IOP Conf. Series: Earth and Environmental Science **108** (2018) 042066 doi:10.1088/1755-1315/108/4/042066

Spatial-temporal Evolution of Vegetation Coverage and Analysis of it's Future Trends in Wujiang River Basin

Jianyong Xiao[1, 2, 3], Xiaoyong Bai[2, 3, *], Dequan Zhou[1], Qinghuan Qian[1, 2, 3], Cheng Zeng[1, 2, 3] and Fei Chen[1, 2, 3]

[1]School of Geography and Environmental Sciences, Guizhou Normal University, Guiyang 550001, China
[2]State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, 99 Lincheng West Road, Guiyang 550081, Guizhou Province, PR China
[3]Puding Karst Ecosystem Observation and Research Station, Chinese Academy of Sciences, Puding 562100, Guizhou Province, PR China

*Corresponding author e-mail: baixiaoyong@126.com

Abstract. Vegetation coverage dynamics is affected by climatic, topography and human activities, which is an important indicator reflecting the regional ecological environment. Revealing the spatial-temporal characteristics of vegetation coverage is of great significance to the protection and management of ecological environment. Based on MODIS NDVI data and the Maximum Value Composites (MVC), we excluded soil spectrum interference to calculate Fractional Vegetation Coverage (FVC). Then the long-term FVC was used to calculate the spatial pattern and temporal variation of vegetation in Wujiang River Basin from 2000 to 2016 by using Trend analysis and Hurst index. The relationship between topography and spatial distribution of FVC was analyzed. The main conclusions are as follows: (1) The multi-annual mean vegetation coverage reveals a spatial distribution variation characteristic of low value in midstream and high level in other parts of the basin, owing a mean value of 0.6567. (2) From 2000 to 2016, the FVC of the Wujiang River Basin fluctuated between 0.6110 and 0.7380, and the overall growth rate of FVC was 0.0074/a. (3) The area of vegetation coverage tending to improve is more than that going to degrade in the future. Grass land, Arable land and Others improved significantly; karst rocky desertification comprehensive management project lead to persistent vegetation coverage improvement of Grass land, Arable land and Others. Residential land is covered with obviously degraded vegetation, resulting of urban sprawl; (4) The spatial distribution of FVC is positively correlated with TNI. Researches of spatial-temporal evolution of vegetation coverage have significant meaning for the ecological environment protection and management of the Wujiang River Basin.

1. Introduction

Vegetation, as the main body of terrestrial ecosystem, vegetation plays an important role in material circulation, energy flow and information transmission, and it is also the most sensitive indicator of global change [1]. It is important to study the spatial distribution and temporal variation of vegetation coverage, and to study the evolution of vegetation and climate change and human activities, to reveal the evolution of regional environmental conditions and to predict future development trends [2].

Normal Differential Vegetation Index (NDVI) is an important indicator of vegetation status [3]. However, interferences introduced by the spectral characteristics of soil components can result in uncertainties in the NDVI products [4]. Thus, the linear spectral unmixing method has been proposed to tackle this problem to estimate the FVC on the earth's surface [5]. FVC is a key biophysical parameter to study the state and function of the earth's ecological system in the time-space scale. Myneni and Tucker analyzed the vegetation coverage changes from 1981-1991 and 1981-1999 respectively. The results showed that vegetation found in the northern hemisphere activity showed a trend of increase, especially middle latitudes, and argues that the enhancement trend because of climate warming [6, 7]. Fu Bojie et al. Used FVC to analyze the change of vegetation coverage in China from 2000-2010, and found that China experienced vegetation greening and browning, and had great spatial heterogeneity [8]. Xiaowei Tong et al. Analyzed the change of vegetation coverage in 2001 and 2013, and found that China's national and local governments implemented a series of ecological restoration projects to restore vegetation coverage [9]. Shibin Ma based on SPOT-VEG NDVI data, combined with vegetation type, meteorological and rocky desertification data, analyzed the changes and driving factors of vegetation in karst area of Guizhou Province, argues that the relationship between vegetation change and climate change must be weighed from the macroscopic point of view effects and climate change on vegetation changes [10]. The study shows that vegetation coverage is a good feature of ecological environment, and it has obvious recovery trend in recent years. Wujiang River Basin is a typical karst area, the ecological environment is extremely fragile; in recent years, and the national and local governments have carried out many ecological environment restoration and management projects. It is of great significance to assess the ecological environment restoration in the Wujiang River Basin through vegetation coverage.

Based on this, this paper takes the Wujiang River Basin as the research object, based on MODIS NDVI data and the MVC, we excluded soil spectrum interference to calculate FVC. Then the long-term FVC was used to calculate the spatial pattern and temporal variation of vegetation in Wujiang River Basin from 2000 to 2016 by using Trend analysis and Hurst index. The relationship between topography and spatial distribution of FVC was analyzed. The aim is to provide scientific basis for ecological restoration of wujiang river basin.

