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Spatial-Temporal Variation and Topographic Effect of Vegetation Cover in Lvliang Mountains Area

Huixia Zhang, Yujie Li, Yongmei Li and Na Zhang

Institute of Geographical Science, Taiyuan Normal University, Jinzhong, Shanxi, 030619, China

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Corresponding Author:
Huixia Zhang
Institute of Geographical Science, Taiyuan Normal University, China
Email: zhanghuixia120@163.com

Abstract: Vegetation cover is an important ecological climate parameter and to a certain extent, it indicates the change in the regional ecological environment. To explore the impact of different terrain factors on the vegetation cover in the Lvliang mountains area and the change and improvement of vegetation cover in this area. MODIS NDVI data from 2010 to 2019 were selected to explore the spatial differences in vegetation cover at different elevations, slopes and aspects by using trend analysis and a terrain difference correction method. The results were as follows. (1) Over the last 10 years, vegetation cover was dominated by the medium-low cover and medium cover. The low cover and medium-low cover were in decline, while the medium cover and medium-high cover were increasing. (2) The proportions of the significantly reduced, basically unchanged and significantly increased vegetation cover changes were 18.49, 48.4 and 33.11%, respectively. Vegetation change generally showed a recovery trend. (3) In terms of elevation and slope, the vegetation decrease type was dominant below an elevation of 1200 m; the vegetation unchanged type was dominant at elevations greater than 1400 m and a slope greater than 6°. The vegetation increase type was dominant in the areas with an elevation of 1200-1400 m and a slope of less than 6°. (4) the aspect had a little effect on vegetation. This research can evaluate the topographic effect of vegetation change more accurately and provide an evidence-based reference for ecological environment governance and ecological construction benefit evaluation in the Lvliang mountains area.

Keywords: Lvliang Mountains Area, Terrain Difference Correction, Trend Analysis, Vegetation Cover

Introduction

Vegetation plays a crucial role in water conservation, protection from wind, sand fixation, and maintaining ecological balance (Shen, 2018). Vegetation cover reflects the ratio of the vertical projected area of the aboveground part of vegetation to the total ground area, which is generally used to represent vegetation changes (Mu *et al*., 2012). Analysis of the changes in vegetation cover over different periods can generally improve our understanding of the internal relationship and action mechanism of different factors in the geographical environment, which can provide useful data for the protection and construction of ecological environments (Aly *et al*., 2016).

Vegetation is often used as a comprehensive indicator of eco-environmental change. Shen (2018) analyzed the relationship between vegetation cover change and terrain factors combined with the spectrum analysis. In early studies, Landsat series images were used to study the relationship between changes in vegetation cover and topographic factors in different regions (Chen *et al*., 2019; Tian *et al*., 2019a; Xiong *et al*., 2018; Zhang *et al*., 2018; Zhao *et al*., 2017; 2019). Subsequently, studies were based on MODIS-NDVI data to study vegetation cover (Dutta *et al*., 2015; Levin, 2016; Qiu *et al*., 2013; Otto *et al*., 2016). Zhu *et al*. (2017) used MODIS EVI data to study the spatial differences in vegetation cover in Chongqing using different topographic factors. Li *et al*. (2015) used MODIS-NDVI to analyze vegetation cover changes and differentiation characteristics in Guizhou Province from 2001 to 2010 and used a pixel dichotomy model, linear regression analysis, and other research methods to process the data. Chen *et al*. (2018) used MODIS-NDVI data, linear regression, and cluster analysis to study the changes in vegetation cover in Hubei Province. Wang and Guo (2018) used remote sensing and GIS technology to study the spatial pattern of topographic factors and vegetation cover in a karst landform area. Bi *et al*. (2012; Tian *et al*., 2019b) analyzed the relationship between vegetation index and terrain and the dominant impact of terrain on vegetation cover. Jabal *et al*. (2022) studied the impact of climate change on crop productivity using the MODIS-NDVI time series. Faye (2022) comparatively analyzed the meteorological drought based on the SPI and SPEI indices and (Ahmad *et al*., 2020) investigated the flow hydrodynamics in a compound channel with layered vegetated floodplains. In mountainous areas, terrain affects the distribution of vegetation and it is the most fundamental factor affecting ecological status. Studying the relationship between terrain (elevation, aspect, and slope) and changes in vegetation cover can show the distribution characteristics of vegetation. There are many studies on the relationship between vegetation cover and topographic factors (Pekin, 2016; Emran *et al*., 2018), but there are only a few studies on topographic differentiation. In our research, the terrain difference was considered and the F-test formula was deduced in trend analysis and applied to this study. MODIS-NDVI data were used to study the terrain difference.

Lvliang mountains area includes 20 counties, including 13 counties in Shanxi Province and 7 counties in Shaanxi Province. All 20 counties in the area are key counties of national poverty alleviation and development and old revolutionary base counties. Ecological and environmental issues have attracted the attention of relevant departments.

There are clear seasonal differences in the Lvliang mountains area. Spring and winter festivals are often affected by the dry and cold wind from the Mongolian Plateau. It is wet and hot in summer and autumn because the loess is easily eroded, there are frequent issues with drought, water flow cutting, water and soil loss, and reservoir siltation (Zhang and Liu, 2020), which have a substantial impact on vegetation cover. To evaluate the topographic effect of vegetation, change more reasonably, we selected13 national poverty-stricken counties in the Shanxi Province of Lvliang mountains area as the research area and processed MODIS Normalized Difference Vegetation Index (NDVI) data of the study area from 2010 to 2019 using ENVI5.3, ArcGIS10.2, and other software. The objectives of this study were as follows: (1) To analyze the temporal and spatial variation characteristics of vegetation cover. (2) To explore the change in vegetation cover by using the trend analysis method. (3) To correct the differences in topographic area. (4) To explore the influence of topographic factors (elevation, slope, and aspect) on vegetation cover.

