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Analysis of Vegetation Coverage Dynamics of YongDeng County Using Normalized Difference Vegetation Index (NDVI) and Pixel Binary Model

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Abstract
Under the current background of global climate change, it is very important to study the temporal and spatial characteristics of vegetation cover which will provide a scientific basis for ecosystem management decisions that will protect the integrity of biodiversity and ensure a continuous supply of valuable ecological services. The objective of this study was to use the normalized difference vegetation index and the pixel binary model in ENVI to analyze the vegetation cover dynamics of YongDeng County using 1993, 2001, 2009, and 2017 satellite images. Satellite images were obtained from the Geospatial Data Cloud (*Http/westdc.westgis.ac.cn*). Combined with the vegetation coverage information and unique ecological characteristics of the study area, the vegetation coverage types were classified into four grades as Grade I (Bare land, water, and built-up environment), grade II (Low yield grassland and sparse vegetation classified), grade III (Middle grassland and vegetation of cultivated land) and grade IV (Dense woodland and shrubs). The results showed a dynamic trend in the different grades of vegetation cover in the study area from 1993 to 2017. Grade I vegetation-covered an area of 1208.72 km² and 1098.09 km² in 1993 and 2001 respectively but decreased to 375.99 km² in 2009 and finally increased slightly to 398.88 km² in 2017. Grade II vegetation cover did not show significant changes over the years considered for this study. It covered an area of 3821.2 km² and 3803.1 km² in 1993 and 2001 respectively. In 2009 and 2017 it covered approximately 3769.2 km² and 3787.82 km² respectively. Grade III vegetation cover showed an increasing trend from 1993 to 2017. From 334.76 km² in 1993, it increased to 468.28 km² and 980.39 km² in 2001 and 2009 respectively, and finally increased further to 1008.5 km² in 2017. Grade IV vegetation-covered an area of 4552.62 km², 442.6 km², and 667.52 km² in 1993, 2001, and 2009 respectively and finally reduced slightly to 596.64 km² in 2017. Economic development in areas such as mining, construction, and urbanization played a major role in [illegible] disturbances as a result of their inaccessible nature to humans. Expansion and Continues farming throughout the year as a result of the presence of an irrigation system in the area accounted for the increasing trend of Grade III vegetation cover. This study reveals there is an urgent need for measures to be put in place to mitigate activities that lead to the removal of vegetation cover as this may have serious implications on the supply of important ecological services.

Keywords: Vegetation coverage, YongDeng, NDVI, Pixel Binary model, dynamic analysis
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1. Introduction

Vegetation, as an important part of the terrestrial ecosystem, is a sensitive indicator of climate and human factors on the environment. The change of vegetation coverage, which represents the degradation or restoration of large scale vegetation, is the most direct manifestation of the impact of the natural evolution of human behavior on the ecological environment (Gürsoy & Atun, 2019). Vegetation respond to climate change, and indicates the magnitude of climate change through its distribution to soil and water conservation, climate regulation, and the stability of the whole ecosystem (Pearson et al., 2013);(Seddon et al., 2016),(Gottfried et al., 2012). Under the current background of global climate change, it is very important to study the temporal and spatial characteristics of vegetation cover which will provide a scientific basis for ecosystem management decisions that will protect the integrity of biodiversity and ensure a continuous supply of valuable ecological services.

In the past, researchers spent a lot of time and manpower to assess the vegetation coverage information of a particular study area, but the extraction of information had certain limitation, resulting in the generation of data which did not give a true reflection of the actual situation. Also, they could not carry out spatio-temporal analysis due to lack of technology. But with the rapid development and advancement of remote sensing technology which has the characteristics of fast acquisition of data, short period and strong timeliness, it is now possible to monitor the change of regional vegetation cover in a large scale and continuous-time (Eismann, 2012); (Awange & Kyalo Kiema, 2013)(Toth & Jóźków, 2016). It has great advantages in processing vegetation coverage information and plays an indelible role in the optimization design of land use and the sustainable development of humans and nature (Ma et al., 2019)(Fonji & Taff, 2014)78.