2. Materials and Methods

2.1. Study Area

Wujiang River is located in southern China (26°9'—28°14' N and 104°19'—108°35' E), the Yangtze River on the south coast of the largest tributary, the first river in Guizhou. Flows through Bijie, Liupanshui, Anshun, Guiyang, Zunyi 5 cities, the total length of 1037km, watershed area 5.10Wkm^2. Wujiang River system was pinnate distribution, watershed southwest high, low northeast, basin karst development. The terrain is dominated by plateaus, mountainous, mountainous and low hills (Fig 1). The elevation within the basin is 325-2855m, the height difference is large, the natural landscape changes obviously. The watershed is a subtropical monsoon climate zone, mild climate, abundant rainfall, the annual average temperature of 13 ~ 18 ℃. There are many types of natural environment, vegetation mainly coniferous mixed forest, arable land vegetation, shrub, plateau meadow and so on. There is a widespread karst rocky desertification in the basin.

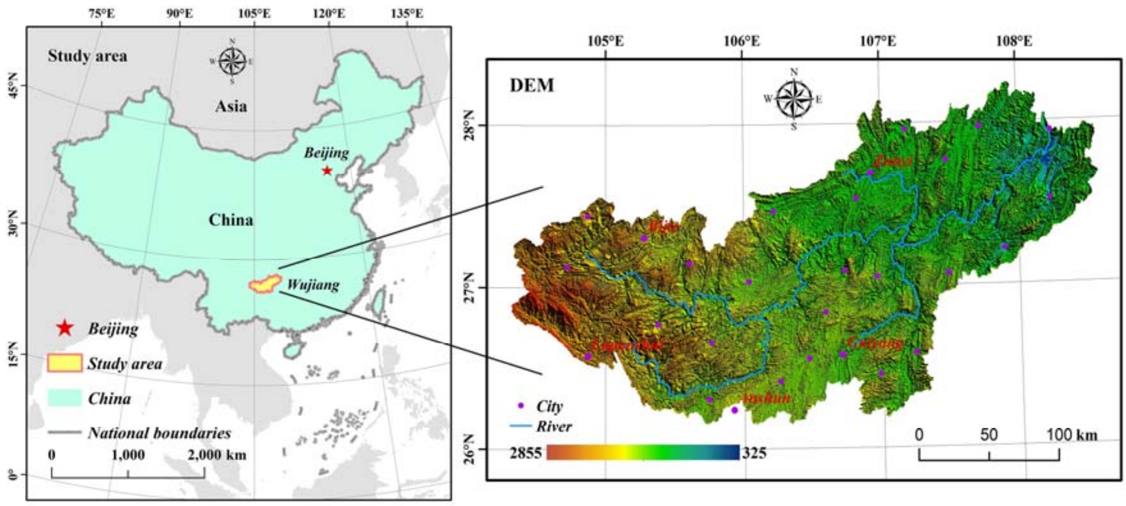

Figure 1. Location (left bar) and Topography (right bar) of the study area.

2.2. Datasets and Processing

The data in this study include MODID NDVI (MOD13Q1), this time scale of the data products is 2000.02–2016.12. DEM is 90m resolution digital elevation data.

Table 1. The main data source.

Data	Web	link
Administrative	National Earth System Science Data Sharing	http://www.geodata.cn/
MOD13Q1	United States Geological Survey	http://glovis.usgs.gov/
SRTM	Geospatial data cloud	http://www.gscloud.cn/
Landuse	Chinese Academy of Sciences Resource and Environment Science Data Center	http://www.resdc.cn/

2.3. Methods

Study on the spatial-temporal evolution of vegetation coverage in Wujiang River Basin, Based on MOD13Q1 data and the MVC, we excluded soil spectrum interference to calculate FVC. Then the long-term FVC was used to calculate the spatial pattern and temporal variation of vegetation in Wujiang River Basin from 2000 to 2016 by using Trend analysis and Hurst index. The relationship between topography and spatial distribution of FVC was analyzed (Fig 2).