Study Area and Data

Overview of the Study Area

Lvliang mountains area is located at the intersection of Shanxi Province and Shaanxi Province, in the middle reaches of the Yellow River. There are 13 counties in Shanxi, including four counties in Xinzhou City, four counties in Lvliang City, and five counties in Linfen City, as shown in Fig. 1. Its geological development is relatively complete and it is an important part of the Loess Plateau. The loess in the area is thick, loose, sparsely vegetated, with little and concentrated precipitation. The hills here are undulating and there are many gullies, resulting in serious soil and water loss. The eastern region has a relatively flat terrain and is the main agricultural area. The mountainous and semi-mountainous area accounts for 92% of the total area. It is a typical loess hilly and gully area with low vegetation cover, lack of water resources, large topographic relief, many gullies, and barren soil (Zhang and Liu, 2020).

Data Sources

The NDVI data used in this study was derived from the MOD13Q1 (16d maximum synthetic vegetation index product) data product in the MODIS data product on the NASA website (http://ecocast.arc.nasa.gov). The spatial resolution of the data is 250 m and the temporal resolution is 16 days. For the data, the Maximum Value synthesis method (MVC) was used to eliminate the impact of cloud cover, generate the monthly NDVI data for the region, and use the average method to generate the annual NDVI data. The study period was from May to October 2010–2019, the plant growth in this period is in the peak season, which can better analyze the temporal and spatial characteristics of vegetation. The county boundary data of Shanxi province comes from the second national land survey data and the Digital Elevation Model (DEM) data come from the SRTM data of the geospatial data cloud platform (http://www.gscloud.cn/), with a spatial resolution of 30 m and a resampling resolution of 250 m.

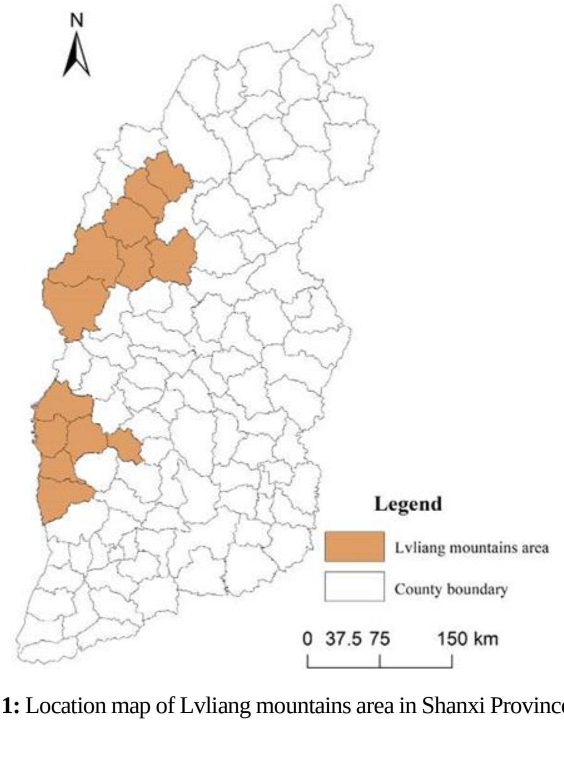
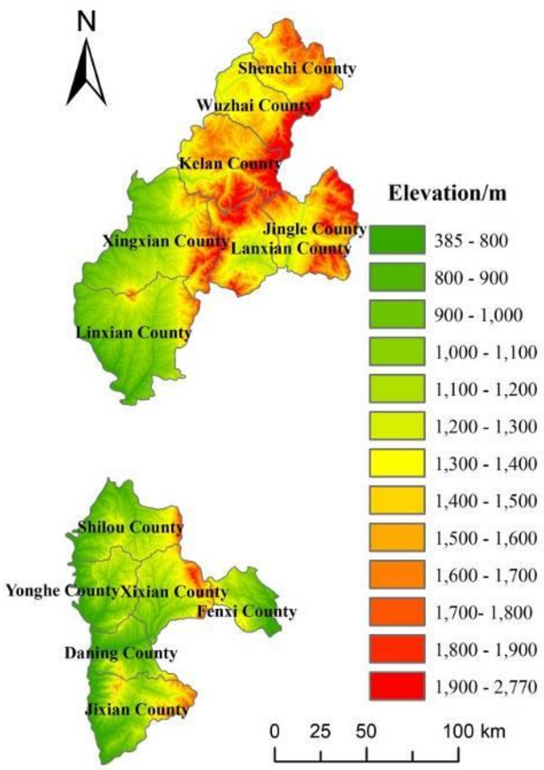


Fig. 1: Location map of Lvliang mountains area in Shanxi Province

Data Processing

The MOD13Q1 NDVI data used in the study were in EOS-HDF format. The maximum value of MOD13Q1 NDVI data in the study area was synthesized and processed to represent the vegetation cover of the area.

