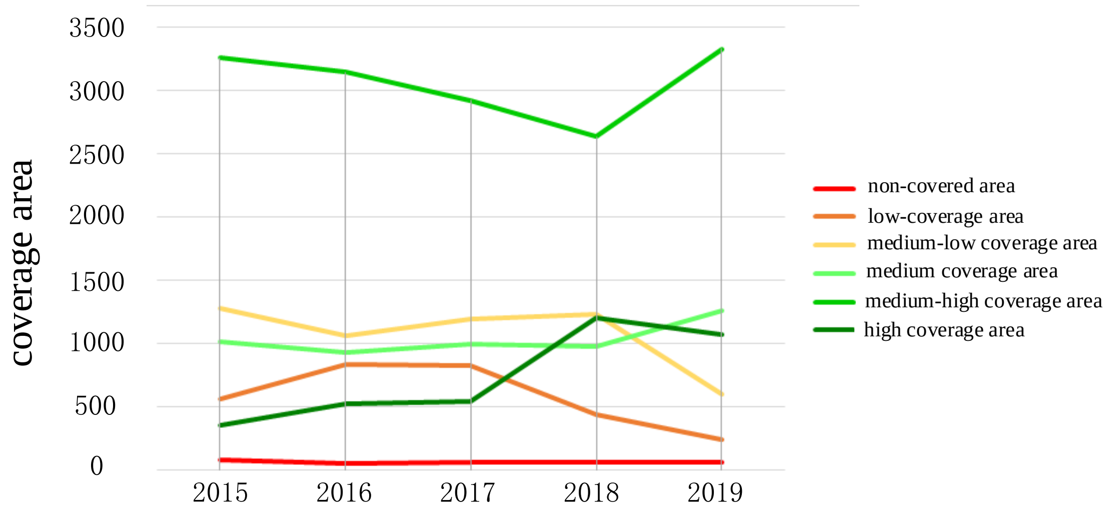
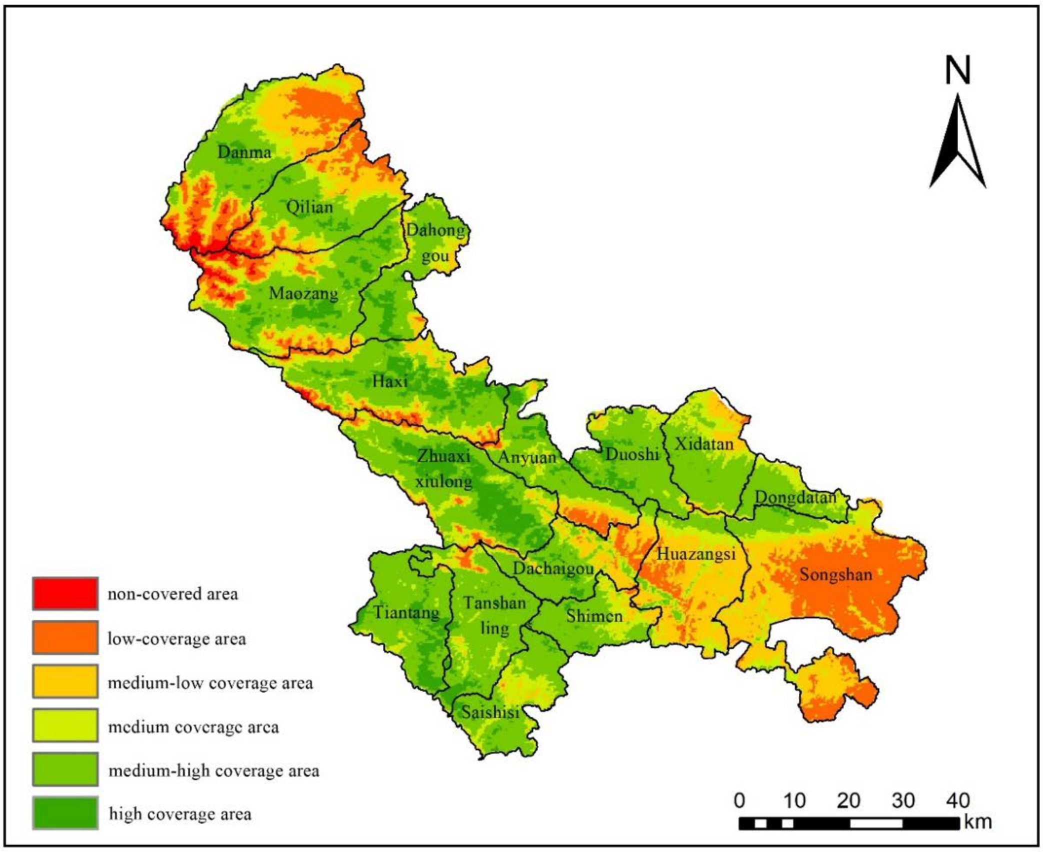