The vegetation index is a combination of different bands of satellite detection data, which can reflect plant growth, vegetation coverage, and biomass (Viña et al., 2011);(Clevers & Gitelson, 2013)910. At present, NDVI (Normalized vegetation index), RV (ratio vegetation index), EVI (enhanced vegetation index), and GVI (green vegetation index) are widely used in vegetation coverage research. Among them, NDVI is the most widely used and has been proven to reflect the changes of vegetation cover, biomass, and ecosystem parameters, and it is one of the most effective parameters to evaluate vegetation status (Hill, 2013)(Tian et al., 2015)(Pettorelli, 2013)(Cao et al., 2018)13141516.

Using different models, several researchers have successfully used NDVI to study the dynamic change of vegetation coverage at the temporal and spatiotemporal scale. For example (Dong et al., 2019); (F. Liu et al., 2019); (Zhu et al., 2019) and many other authors have successfully used NDVI to analyze the temporal and spatial changes in vegetation cover. It is therefore without a doubt that NDVI has helped to advance research in the area of vegetation coverage dynamics. Based on previous research methods, this paper uses the ETM+ image of YongDeng County in 1993, 2001, 2009, and 2017 as the data source to extract the normalized vegetation index (NDVI) of the area, and then apply the pixel dichotomy model to estimate the vegetation coverage dynamics of YongDeng County of Gansu Province to provide reliable data for ecosystem management decision.

2.0 Materials and methods

2.1 Study area

YongDeng County is a fragile ecological zone located in Gansu Province and is found at Longitude 102°36' to 103°45' E and Latitude 36°12' to 37°07' N. The county has 13 towns and covers an estimated area of about 6090 km² and comprises of naturally hilly landforms with the north-w estern part having natural forest. Flowing through the southern part of the study area is the yellow River. The study area has a continental type of climate with an average temperature of 5.9 °C. The total population as at 2010 was 522,000 with an annual growth rate of 7.41%.

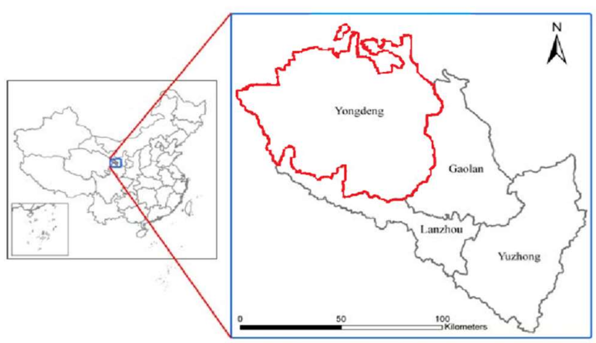


Fig. 2.1 study area

2.2 Data source

Remote sensing image data comes from a variety of satellite products, mainly including Landsat series satellite digital products, MODIS land standard products, DEM digital elevation data products, etc. The ENVI processing software generally uses Landsat digital products, which have high resolution and multiple calculation bands. The Data (Landsat 8 ETM+ images of 1993, 2001, 2009, and 2017) for this study were acquired from Geospatial Data Cloud (*Http/westdc.westgis.ac.cn*). The satellite carries eight-band sensors that can sense visible light to infrared bands in different ranges, with a resolution of 30m.

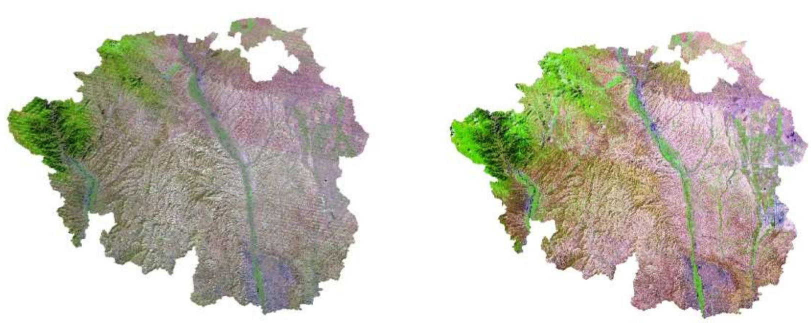
2.3 Vegetation coverage extraction method