The terrain factors selected in this research include elevation, slope, and aspect. Slope and aspect data were mainly generated using DEM. According to the literature and the actual distribution of elevation in the Lvliang mountains area (Zhu *et al*., 2017), the elevation was divided into one level every 100 m. As the area above 1900 meters was very small, 1900-2770 was divided into one level and the elevation of the study area was divided into 13 levels in total, as shown in Fig. 2(a), which were 385-800 m, 800-900 m, 900-1000 m, 1000-1100 m, 1100-1200 m, 1200-1300 m, 1300-1400 m, 1400-1500 m, 1500-1600 m, 1600-1700 m, 1700-1800 m, 1800-1900 m and 1900-2770 m. Based on the classification principle of slope and aspect grade, according to the technical regulations for the second national land survey, the slope was divided into five grades, as shown in Fig. 2(b); namely, flat slope (≤2), gentle slope (2°-6°), slope (6°-15°), steep slope (15°-25°) and dangerous slope (>25°). The aspect was divided into five levels; namely, flat area, shady slope area (315°-45°), half-shady slope area (45°-135°), sunny slope area (135°-225°), and semi-sunny slope area (225°-315°), shown in Fig. 2(c).



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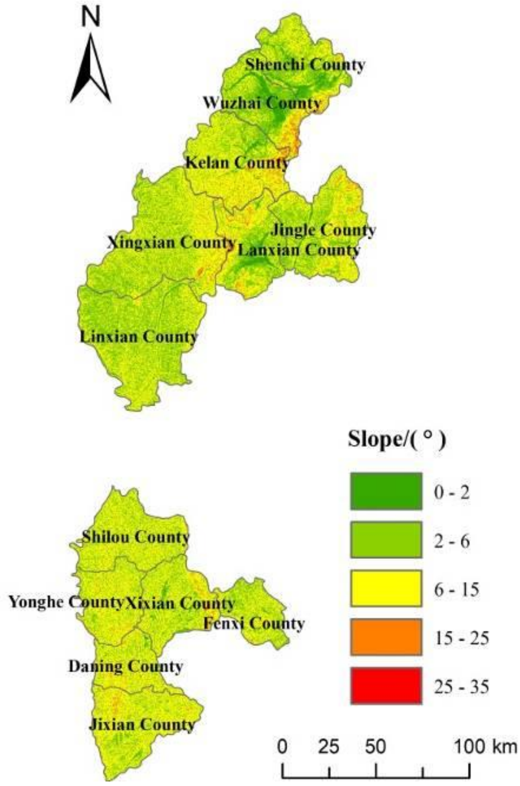

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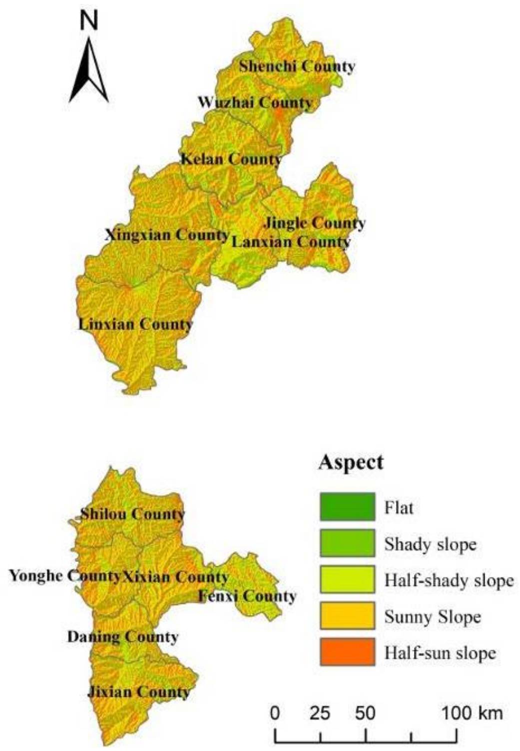

(c)

Fig. 2: The spatial distribution map of elevation, slope, and aspect in the Lvliang mountains area; (a) Elevation; (b) Slope; (c) Aspect

Materials and Methods

Vegetation Cover (FVC)

The calculation of vegetation cover adopted the dimidiate pixel model. The theory of the model assumes that each pixel can be decomposed into pure soil and pure vegetation. The pixel information S can be expressed as the sum of soil cover information S_{soil} and vegetation cover information S_{veg} (Zhang *et al*., 2018) Namely:

$$S = S_{soil} + S_{veg} \tag{1}$$

where, S_{soil} refers to the pixel value of pure soil and S_{veg} refers to the pixel value of pure vegetation. According to the principle of the dimidiate pixel model, $NDVI_{soil}$ indicates the $NDVI$ value of pixels without vegetation cover, and $NDVI_{veg}$ represents the $NDVI$ value of the pixel covered by pure vegetation. The Vegetation Cover (FVC) calculated by $NDVI$ can be expressed as:

$$FVC = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \tag{2}$$

In this study, 0.5% confidence was selected; i.e., the cumulative percentage of 0.5% is pure soil pixel and 99.5% is pure vegetation pixel (Zhu *et al*., 2017). The corresponding $NDVI$ are $NDVI_{soil}$ and $NDVI_{veg}$ respectively. The vegetation cover was divided into five levels according to the percentage: Low cover (0-20%), medium-low cover (20-40%), medium cover (40-60%), medium-high cover (60-80%), and high cover (80-100%) (Zhang *et al*., 2022).