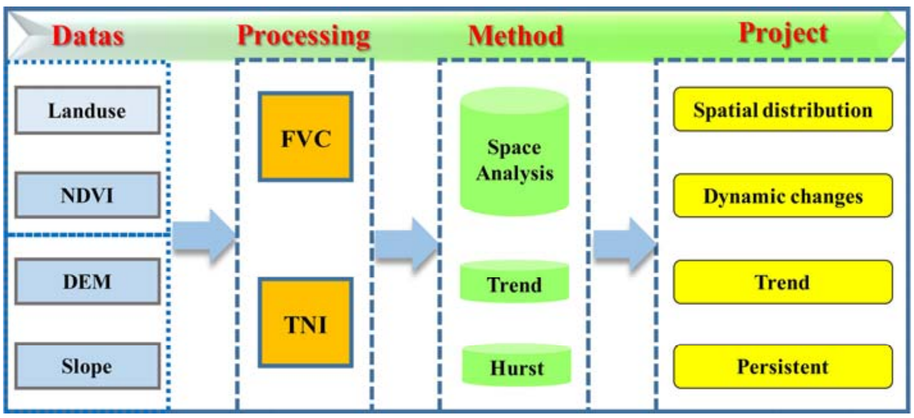

Figure 2. Flowchart of .spatial-temporal evolution of vegetation coverage

2.3.1. The FVC. MODIS product data involve sinusoidal projection. Firstly, the resulting product data batch is subjected to projection transformation by utilising the MODIS Reprojection Tools provided by NASA. This batch is converted into an ALBERS area projection and WGS-84 coordinate system, and the HDF format is converted into TIFF format [11]. The image data are then geometrically corrected and cut. FVC refers to the ratio of the vertical projected area of the canopy to the total soil area. Estimates are made with the pixel dichotomy model [12]. The formula is presented as follows:

$$FVC = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \tag{1}$$

Where "$NDVI_{soil}$" and "$NDVI_{veg}$" are the NDVI values of the pixel, bare land and pure vegetation pixel, respectively. With the NDVI value statistics, the cumulative frequency of 1% "$NDVI_{soil}$" and cumulative frequency of 99% "$NDVI_{veg}$" [13]. This study utilises a complete growing season. The MVC is used to calculate the monthly value, while the average method is adopted to obtain the annual value.

2.3.2. The Trend of FVC. The annual variation trend of FVC is expressed by the slope of the least squares linear regression equation of each raster. The specific formula is as follows:

$$k = \frac{n\sum_{i=1}^{n}(i \times M_{FVC,i}) - \sum_{i=1}^{n} i \times \sum_{i=1}^{n} M_{FVC,i}}{n \times \sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2} \tag{2}$$

Represents the trend "k"of FVC. When "k"> 0, the trend of vegetation coverage over 17 years is increasing, otherwise, it decreases. The apparent degree of FVC change depends on the value of "k". Where: "n" is 17, "i" is the serial number, "MFVC, i" is the first year of FVC. At present, the trend of MFVC, "k" value change is not uniform. The study found the value of "k" in line with the normal distribution, vegetation cover change will be divided into five grades, as follows: Degradation ("k"≤-0.01), slightly degradation (-0.01≤"k"＜-0.05), Stableness (-0.05≤"k"＜0.05), slightly improvement (0.05≤"k"＜0.01) and Improvement ("k"＞0.01) [14].

2.3.3. The Hurst of FVC Trends. Hurst index is an effective method to describe the dependence of long-term sequence information quantitatively [15]. In recent years, Hurst index has been widely used in vegetation change research:

1. Consider the FVC time series "FVCt", "t" = 1, 2, 3, 4, ..., n, for any positive integer t ≥ 1, define the time series of the mean sequence,

$$\overline{FVC}_{(\tau)} = \frac{1}{\tau}\sum_{t=1}^{\tau} FVC_{(\tau)} \quad ,\tau=1,2,\ldots,n \tag{3}$$

2. To calculate the cumulative deviation,

$$X_{(t,\tau)} = \sum_{t=1}^{t}(FVC_{(t)} - \overline{FVC_{(\tau)}}) \quad ,1\le t\le\tau \tag{4}$$

3. To create the range sequence,

$$R_{(\tau)} = \max_{1\le t\le \tau} X_{(t,\tau)} - \min_{1\le t\le \tau} X_{(t,\tau)} \quad ,\tau=1,2,\ldots,n \tag{5}$$

4. To create the standard deviation sequence,

$$S_{(\tau)} = \left[\frac{1}{\tau} \sum_{t=1}^{\tau} (FVC_{(t)} - FVC_{\tau})^{2} \right]^{\frac{1}{2}} \quad ,\tau=1,2,\ldots,n \tag{6}$$

To rescale the range,

$$\frac{R_{(\tau)}}{S_{(\tau)}} = (c\tau)^{H} \tag{7}$$

Where "H" is the Hurst index and the Hurst empirical formula is obtained for both sides of the formula. Based on the time series and the Hurst empirical formula, a cluster of "H" values is obtained by least squares fitting. The straight slope is the modified Hurst index (H).

Hurst index ("H"value) can reflect the randomness or persistence characteristics of FVC time series. When 0.5 <"H" <1, the time series has long-range dependency, which is persistent, that is, the future change is consistent with the past trend. The higher the persistence, when "H" = 0.5, then the FVC time series is a random sequence, there is no long-term correlation; when 0 is the same as the increase in the trend of the region will continue to increase in the future, and vice versa, 0<"H" <0.5, it indicates that the time series is counter-persistence, that is, the future trend of change is contrary to the past [16].