The measurement methods of vegetation coverage are generally divided into surface measurement methods and remote sensing estimation (“Above Ground Biomass Estimation Methods and Challenges: A Review,” 2019); (Alam et al., 2018). Surface measurement is used for measurement on the field whereas remote sensing estimation is often used for regional measurement(Anurogo et al., 2018) (Knauer et al., 2018). The surface measurement is widely used in low-grade vegetation cover and small surface area. Because the method is limited by a series of factors such as weather and environment, and large-scale measurement consumes manpower and material resources, the larger the measurement area, the greater the error of the results obtained. Therefore, the accuracy obtained by this method is questionable; it is difficult to dynamically measure the point data measured by the surface measurement method in large space, and to dynamically analyze the vegetation coverage in a large area.
In contrast, satellite sensors can be used to obtain the research area’s images at any given time. The data source is not time-consuming, and the data information is not limited by weather, environment, and other factors. Moreover, the remote sensing image used by the remote sensing estimation method has the characteristics of hyperspectral resolution and spatial resolution, and provide real-time change data, which can reflect the vegetation coverage information in regional measurement, and provide convenience for the analysis of vegetation coverage change trend. The processing flow of this method is as follows; first radiometric calibration, then rapid atmospheric correction, then image strip removal, vector cutting according to vector boundary map, registration of the cut image, NDVI calculation with remote sensing image processing software, NDVI gray value of ETM image in different periods obtained, and finally, vegetation coverage is estimated by pixel binary model.

2.4 Image processing

After the rapid atmospheric correction of downloaded images to obtain the remote sensing image, the strip covering the images were removed to obtain the vector file map of YongDeng County. ENVI software was used to cut the remote sensing image according to the vector file to obtain the image map of YongDeng County as shown in Figure 2. Based on the image of 2017, the comparison between 2009, 2001, and 1993 was made. The ground control point procedure was used to register the 2017 satellite image. In selecting the control points, 30 points with obvious characteristics are selected to match each other, which requires that the overall error after registration is limited to 0.5 pixels, and the corrected parameters are selected and the selected image is output. (Castejon et al., 2015);(Wang et al., 2015).

1993 image **2001 image**



2009 image **2017 image**

Figure 2.2 satellite images of YongDeng County (1993-2017)

2.5 Extraction of normalized vegetation index

NDVI is a parameter used to test vegetation coverage area, which can reflect the influence of plant canopy background, such as dead leaves, moist land, etc. (Alam et al., 2018). The spectral information of ground objects is obtained by sensors, and then the ENVI image processing software is used also known as a standardized vegetation index. Because NDVI can eliminate the influence of local and satellite observation angle, cloud shadow, and other radiation changes related to the atmosphere, and enhance the sensing ability to the ground objects it is the most widely used of the 40 vegetation indexes at present (Karnieli et al., 2010);(Q. Liu et al., 2020). It objectively reflects the land use and vegetation coverage of the research area corresponding to each pixel to a certain extent. Expressed as NIR (0.7~1.1μm) in the near-infrared band and visible Red band (0.4-0.7μm), these two, the ratio of the difference between values and the sum of the two values

$$DNVI = \frac{NIR - R}{NIR + R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where R represents the reflection value of the ground object in the red band
NIR represents reflection value of ground objects in the near-infrared band
With the above equation, the NDVI of the study area was generated as shown in **figure 3**