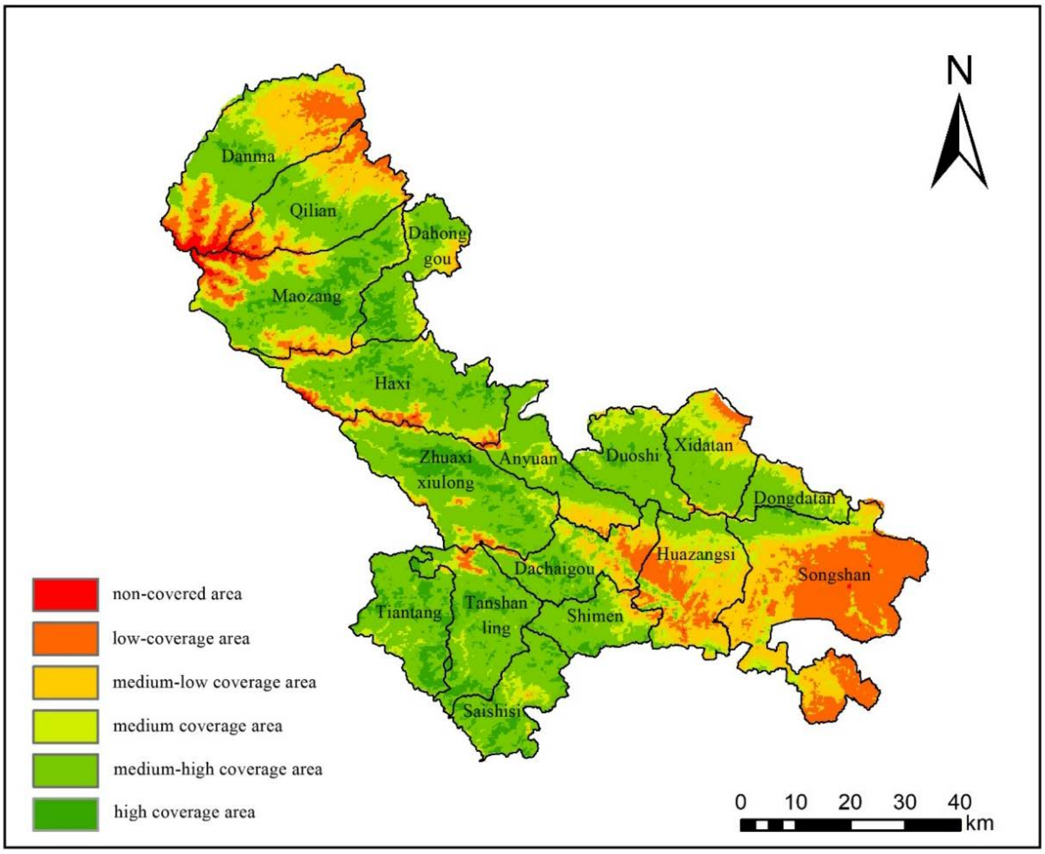