2.3.4. The terrain niche index (TNI). The TNI was utilized to characterize the topographic variation in South China. It was calculated as:

$$TNI = \lg\left[(\frac{e}{E}+1)\times(\frac{s}{S}+1) \right] \tag{8}$$

Where"e"and "E"are the elevation of the pixel and the average elevation of the study area respectively, whereas"s"and"S" signify the slope of the pixel and the average slope of the study area. Large TNI values correspond to higher elevation and larger slope angles, being typical for karst plateaus and gorges. In contrast, smaller TNI values indicate lower elevation and smaller slope angles. Medium TNI values are found in areas of a higher elevation but small slope angle, or low elevation but with larger slope angles, or moderate elevation and slope angle [17].

3. Results

3.1. Vegetation Patterns and Dynamics during 2000–2016

From 2000 to 2016, the FVC of the Wujiang River Basin fluctuated between 0.6110 and 0.7380, and the overall growth rate of FVC was 0.0074/a. The 17-year average was 0.6567 (Fig 3).

The spatial distribution of vegetation is affected by natural conditions and human activities. The average vegetation coverage in the Wujiang River Basin in the past 17 years is as follows: the multi-annual mean vegetation coverage reveals a spatial distribution variation characteristic of low value in midstream and a high level in other parts of the basin (Fig 5). From the landuse point of view,the Forest land FVC (0.6853) value is the highest, followed by Grassland (0.6434), followed by Arable land (0.6268), water area (0.5345), Residential land (0.4563), the Others (0.3541) lowest (as shown in

Table 2). The study area of FVC less than 0.4 accounted for 0.5%, mainly distributed in Water area and others. FVC in the 0.4-0.6 between the vegetation coverage areas accounted for 7.3%, mainly in Guiyang, Bijie, Liupanshui, Anshun and other urban areas and the surrounding areas. The coverage ratio of FVC in the vegetation coverage area between 0.6 and 0.8 is widely distributed in the watershed. FVC greater than 0.8 high vegetation coverage area accounted for 13.3%, mainly distributed in Forest land.

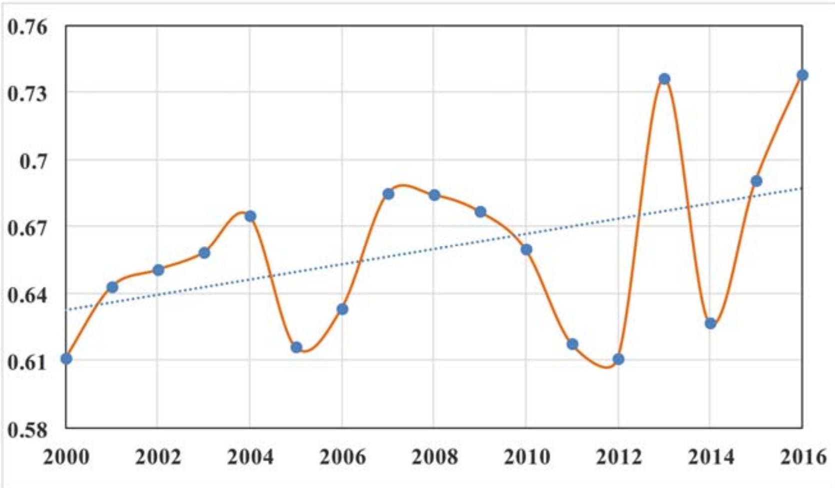

Figure 3. Inter-annual variations of FVC in Wujiang from 2000 to 2016

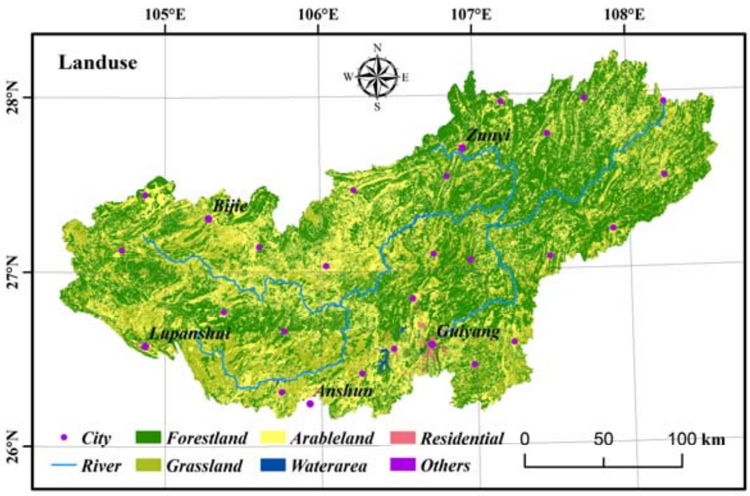

Figure 4. Spatial distribution of landuse types in Wujiang.