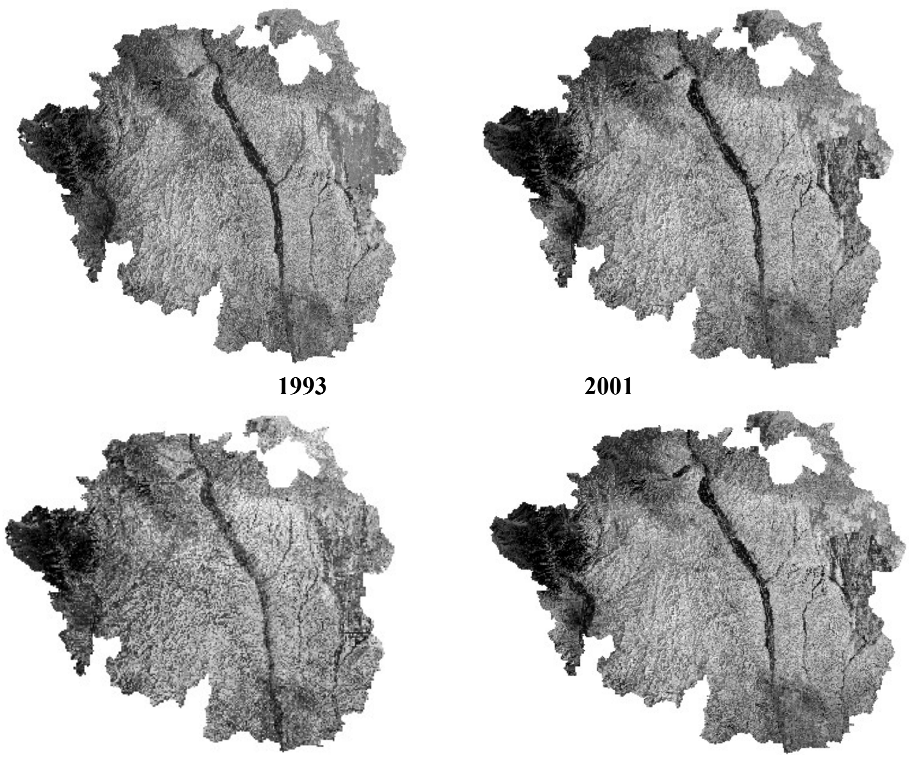


Figure 2.3 NDVI maps of the study area under the different years (1993-2017)

2.6 Estimation of vegetation coverage with 25 pixel binary model

NDVI has a good performance in estimating vegetation coverage in the binary pixel model, and the accuracy of the results is more than 95% (Dong et al., 2019). Each corresponding pixel to the image on the surface is assumed to have two forms, i.e. vegetation that is completely covered and those that are not. Each pixel's NDVI is the average values of NDVI which correspond to areas that have vegetation and areas that does that have.

The weight is the ration of the two vegetation types in the pixel, therefore the calculation formula of vegetation coverage is expressed as;

$$V_C = \frac{NDVI - NDV_{soil}}{NDVI_{veg} - NDVI_{soil}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where $NDVI_{soil}$ is the NDVI of the area without vegetation coverage (bare land) and $NDVI_{veg}$ Is the pixel NDVI value of the area with complete vegetation coverage (vegetation land).

According to the land use type map of YongDeng County, combined with the vegetation coverage information and unique ecological characteristics of the county, the vegetation coverage types were classified into four grades, as shown in **Table 2.1**. ENVI processing software was used to obtain the time series (1993-2017) vegetation coverage maps as shown in **figure 4**.

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Table 2.1 Vegetation coverage classification of YongDeng County

Grade of Veg. cover	Land-use type	Level of vegetation coverage
I(<25)	Bare land, water, and built-up environment	Lower vegetation cover
II (25~50)	Low yield grassland and sparse vegetation	Low vegetation cover
III (50~75)	Middle grassland and vegetation of cultivated land	Medium vegetation
IV (>75)	Dense woodland and shrubs	High vegetation cover