Figure 2 2015-2019 Statistical line chart of vegetation coverage classification



(a) 2015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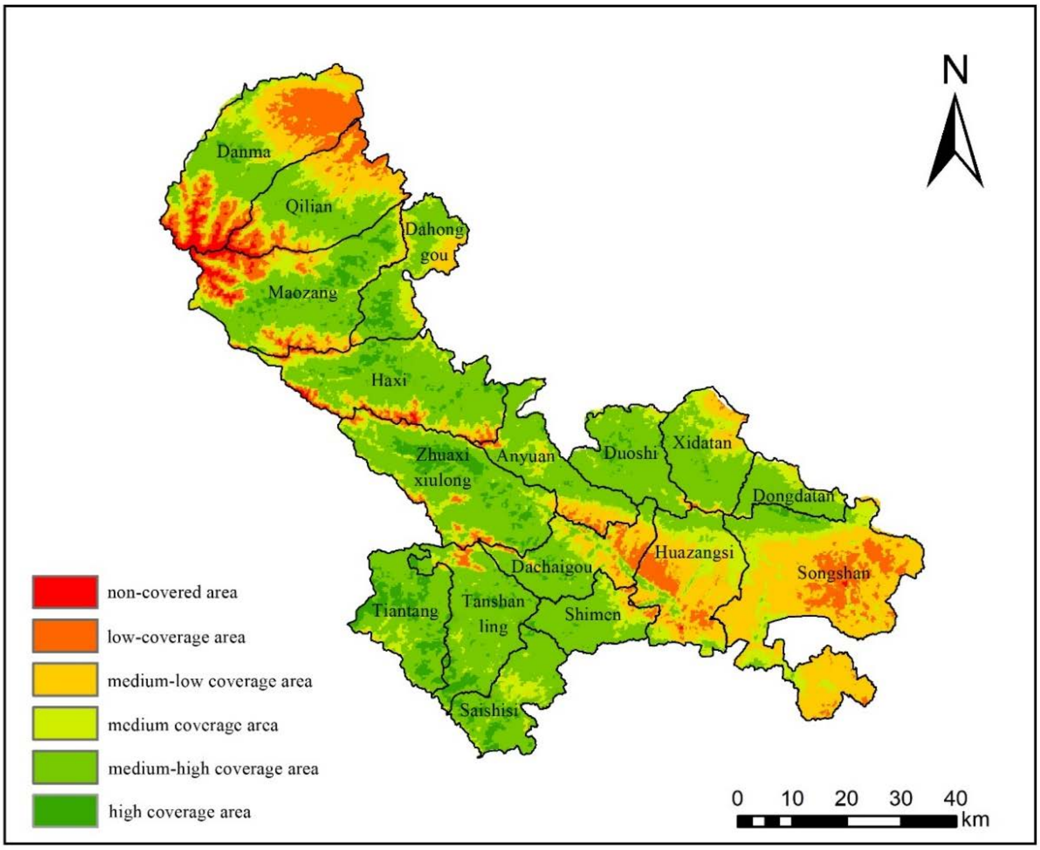