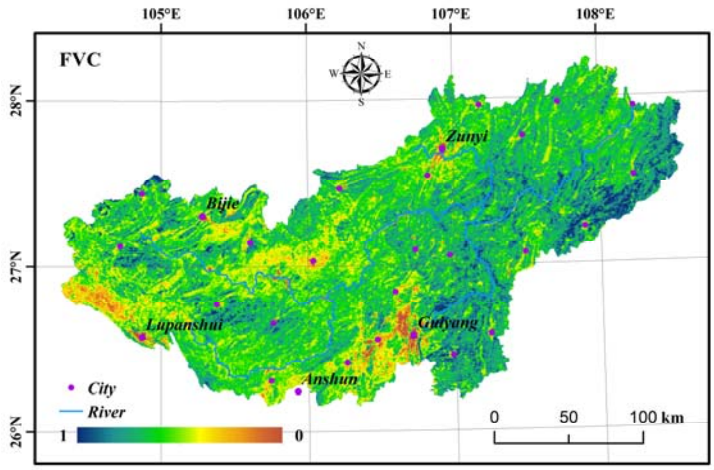

Figure 5. Spatial distribution of FVC in Wujiang.

Table 2. Comparison of FVC values under different landuse types

Landuse	**FVC**	**Allocation ratio (%)**					
		Area ratio	< 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	≥ 0.8
Forest land	0.6853	48.75	0.00	0.05	1.36	36.38	10.97
Grassland	0.6434	18.27	0.00	0.04	1.48	15.48	1.28
Arableland	0.6268	31.94	0.00	0.13	4.01	26.75	1.05
Water area	0.5345	0.42	0.02	0.04	0.15	0.19	0.01
Residential land	0.4563	0.60	0.00	0.20	0.28	0.11	0.00
Others	0.3541	0.02	0.00	0.00	0.01	0.01	0.00

3.2. Vegetation Trends and Future Vegetation Trends in Different Landuse

The area of vegetation coverage tending to improve is more than that going to degrade in the future (improved area> degraded area). Improvement (28.03%) and slightly improvement (50.65%) of vegetation coverage was mainly distributed in the upper reaches. Degradation (1.63%) and slightly degradation (6.51%) of vegetation cover was mainly distributed at downstream. Stableness (13.19%) of the vegetation distributed within the watershed. Grass land, Arable land and others improved significantly; Residential land is covered with obviously degraded vegetation (Fig 6).

Hurst refers to (from 0 to 0.89), the mean of “H” is 0.56 and the standard deviation is 0.0883 in the study area. In the 59% of the study area, the “H” value was 0.5 or more and the distribution was more dispersed.The spatial distribution of FVC variation character based on Hurst index, by the dynamic trend of FVC and Hurst index spatial analysis. Persistence improvement (16.82%) and persistence slightly improvement (25.97%) vegetation coverage was mainly distributed in the Grasslands and Others upstream of the basin; Persistence degeneration (1.33%) and persistence slightly degradation (3.45%) Mainly distributed in the Residential land; Persistence stableness vegetation coverage accounted for 6.11% of the study area, the Uncertainty of the trend of vegetation coverage accounted for 48.33% relatively evenly distributed in various types of landuse (Fig 7and 8).