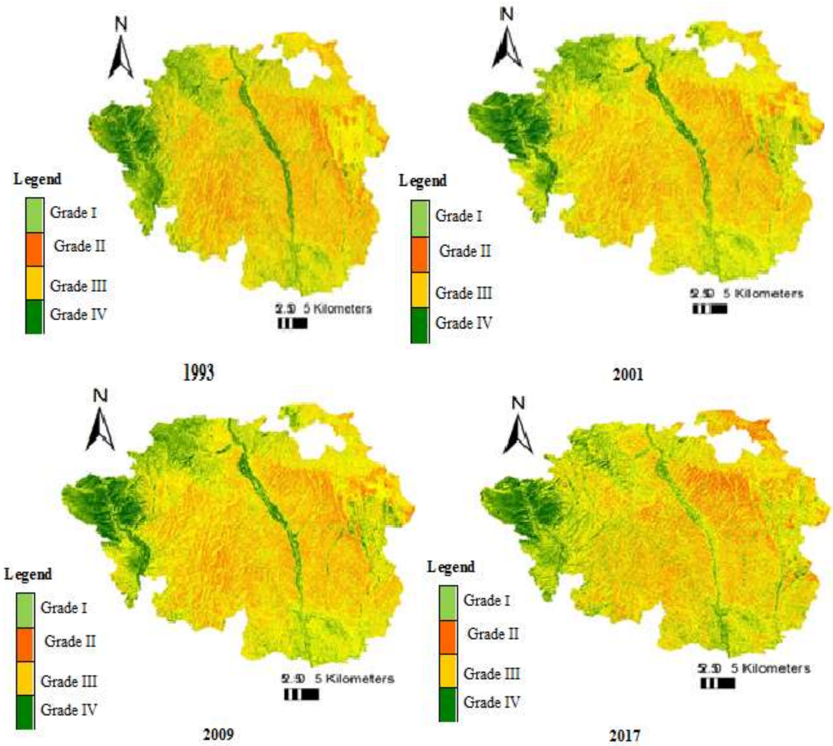

Fig 2.4 produced pixel binary model vegetation cover

3.0 Results and discussion

Based on the analysis of the four different year's images (Fig. 4) the vegetation coverage area and the area occupied in YongDeng counted were calculated as shown in Table 3.

Table 3.1 vegetation Grades and their coverage in the study area (1993-2017)

	1993		2001		2009		2017	
Grade of Veg. cover	**Area (Km²)**	**Per. (%)**	**Area (Km²)**	**Per. (%)**	**Area (Km²)**	**Per. (%)**	**Area (Km²)**	**Per. (%)**
I	1208.72	20.9	1098.09	18.4	375.99	6.7	396.88	6.8
II	3821.2	65	3803.01	65	3769.28	64.5	3787.82	64.8
III	334.76	6	468.28	8	980.39	16.8	1008.5	17.3
IV	4552.62	8	442.63	8	667.52	11.4	596.64	10.2

The results in Table 1 above indicate that the vegetation cover area of grade I (bare land, water, and built-up environment) showed a dynamic trend under the various years of study. Covering an area of 1208.72 km² in 1993, it reduced to 1098.09 km² in 2001. There was a further reduction to 375.99 km² in 2009 but it increased slightly to 396.88 km² in 2017. YongDeng County has experienced rapid economic development in recent years as a result of the increasing development of industrial and construction industries. Consequently, the demand for accommodation, transport systems, schools, water supply, etc. has also increased over the years. This has led to the clearing of new land for development and other uses which has resulted in a reduction in vegetation cover area of grade I vegetation in the area.

Grade II vegetation cover type which was classified in this study as low yield grassland and sparse vegetation did not show a significant change from 1993 to 2017. In 1993 and 2001 it covered an estimated area of 3821.2 km² and 3803.01 km² respectively. In 2009 it reduced to 3769.28 km² but increases slightly to 3787.82 km² in 2017. Following the characteristic hilly nature of the study area, much of the low yield grassland cover are located on inaccessible mountains and therefore experience less disturbance from human activities. This might be a reason for the insignificant change in Grade II vegetation. From the images produced, significant portions of low yield grassland and sparse vegetation are distributed in the middle part of the study area and are far from areas where people inhabit. The distance of these lands makes their use for activities such as farming very discouraging and as a result, they experience fewer disturbances. This makes their vegetation intact even with the generation of new species springing up.

Significant changes in grade III vegetation cover (middle grassland and vegetation of cultivated land) were noted from 1993 to 2017. It covered an area of 334.76 and increased to 468.28 in 2001. It further increased from 980.39 km² in 2009 to 1008.5 in 2017. Generally, the grade III vegetation cover showed an increasing trend from 1993 to 2017. An increase in agricultural activities to meet the growing demand of the population means the cultivation of more crops in the area. In the study area, the cultivation of crops is done throughout the year due to the presence of an efficient irrigation system that ensures a continuous supply of water. As a result, there is a constant presence of vegetation cover offered by the leaves of cultivated crops.