(b) 2016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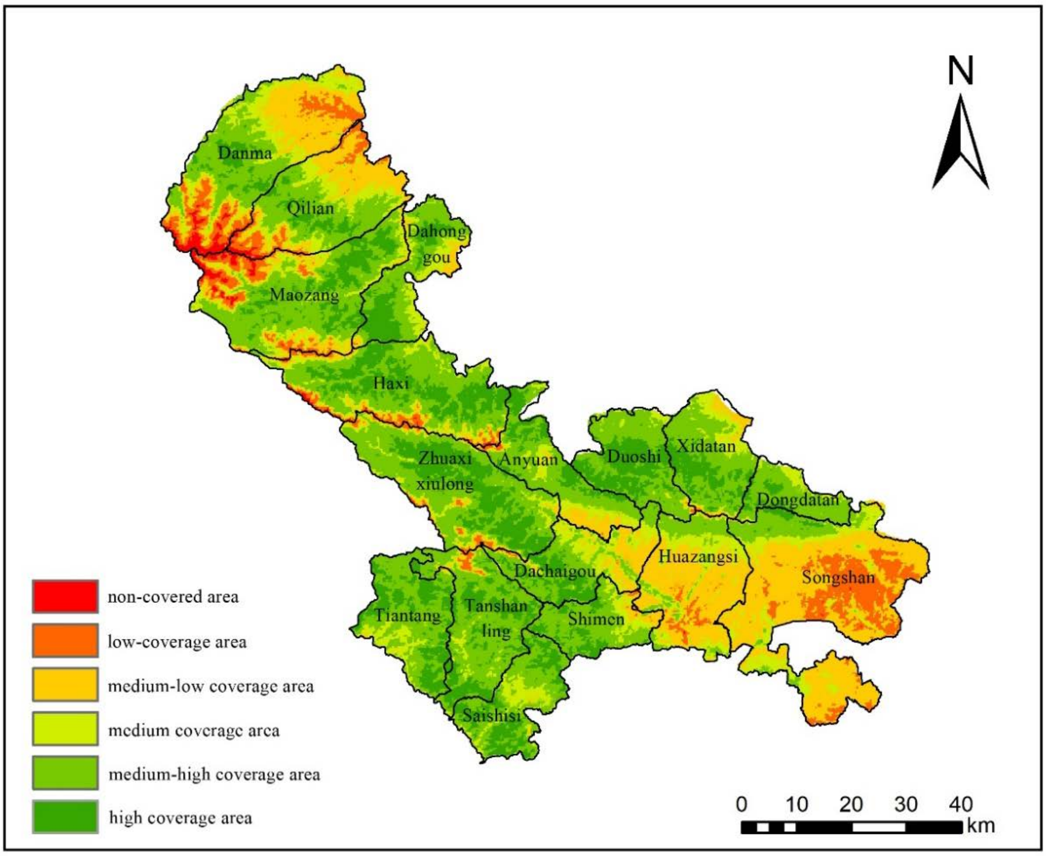
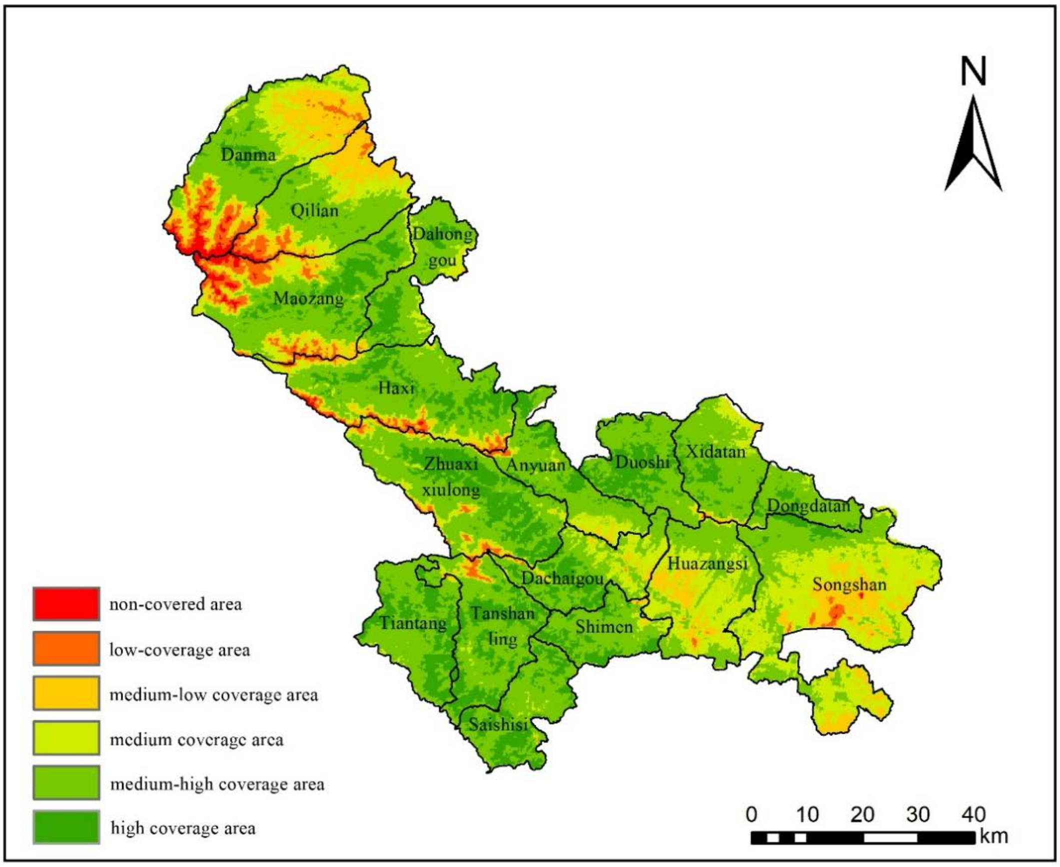
(c) 2017