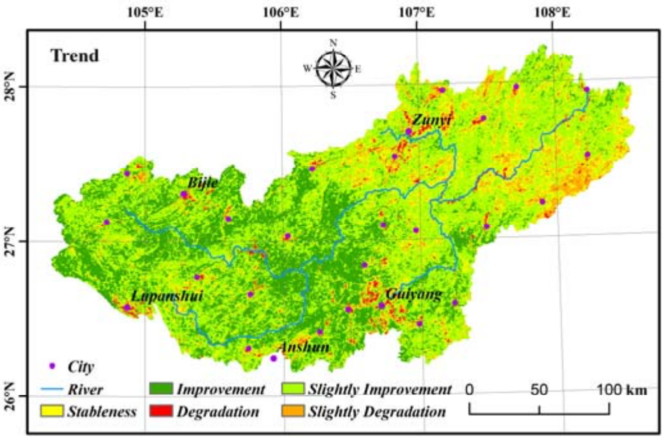

Figure 6. Trends of FVC in Wujiang from 2000 to 2016

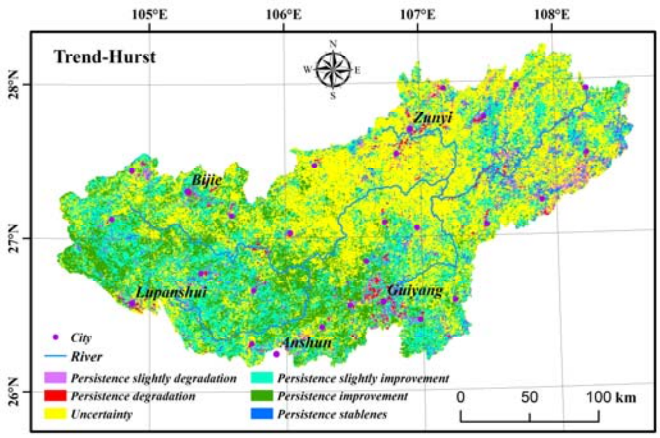

Figure 7. Spatial distribution of FVC variation character based on Hurst index

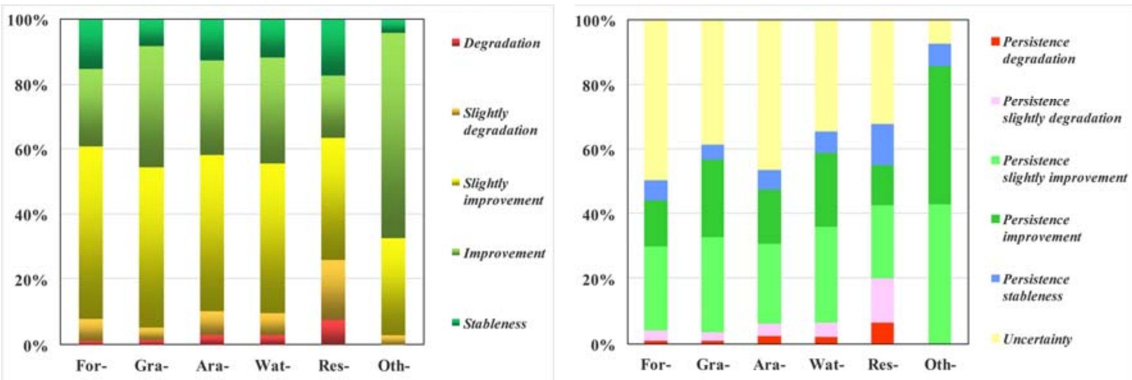

Figure 8. The area ratio (percentage cover) of different vegetation trends (2001 to 2013) (left bar) andfuture vegetation trends (right bar) in different project regions

3.3. *Distribution of FVC for Different Terrain Conditions*

Previous studies, the terrain is the main controlling factor in the spatial distribution of FVC [18]. In this paper, TNI is calculated by dividing DEM and Slope. TNI values between 0-1.2, it was divided into 6 levels. On the whole, downstream and southern watershed, such as low altitude, low slope, TNI value is low; Guiyang, Anshun, Zunyi and other areas of the city area slope small, low value TNI

(Figure 9). FVC will be divided into 10 levels by using natural breakpoint. We take FVC and TNI to do spatial overlay analysis. It is found that when TNI is less than 0.2, the lower FVC value is larger than that of FVC, and when the TNI value is between 0.2-0.4, the FVC mean is higher; the FVC mean is highest when the TNI value is between 1-1.2; all in all, the spatial distribution of FVC is positively correlated with TNI (Fig 10).

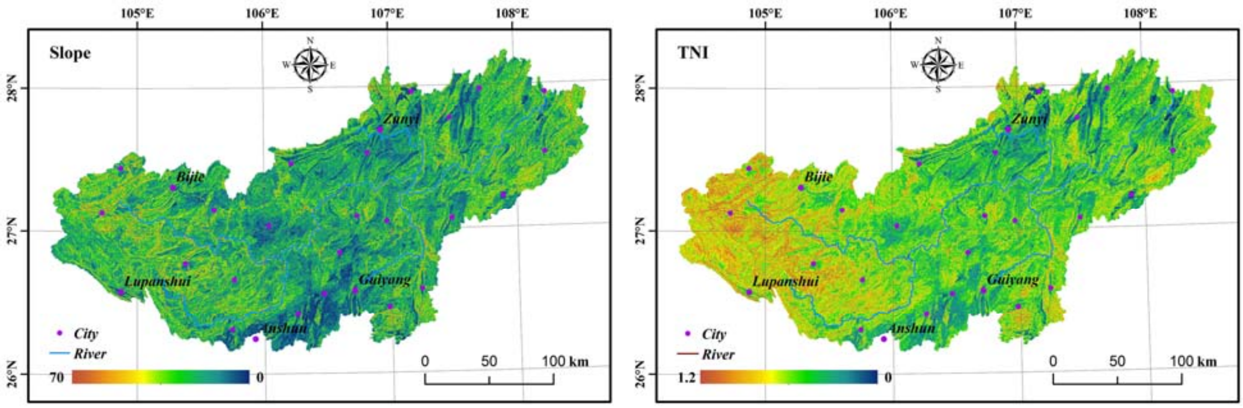

Figure 9. Spatial distribution of Slope (left bar) and TNI (right bar) in Wujiang