The vegetation coverage of Grade IV (Dense woodland and shrubs) showed a dynamic trend from 1993 to 2017. It covered an estimated area of 4552.62 km² and 442.63 km² in 1993 and 2001 respectively. The vegetation covers of this Grade increased to 667.52 km² in 2009 but reduced in 2017 to 596.64. Following the Chinese government's intervention policy of returning farmlands to forest lands through the green for grain project and other conservation programs, the area has witnessed a significant increase in vegetation coverage in previously degraded lands. At the county level, great importance to the implementation of afforestation, beautification of home, and other conservation programs have been introduced. This has led to the cultivation of trees and the creation of aesthetic gardens in strategic areas which have contributed significantly to an increase in the vegetation cover of the area.

3.1 Vegetation coverage change transfer and change intensity

Table 3 below shows the vegetation change transfer observed from 1993 to 2017. In the study area, rainfall and temperature variability coupled with the various land-use systems has contributed significantly to the conversion of one-grade vegetation type to others.

Table 3.2 vegetation change transfer (km²) from 1993 to 2017

		2017			
Vegetation cover Grade		Grade I	Grade II	Grade III	Grade IV
1993	I (<25)	1208.72	0.76	0.32	1.45
	II (25~50)	1.45	3787.82	0.1	0.76
	III (50~75)	1.05	0.37	1008.5	0.56
	IV (>75)	0.33	0.1	0.0	596.64

The results indicate that from 1993, about 0.33km² and 0.1km² of grade I and grade II vegetation cover type respectively were converted to grade IV vegetation cover type. This follows the implementation of the government's conservation programs of returning farm and bare lands to forest lands. Grade I vegetation also lost about 1.45km² to grade II vegetation type as a result of the removal of vegetation for agricultural activities and urbanization. Grade III vegetation cover was also changed to other vegetation cover types losing 0.56 km², 0.37km², and 1.05km² to grade IV, grade II and grade I vegetation cover types. Generally, most of the vegetation grade types were transferred into grade IV vegetation cover type in the study area.

Table 3.3 vegetation change intensity (%) from 1993 to 2017

Vegetation cover Grade	1993-2001	2001-2009	2009-2017	1993-2017
I (<25)	-0.03	-0.07	-0.92	-0.34
II (25~50)	0.41	-0.53	-0.21	-0.11
III (50~75)	1.98	0.65	1.05	0.19
IV (>75)	2.11	2.81	1.31	1.24

Table 3.3 above shows the changing intensity of the various Grades of vegetation types in the study area. Grades III 3 and IV, vegetation cover types showed a positive change intensity index of 0.19 and 1.24 respectively from 1993 to 2017. The positive change intensity indexes of these two grades of vegetation indicate they increased over the years. Afforestation and other conservation programs as stated earlier were noted to be the driving forces for the increase in the vegetation cover of these two grades. Contrary to this, grades I and II showed negative change intensity of -0.34 and -0.11 respectively as the vegetation cover of these two reduced over the years. The conversion of the lands on which these vegetation covers are found, into other land-use types such as construction, mining and agricultural production accounted for the reduction in the vegetation cover of grade I and II vegetation cover types in the study area.

4.0 Conclusion and recommendation

In this paper, the pixel dichotomy model is used to study the vegetation cover dynamics of YongDeng County in

1993, 2001, 2009, and 2017. According to the analysis of the results of the study on the dynamic situation of vegetation cover, in recent years, the economy of YongDeng County has been developed rapidly, and a large number of industrial constructions have led to the removal of vegetation cover. At the national and county level, the implementation of conservation programs such as afforestation, beautification of homes, and the environment through the creation of aesthetic gardens have had a significant influence on vegetation cover. Through the analysis, it can be concluded that in the recent 23 years (1993-1027), the construction industry has been the main driving force that has had a great impact on the vegetation coverage of YongDeng County. Following this, it is recommended that urgent measures be put in place to control activities that lead to the removal of vegetation cover as this may affect the supply of valuable ecosystem service.

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