(d) 2018



(e) 2019

Figure 3 The vegetation coverage of Tianzhu Tibetan Autonomous County in 2015-2019

According to the analysis of vegetation coverage and area data in the study area based on ArcGIS 10, in terms of spatial distribution, due to the high altitudes in the southwest of Danma Township, the west of Qilian Township, the northwest of Maozang Township, the northwest and the south of Haxi Township, the plateau frozen earth is not suitable for vegetation growth, so the vegetation coverage does not change significantly in 5 years. The change is the most significant in Huazangsi Town and Songshan Town. Most of Songshan Town is non-covered area in 2015, which become medium coverage area and medium-low coverage area in 2019.

According to figure 3, seen from the analysis of inter-annual coverage changes, non-covered area decreases from 83.31 km^2 in 2015 to 69.69 km^2 in 2017, showing significant changes in two years. However, due to inherent factors such as altitude and climate, the annual change after 2017 is less than 0.5 km^2 and tends to stabilize. The low coverage area begins to decrease after increasing to the extreme value of 837.19 km^2 in 2016, with a total decrease of 597.06km^2 by 2019. The medium coverage area and the medium-low coverage area decrease slightly from 2015 to 2018, and in 2019, the medium-low coverage area decreases to a minimum of 598.5 km^2, and the medium coverage area increases to a maximum of 1256.81 km^2. The medium-high coverage area and the high coverage area present an overall growth trend, of which the high coverage area increases to a maximum of 1201 km^2 in 2018, while the medium-high coverage area decreases to a minimum of 2635.69 km^2 in 2018 and then increases sharply to 3,234.31 km^2 in 2019. Seen from the total coverage of each level, the non-covered area, low and medium-low coverage areas present negative growth, while the medium, medium-high, and high coverage areas present positive growth. High coverage area has the biggest increase of 710.42. km^2, while medium-low coverage area has the biggest decrease of 679.13 km^2.

4.2 Analysis of changes between different vegetation coverage levels in the study area

In the ArcGIS 10 software, the vegetation coverage map from 2015 to 2019 is reclassified according to the vegetation coverage classification standard in Table 1, and the spatial overlay analysis function is used to obtain the area transfer matrix and the level change rate transfer matrix of the vegetation coverage in 2015-2019. The results are shown in Table 3.

Table 3 The vegetation coverage transfer matrix from 2015 to 2019

	2019	Non-covered area	Low-coverage area	Medium-low coverage area	Medium coverage area	Medium-high coverage area	High coverage area
2015	Non-covered area	50.8125	14.75	0.0625	0	0	0
	Low-coverage area	14.125	188.5625	157.9375	80.0625	2.5625	0
	Medium-low coverage area	0.1875	34.9375	395.4375	694.25	103.6875	0.0625
	Medium coverage area	0	1.6875	44.5	407.6875	525.5625	0.5625
	Medium-high coverage area	0.0625	0.1875	0.5625	74.75	2303.625	256.5
	High coverage area	0	0	0	0.0625	388.875	812.4375

It can be seen from the matrix that the diagonal elements are unchanged parts, the changed parts are mostly concentrated on the left and right neighboring elements of the diagonal elements, showing obvious trend of shifting to high-level coverage areas. Where, medium-low coverage area has the most transfer volume of 694.25 km^2 towards high coverage area (medium coverage area). Except for non-covered areas, all the other five levels have degraded to low-level coverage areas. High coverage area has the largest transfer volume of 388.875 km^2, which suggests that the vegetation system in this area is relatively fragile and prone to vegetation degradation.