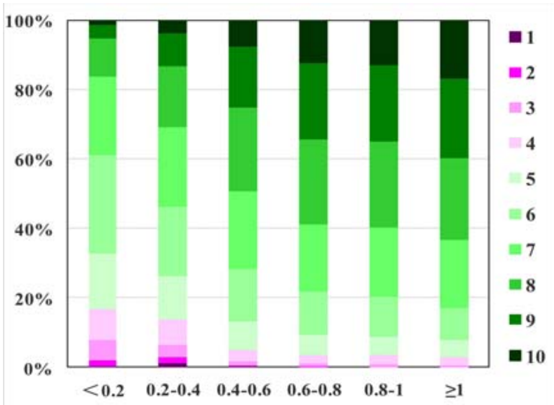

Figure 10. Statistics of FVC grade by different TNI grade

4. Discussion

The FVC in the Wujiang River Basin has an average value of 0.6567 in 2000-2017, consistent with the vegetation coverage in the region [9, 10] . From the landuse point of view,the Forest land FVC value is the highest, followed by Grassland, followed by Arable land, water area, Residential land, the Others lowest. This is similar to previous studies [14]. There are obvious differences in the spatial distribution of vegetation coverage in the Wujiang River basin, which is the result of the combination of natural conditions and human activities. In general, the vegetation coverage in the middle reaches of the Wujiang River is slightly lower than that in the upper and lower reaches, mainly due to the medium elevation of the middle reaches of the river, the flat terrain and the low TNI value. Construction land and arable land accounted for a higher proportion in the landuse, and the vegetation coverage is low .In the upper reaches, due to the high altitude, high slope, and high TNI value, the landuse is dominated by grassland and arable land, and the vegetation coverage is higher. The vegetation coverage is higher in the lower reaches, although the elevation is low,the slope is large and the TNI value is low, the landuse is dominated by forest land, and the vegetation coverage is higher. Due to human activities frequently, FVC value is lower in Guiyang, Anshun, Liupanshui, Zunyi, Bijie and other urban areas [19].

From 2000 to 2016, the vegetation coverage in the Wujiang River Basin changed significantly, and the vegetation as a whole was improved, which was the result of the positive effects of human activities [20]. More than half of the vegetation in the basin has been improved, and the improved vegetation is mostly arable land, grassland and others. With the rapid economic development and the reduction of farmers' dependence on land, the impact of unreasonable activities on rocky desertification has been reduced. The government advocates returning farmland to forest and grassland and other ecological management projects [21]. The degraded areas are mostly in the construction area, which is mainly caused by city expansion such as urban expansion and road network construction. It is noteworthy that, in the future trend of change, continuously improved landuse is among the most obvious. In recent years, the national and local governments have continued to carry out the comprehensive management of rocky desertification in the Wujiang River Basin, resulting in rocky desertification-based other vegetation has been continuously improved [21]. The area of persistent degradation is dominated by construction land, due to sustained urban expansion. In the future urban development process, we should strengthen the surrounding ecological environment management and protection.

Many factors will affect the results of the study. In this paper, MOD13Q1 is used as the data source to calculate FVC. On the calculation method, the maximum data is obtained by the maximum value method, and the month data are obtained by the maximum value of the synthetic method and then the average annual data are obtained by the average value, and the error of the data due to the weather is eliminated. Compared with the actual research, the research results are in line with the actual situation. At the same time, there are still many improvements in the research of this paper. In the study period, there is a minimum value in some years, combined with the previous research experience which is caused by extreme climate. Due to the limitations of the data, this article is not in-depth discussion.

5. Summary and Conclusions

Based on MODIS NDVI data and the MVC, we excluded soil spectrum interference to calculate FVC. Then the long-term FVC was used to calculate the spatial pattern and temporal variation of vegetation in Wujiang River Basin from 2000 to 2016 by using Trend analysis and Hurst index. The relationship between topography and spatial distribution of FVC was analyzed. The main conclusions are as follows:

The multi-annual mean vegetation coverage reveals a spatial distribution variation characteristic of low value in midstream and high level in other parts of the basin, owing a mean value of 0.6567.

From 2000 to 2016, the FVC of the Wujiang River Basin fluctuated between 0.6110 and 0.7380, and the overall growth rate of FVC was 0.0074/a.

The area of vegetation coverage tending to improve is more than that going to degrade in the future. Grass land, Arable land and Others improved significantly; karst rocky desertification comprehensive management project lead to persistent vegetation coverage improvement of Grass land, Arable land and Others. Residential land is covered with obviously degraded vegetation, resulting of urban sprawl. TNI is the composite index of DEM and Slope, the spatial distribution of FVC is positively correlated with TNI.