The Trend Analysis

Trend analysis adopts the univariate linear regression calculation method, which is used to perform regression analysis on a group of time-varying sequence data by using the trend line, to predict its change trend. In this study, the least square method was used to fit the interannual variation trend of vegetation cover pixel by pixel. θ_{slope} represents the change in slope, $\theta_{slope}>0$ indicates that the vegetation is increasing, $\theta_{slope} = 0$ indicates that the vegetation has not changed, $\theta_{slope}<0$ indicates that the vegetation is decreasing. The θ_{slope} is tested by the F test. When the confidence is 95%, the critical value of F is 5.32. If the value of F is greater than 5.32, the changing trend is significant; if the value of F is less than 5.32, the changing trend is not significant. Based on the intersection analysis between the change trend map and the test map, the changes in vegetation are divided into three types: Significantly increased, basically unchanged, and significantly reduced (Zhu *et al*., 2017; Wang and Yan, 2020).

$$\theta_{slope} = \frac{n \times \sum_{i=1}^{n} i \times FVC_i - \sum_{i=1}^{n} i \sum_{i=1}^{n} FVC_i}{n \times \sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i\right)^2} \tag{3}$$

$$F = \frac{SSR}{SSE / (n-2)} \tag{4}$$

$$SSR = \sum_{i=1}^{n}\left(F\hat{V}C_i - \overline{FVC}\right)^2 SSE = \sum_{i=1}^{n}\left(FVC_i - F\hat{V}C_i\right)^2 \tag{5}$$

$$F\hat{V}C_i = \hat{\theta} + \theta_{slope} \cdot i,\ \hat{\theta} = \overline{FVC} - \theta_{slope} \cdot \bar{i} \tag{6}$$

where, i represents the year number from 1 to 10 and n represents the total number of years. FVC_i represents the vegetation cover in the ith year, SSR is the sum of squares of regression, SSE is the sum of squares of errors, $F\hat{V}C$ is the regression value of vegetation cover in the year i and $\overline{FVC}$ is the average vegetation cover in the study period.

Terrain Area Difference Correction

When studying the impact of terrain on vegetation change, there is often a change type, which has a small area in the terrain but accounts for a large proportion of the whole study area. This affects the rationality of evaluating the impact of different terrain factors on vegetation change. Therefore, to eliminate the influence of different terrain factors on the absolute area and clarify the influence of different terrain conditions on the distribution of vegetation change types and their evolution trend, it is necessary to correct the difference in terrain area. The terrain area difference correction coefficient K is used to eliminate the uncertainty of vegetation restoration evaluation caused by different terrain absolute areas. The calculation formula of K is as follows (Zhu *et al*., 2017):

$$k = \frac{s_{ie}}{s_e} / \frac{s_i}{s} \tag{7}$$

where, S_{ie} refers to the area of i change type in e terrain. S_e represents the total area of e terrain, S_i represents the total area of i change type and s represents the total area of the study area. $K>1$ indicates that the I change type is dominant in e terrain distribution; $K = 1$ indicates that the change type of i is stably distributed in e terrain; $K< 1$ indicates that the i change type is not dominant in e terrain distribution (Li *et al*., 2015). The dominance analysis is carried out according to the calculated K value.

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Results and Analysis

Temporal and Spatial Variation Characteristics of Vegetation Cover

From 2010 to 2019, the vegetation in the Lvliang mountains area was dominated by medium-low cover and medium cover and the total proportion of the two exceeded 75% of the total. The medium cover and medium-high cover mainly showed an upward trend and the low cover and medium-low cover mainly showed a downward trend. The high cover was extremely low and the proportion did not exceed 4%, as shown in Fig. 3. Figure 4 shows that the medium-high cover was mainly distributed at the intersection of Kelan County, Xingxian County, and Lanxian County, and the northwest of Jixian County. High vegetation cover was mainly distributed at the intersection of Xixian County and Fenxi County. It can be seen from Fig. 3 that from 2010 to 2014, the changes in vegetation cover were mainly medium-low cover and medium cover, the proportion of medium-high cover was increasing and the proportion of low cover and medium cover was decreasing. From 2014 to 2015, the low cover, and medium-low cover increased and the medium cover decreased significantly. From 2015 to 2018, the medium-low cover decreased year by year, the medium cover increased year by year, the medium-high cover and the high cover are also increasing in 2019, the medium cover, and medium-high cover decreased and the medium-low cover increased. It can be seen that the vegetation cover in the Lvliang mountains area shows an increasing trend, which is closely related to the conversion of farmland to forest and ecological environment protection in this area in recent years. At the same time, it is also affected by natural conditions such as climate.

According to formula (3), Fig. 5 was obtained. Between 2010 and 2019, the proportions of the significantly reduced, basically unchanged, and significantly increased vegetation cover were 18.49, 48.4 and 33.11%, respectively.