4.3 Spatial model analysis of the dynamic change of vegetation coverage

In order to quantitatively analyze the spatial change process of vegetation coverage in different districts of Tianzhu Tibetan Autonomous County, this study uses four theoretical models of transfer rate (TRL), addition rate (IRL), change rate (CCL), and annual change rate (K) to analyze vegetation coverage in Zhu Tibetan Autonomous County. Based on the model formula introduced above, the spatial dynamic change index data of vegetation coverage in different districts of Tianzhu Tibetan Autonomous County can be derived according to the vegetation coverage area change data at all levels and the vegetation coverage area transfer matrix data during different periods from 2015 to 2019, as shown in Table 4.

Table 4 Dynamic change index data table of vegetation coverage

Level	Transfer rate (TRL)	Addition rate (IRL)	Change rate (CCL)	Annual change rate (K)
High coverage area	0.21	1.89	2.47	1.92
Medium-high coverage area	0.49	0.76	3.25	0.81
Medium coverage area	0.32	0.21	0.35	0.15
Medium-low coverage area	6.08	1.81	7.90	-4.26
Low coverage area	5.56	1.90	7.47	-3.65
Uncovered area	1.85	1.29	0.15	-0.56

The results show positive changes in the annual change rate in high coverage, medium-high, and medium coverage areas in Tianzhu Tibetan Autonomous County. The high coverage area has the highest annual change rate (K) of 1.92, medium coverage area has the lowest annual change rate of 0.15 among the six levels, while the medium-high coverage area has the highest change rate (CCL) of 3.25, indicating that the vegetation in the medium-high coverage area is most affected by external factors. The vegetation coverage in the medium-low coverage area, low coverage area and non-covered area presents negative change, with vegetation transfer rate higher than that in the positive change area. Where, medium-low coverage area has the highest annual change rate. Combining its transfer rate (TRL) and Table 3, it can be seen that medium-low coverage area has the biggest transfer volume and the fastest rate.

This suggests that the vegetation in medium-low coverage area, low coverage area and non-covered area tends to shift to higher vegetation levels, and the vegetation area in high-coverage area with the best vegetation coverage tends to grow.

4.4 Spatial evaluation of vegetation coverage

According to Table 2, the average annual NDVI of the study area increases from 57.9% in 2015 to 64.8% in 2019. The vegetation coverage change trend of the entire study area is classified into five levels: worse, unchanged, slightly better, better and obviously better. The spatial distribution of vegetation coverage in this area is evaluated as shown in the figure below.