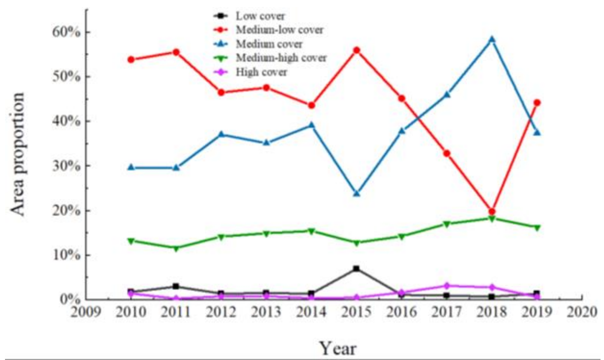
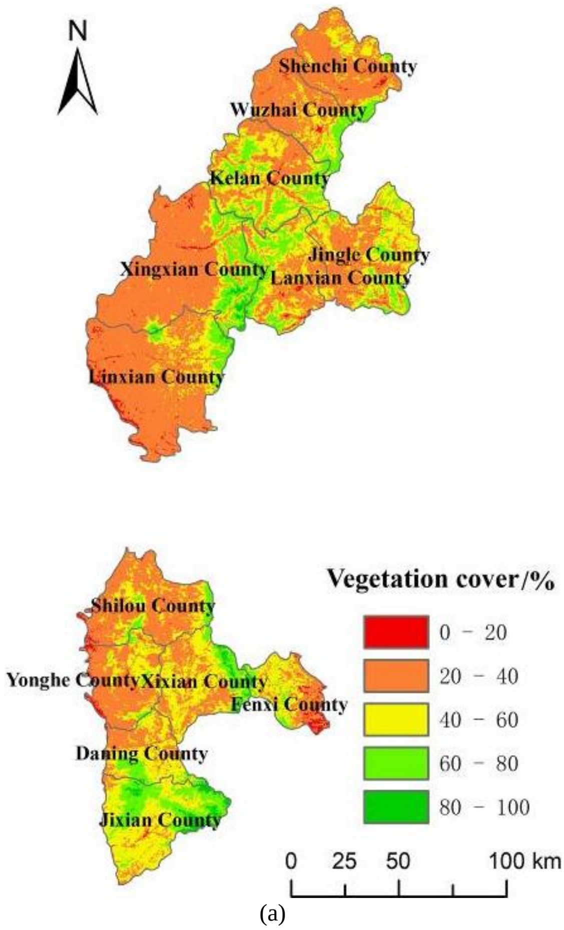


Fig. 3: The vegetation cover change in the Lvliang mountains area during 2010-2019

The significantly reduced vegetation area was mainly distributed in the south of the Lvliang mountains area, primarily in Yonghe County, Shilou County, Xixian County, Daning County, and Jixian County, as shown in Fig. 5. As it is an integral part of the Western Shanxi Plateau, with vertical and horizontal gullies, serious soil and water loss, relatively low altitude and greatly affected by human activities, compared with other areas, the vegetation in this area is reduced more. The unchanged vegetation was the largest proportion. It is distributed in the north and south of the Lvliang mountains area, mainly in areas with high altitudes and less affected by human activities. The areas with a significant increase in vegetation were mainly distributed in the north of Lvliang mountains area and almost all counties in the North (Shenchi County, Wuzhai County, Kelan County, Xingxian County, Lanxian County, Jingle County, and Linxian County) have a significant increase in vegetation. This is due to the relevant policies of Shanxi Province to prohibit the destruction of ecological forests and return farmland to the forest in the Lvliang mountains area.



(a)

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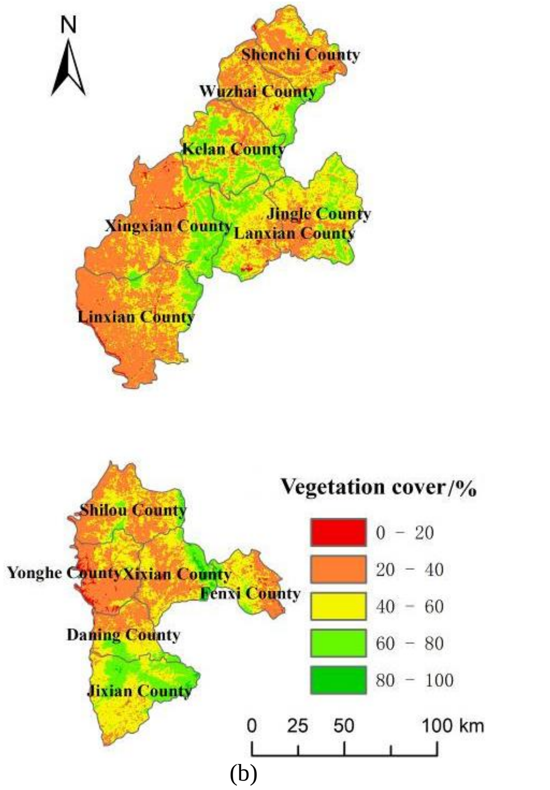

Fig. 4: The spatial distribution map of vegetation cover in the Lvliang mountains area in 2010 and 2019; (a) 2010;(b) 2019

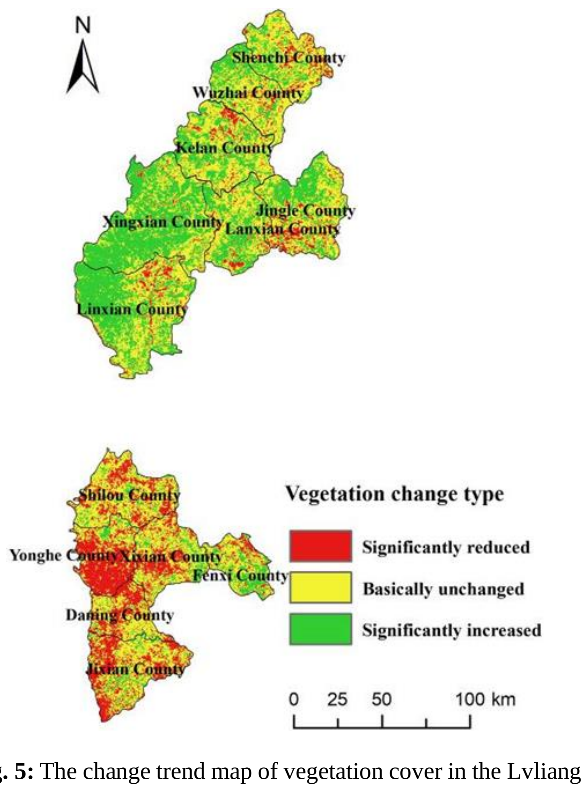

Fig. 5: The change trend map of vegetation cover in the Lvliang mountains area from 2010 to 2019

Topographic Effect of Vegetation Cover

Changes in Vegetation Cover at Different Elevations

Changes in natural factors such as temperature, precipitation, and soil are affected by elevation changes and this leads to vertical zones of mountain vegetation. In different vertical zones, the degree of impact will be different due to the interference of human activities and the impact of climate change.

In our study, the vegetation decreasing type showed a downward trend, the vegetation unchanged type showed an upward trend and the vegetation increasing type showed a first upward and then downward trend (Fig. 6). It can be seen from Fig. 6, the areas with the dominant distribution of vegetation cover change ($k>1$) were different. The vegetation decreasing type was the dominant distribution when the elevation was less than 1200 m, the vegetation unchanged type was the dominant distribution when the elevation was greater than 1400 m and the vegetation increase type was the dominant distribution when the elevation was 900-1100 m and 1300-1500 m. In the area with an elevation of less than 1200m, the distribution advantage of vegetation decreasing type was obvious ($1.13<K<1.2$). With the decrease in elevation, the advantage was more obvious, indicating that the vegetation decreasing type was dominant in this area. The vegetation unchanged type was dominant when the elevation was greater than 1400m ($1.01<K<1.58$). With the increase in elevation, the advantage was more obvious. The vegetation increase type showed a dominant distribution between 900 and 1100m ($K = 1.19$) and between 1300 and 1500m ($1.13<K<1.16$).

In different elevation areas, the changes in vegetation cover were mainly of the vegetation unchanged type, followed by the vegetation increase type and vegetation decreasing type, as shown in Fig. 7. The vegetation increase type was between 37-40% in the area at an elevation of 900-1100 and 1300-1500 m and less than 35% at other elevations. The vegetation unchanged type exceeded 50% in the area with an elevation greater than 1500 m, the highest was 76.51 and 38-49% in other areas. The vegetation decreasing type was 40.69 at 385-800 m and less than 30% in other areas.

To summarize, the change in vegetation cover in the Lvliang mountains area is closely related to the elevation. In the area with an elevation of less than 1200 m, changes are influenced by human activities and the vegetation decreases significantly. In areas with an elevation greater than 1400 m, there is little human influence, and the stability of vegetation cover increases. At elevations of 1200-1400 m, there is high terrain and reduced human activities. It is the main area for returning farmland to forest and, here, the vegetation shows an increasing trend.

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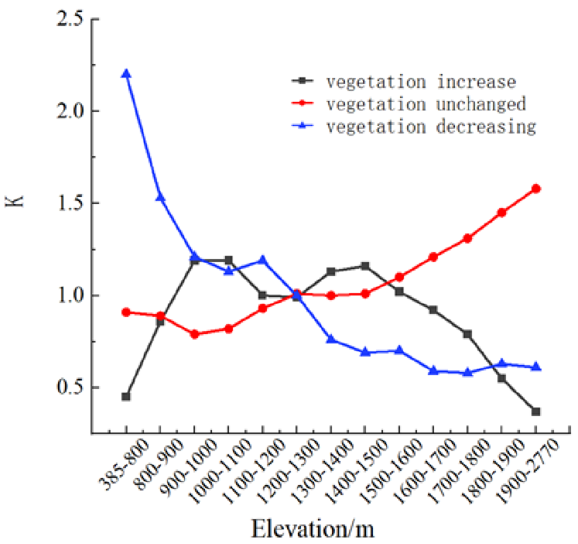

Fig.6: The changing trend of terrain area difference correction coefficient K of vegetation change type with elevation

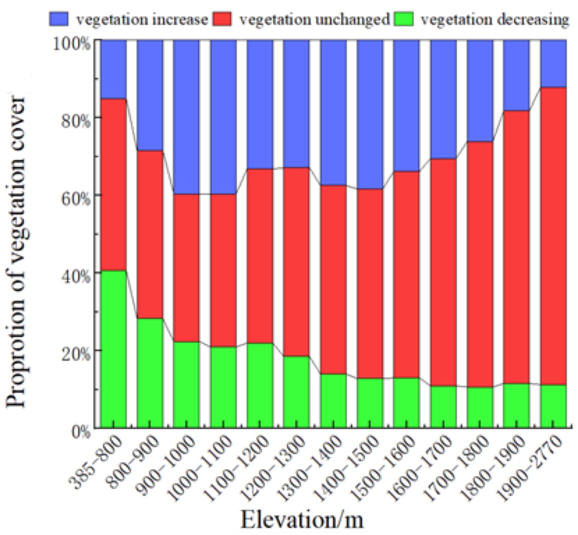

Fig. 7: The area ratio of different vegetation change types at different elevations

Changes of Vegetation Cover under Different Slopes

The steepness and gentleness of the slope will affect the water and soil. The abundance and scarcity of water and soil will affect the species and quantity of aboveground plants. Finally, it affects the vegetation cover. Therefore, different grades of slope have different effects on vegetation cover.