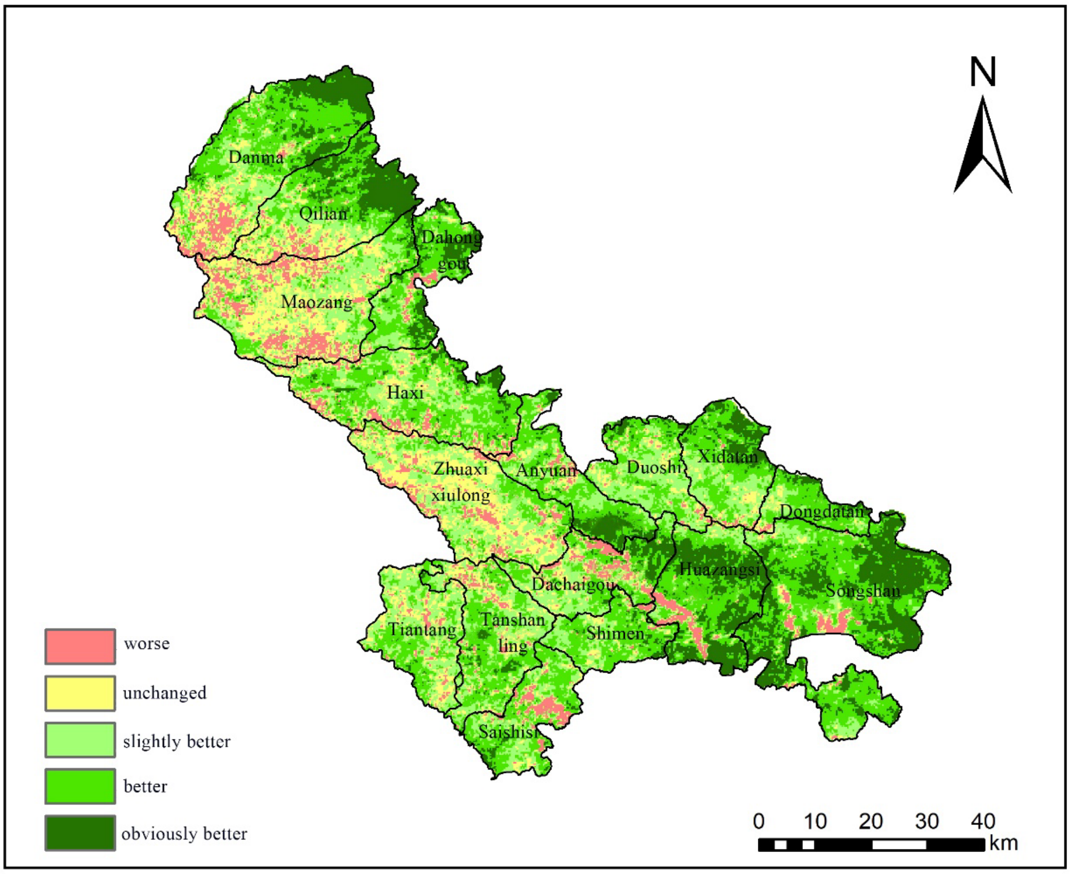


Figure 4 The trend chart of overall regional change

According to Figure 4, analyzed from the perspective of spatial distribution, the obviously improved areas are concentrated in the east of Danma Township, the east of Qilian Township, Huazangsi Town, the south of Anyuan Town, Dachaigou Town, and Songshan Town. Previously, these areas were mainly medium-low coverage areas, low-coverage areas. Worse areas are small and scattered distributed in the plateau and mountainous areas of Danma, Maozang and Qilian Township and the line from Tianzhu County to Anyuan Town (that is, the urban area around Lianhuo Expressway).

According to data analysis, the worse part accounts for 492.82 km^2 of the entire study area, the unchanged area is 999.56 km^2, the slightly better area is 1670.81 km^2, the better area is 2340.06 km^2, and the obviously better area is 1051.25 km^2. On the whole, there is obvious trend of improvement.

5. Conclusion

In summary, the overall vegetation coverage of Tianzhu Tibetan Autonomous County displays an upward trend from 2015 to 2019. The vegetation in medium-low coverage area, low coverage area, and non-covered area tends to shift to higher vegetation levels. The vegetation area of high coverage area with the most vegetation coverage is increasing, and medium-low-coverage area exhibits the most significant shift to higher levels, such as Huazangsi Town and Songshan Town. The two areas are mostly shallow mountains suitable for plantation of artificial forests to greatly increase the vegetation coverage, conservation water. However, due to the plateau permafrost and the plateau monsoon climate in the Qilian Mountains, it is not suitable for vegetation growth, there are still a small part of the area with small changes in vegetation coverage and even vegetation degradation. For vegetation degradation in plateau areas, the local government should pay attention to it and promptly implement ecological restoration projects and glacier environmental protection projects. For vegetation degradation in urban areas, it is recommended to implement system of ecologically well-off villages and towns, vigorously support the planting of trees, shrubs, flowers, and construct small parks and green spaces to improve the urban environment.

On the whole, it is not difficult to predict that as long as the basic national policy of environmental protection remains unchanged, the vegetation coverage of Tianzhu Tibetan Autonomous County will become higher and higher and the ecological environment will improve year by year. However, judging from the present situation, the task of environmental protection still has a long way to go. In particular, in the plateau areas in the northwest, the cultivation intensity and survival rate of plateau vegetation should be increased. The area of urban residents and industrial land should be rationally planned, the basic national policy of environmental protection should be maintained, so that environment development is valued in efforts to develop the economy.

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