With an increase in slope, the vegetation decrease type first increased slowly and then decreased and the vegetation unchanged type first remained stable and then increased, as shown in Fig. 8. In our study, the vegetation increase type began to maintain a stable state and then showed a downward trend. In the area with a slope less than 6°, the distribution of vegetation increase type was dominant (1.15<K<1.16). In the area with a slope greater than 15°, the vegetation unchanged type was dominant (1.02<K<1.67).

In different slope areas, the vegetation cover was mainly the vegetation unchanged type. The vegetation unchanged type increased with the increase of slope, as shown in Fig. 9. Among the different vegetation types, the maximum proportion of vegetation decrease type was 19.87% at 15°-25°, and the proportion of vegetation unchanged types was more than 45% and the maximum was 80.96% at more than 25°. The proportion of vegetation increase type was more than 30% at less than 15° and in other areas was less than 20%.

In conclusion, in the area with a slope less than 6°, vegetation increase was dominant. In the area greater than 6°, the vegetation unchanged type showed a dominant distribution, indicating that the steeper the slope, the lower the human activity, the more stable the vegetation distribution, and the smaller the change.

Changes in Vegetation Cover in Different Aspects

The distribution of plants is affected by different aspects and has different characteristics. On the sunny side, the light is strong, the water content is low and the vegetation cover is high, which is suitable for the growth of sun-loving plants. The shady area has weak light and high humidity, which is suitable for the growth of shade-loving and moisture-loving plants.

Aspect has alittle effect on vegetation, as shown in Fig. 10. The vegetation decrease type was dominant on sunny and semi-sunny slopes(K>1), but not at other aspects (K<1); the distribution of vegetation unchanged type was weak dominant in the semi-shady slope. Vegetation increase type was dominant on flat land and shady slopes.

In different aspect areas, the vegetation cover was mainly unchanged type and increase type, as shown in Fig. 11. In all aspects, the area of vegetation increase type was 32-39%; the area of vegetation unchanged type was between 46-49%; the area of vegetation decrease type was 15-20%. The change in each vegetation cover type was within 7%. On the whole, the aspect had little effect on vegetation cover.

To summarize, on sunny and semi-sunny slopes, the vegetation decrease type was dominant and the vegetation increase type was dominant in flat areas. This is because the flat area is generally cultivated or built on and is most affected by human beings. On semi-shady and shady slopes, vegetation unchanged type and increase type were dominant.

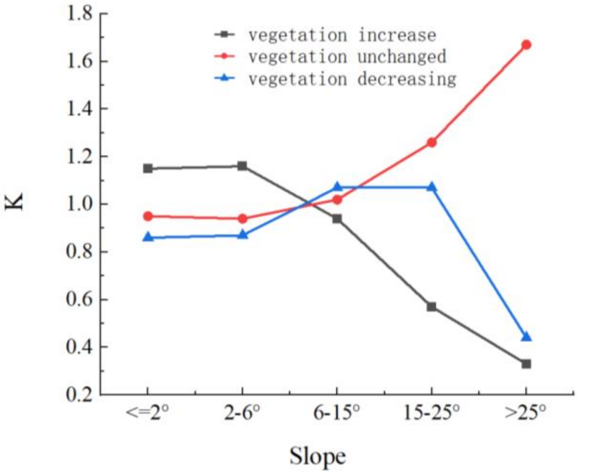

Fig. 8: The changing trend of terrain area difference correction coefficient K of vegetation change type with slope

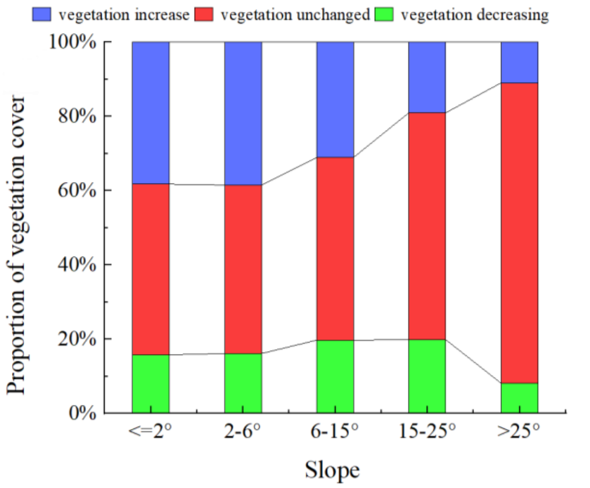

Fig. 9: The area ratio of different vegetation change types on different slopes

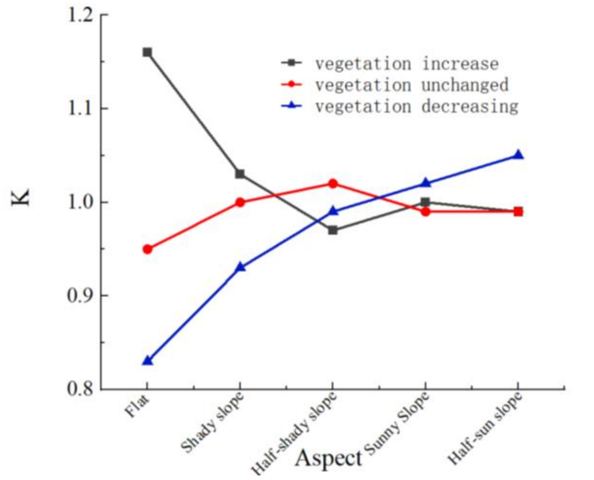

Fig. 10: The changing trend of terrain area difference correction coefficient K of vegetation change type with an aspect

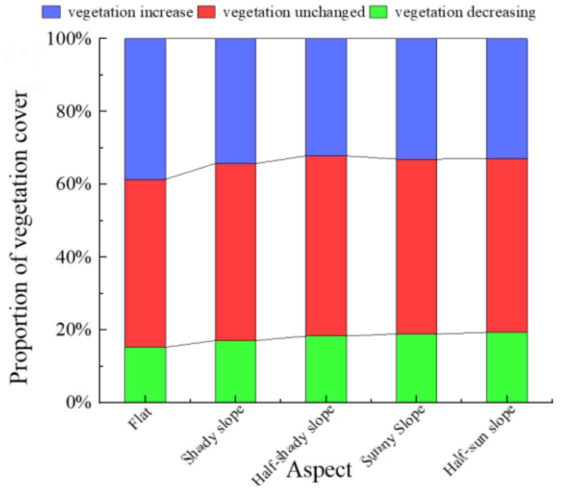

Fig. 11: The area proportion of different vegetation change types in different aspects

Discussion

This study used remote sensing and GIS technology to analyze the vegetation cover in the Lvliang mountains area from 2010 to 2019 based on MODIS NDVI data and discusses its temporal and spatial changes and topographic characteristics, which has certain scientific significance and reference value for the protection of vegetation in Lvliang mountains area. The study of vegetation cover here is conducive to the ecological green development of the Lvliang mountains area:

(1) Temporal and spatial variation characteristics of vegetation cover

The change in vegetation cover was studied from two aspects of time and spatial distribution. This part mainly studied the area proportion of vegetation cover levels from 2010 to 2019. During this period, the medium-low cover and medium cover fluctuated greatly and the vegetation cover of other levels was small. At the same time, the spatial distribution characteristics of different levels were also studied. At present, there is no research on the change in vegetation cover in the Lvliang mountains area. Our research can find the temporal and spatial distribution of vegetation in the Lvliang mountains area.

We used a trend analysis method to study vegetation change. The changes in vegetation cover were divided into three situations, which were significantly reduced, basically unchanged, and significantly increased, each accounting for a certain proportion. The θ_{slope} was tested by the F test. The F-test formula was deduced and applied to this study. Many studies (Tian *et al*., 2019a) did not use F-test when using the trend analysis method.

(2) Topographic effect of vegetation cover changes

The terrain area difference correction method was used to study the relationship between vegetation cover change (vegetation increase, vegetation unchanged, and vegetation decreasing) and terrain factors, and the K value was used to study whether there was dominant distribution under each level of terrain factors. It can eliminate the influence of terrain and further study the relationship between vegetation cover and terrain factors. The traditional research on the relationship between vegetation cover and topographic factors can only study the relationship between vegetation cover and elevation, slope, and aspect as a whole (Zhang *et al*., 2022; Tian *et al*., 2019a).

(3) Differences from other studies

In the area with a slope less than 6°, vegetation increase was dominant. This result was inconsistent with Zhu *et al*. (2017), who found that the area with vegetation less than 6° was dominated by vegetation reduction types; although he studied Chongqing City. The main reason was that the population migration under the background of the poverty alleviation policy in the Lvliang mountains area had led to the increase of abandoned land, which had led to the increase of vegetation cover

Our study had some limitations. First, Limited to the short duration, the year of vegetation cover change was relatively short. Second, due to the lack of relevant data on vegetation cover in the Lvliang mountains area, it was not possible to analyze other factors affecting vegetation growth, such as climate and hydrological factors. Particularly in areas with low altitudes and slopes, human factors may have a strong influence. In further research, we would study the impacts of climate and human activities on vegetation cover and study the changes in vegetation cover over a long period of time.

Conclusion

In this study, the MODIS NDVI data of the Lvliang mountains area from 2010 to 2019 were used to analyze the temporal and spatial changes in vegetation cover and topographic effects. The results show that:

(1) Over the last 10 years, the vegetation in the Lvliang mountains area was mainly medium-low cover and medium cover. The medium cover and medium-high cover mainly showed an upward trend and the low cover and medium-low cover mainly showed a downward trend. The proportions of the significantly reduced, basically unchanged, and significantly increased vegetation cover changes were 18.49, 48.4 and 33.11%, respectively. This showed that the vegetation cover in the Lvliang mountains area was generally increasing, which was closely related to the conversion of farmland to forest and ecological environment protection in the Lvliang mountains area in recent years. However, there were still some fluctuations, which may be related to climate and natural disasters
(2) Topographic factors had obvious effects on vegetation. The vegetation decrease type was dominant in the areas with elevations less than 1200 m. The vegetation unchanged type was dominant in the areas with an elevation greater than 1400 m and slope greater than 6°. And the vegetation increase type was in the range of 1200-1400 m and the region with a slope less than 6° was dominant. In this terrain, the vegetation was relatively fragile, prone to fluctuations, and had high resilience and quick recovery, but was prone to degradation. It is an area that needs more attention in future ecological governance
(3) Combined with the actual situation and previous studies, it was found that the research on the relationship between vegetation cover and terrain using the spatial difference of vegetation cover was more effective than the simple research, but more in-depth research is needed to verify it

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Authors' Contributions

Huixia Zhang, Yujie Li and Yongmei Li: Designed and performed the experiments, analyzed the data and drafted the manuscript.

Na Zhang: Drew some figures.

Ethics Approval

This article does not contain any studies with human or animal subjects performed by any of the authors.

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