Acknowledgments

This research work was supported jointly by National Key Research Program of China (No.2016YFC0502300, 2016YFC0502102, 2014BAB03B02), International cooperation research projects of the national natural science fund committee (No. 41571130074& 41571130042), Science and Technology Plan of Guizhou Province of China (No.2012-6015), Agricultural Science and Technology Key Project of Guizhou Province of China (No.2014-3039), Science and technology cooperation projects(No.2014-3), Science and Technology Plan Projects of Guiyang Municipal Bureau of Science and Technology of China (No.2012-205). The National Natural Science Fund (No.41461041). Qian Science and Combined major Projects ([2017]3001-06).

References

[1] J. A. Foley, S. Levis, M. H. Costa, et al., Incorporating Dynamic Vegetation Cover within Global Climate Models [J]. Ecological Applications, 2000, 10(6): 1620-1632.
[2] S. F. Jia, W. B. Zhu,, et al., A statistical spatial downscaling algorithm of TRMM precipitation based on NDVI and DEM in the Qaidam Basin of China [J]. Remote Sensing of Environment, 2011, 115(12): 3069-3079.
[3] A. Anyamba, C. J. Tucker, Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003[J]. Journal of Arid Environments, 2005, 63(3): 596-614.
[4] J. D. Willem, L. W. Van, J. Barron, et al., Multi-sensor NDVI data continuity: Uncertainties and implications for vegetation monitoring applications [J]. Remote Sensing of Environment, 2006, 100(1):67-81.
[5] B. C. Rundquist, The influence of canopy green vegetation fraction on spectral measurements over native tallgrass prairie [J]. Remote Sensing of Environment, 2002, 81(1): 129-135.
[6] R. B. Myneni, C. D. Keeling, C. J. Tucker, et al., Increased plant growth in the northern high latitudes from 1981 to 1991 [J]. Nature, 1997, 386(6626): 698-702.
[7] C. J. Tucker, D. A. Slayback, J. E. Pinzon, et al., Higher northern latitude normalized difference vegetation index and growing season trends from 1982 to 1999. [J]. International Journal of Biometeorology, 2001, 45(4): 184-90.
[8] Y. Lü, L. Zhang, X. Feng, et al., Recent ecological transitions in China: greening, browning, and influential factors [J]. Scientific Reports, 2015, 5(1): 8732.
[9] X. W. Tong , K. L. Wang, M. Brandt, et al., Assessing Future Vegetation Trends and Restoration Prospects in the Karst Regions of Southwest China [J]. Remote Sensing, 2016, 8(5): 357-357.
[10] S. B. MA., Y. L. An, G. B. Yang, Y. R. Zhang. The Analysis of the Difference Vegetation Variation and Driver Factors on NDVI Change in Karst Region: A Case on Guizhou [J]. Ecology and Environmental Sciences, 2016, 25(7): 1106-1114.
[11] R. Suzuki, K. Masuda, D. G. Dye, Interannual covariability between actual evapotranspiration and PAL and GIMMS NDVIs of northern Asia. Remote Sens. Environ. 2007, 106, 387-398.
[12] E. Ivits, M. Cherlet, S. Sommer, et al. Addressing the complexity in non-linear evolution of vegetation phenological change with time-series of remote sensing images [J]. Ecological Indicators, 2013, 26(3): 49-60.
[13] W. Song, X. Mu, G. Ruan, et al., Estimating fractional vegetation cover and the vegetation index of bare soil and highly dense vegetation with a physically based method [J]. International Journal of Applied Earth Observations & Geoinformation, 2017, 58: 168-176.
[14] F. Y. Cheng, S. L. Liu, Y. J. Yin, Y. H. Lü, N. N. An, X. M. Liu, The dynamics and main driving factors of coastal vegetation in Guangxi based on MODIS NDVI. Acta Ecologica Sinica,2017,37(3): 788-797.
[15] H. E. Hurst, Long term storage capacities of reservoirs [J]. Transactions of the American Society of Civil Engineers, 1951, 116(12): 776-808.
[16] L. H. Yuan, W. G. Jiang, W. M. Shen, Y. H. Liu, W. J. Wang, L. L. Tao, H. Zheng, X. F. Liu, The spatio-temporal variations of vegetation cover in the Yellow River Basin from 2000 to 2010． Acta Ecologica Sinica, 2013, 33(24): 7798-7806．.
[17] Y. U. Hong, H. Zeng, Z. Y. Jiang, Study on Distribution Characteristics of Landscape Elements along the Terrain Gradient [J]. Scientia Geographica Sinica, 2001.
[18] Y. Lu, G. T. Dong, S. T. Yang, Spatio-Temporal Variation in NDVI in the Yarlung Zangbo River Basin and Its Relationship with Precipitation and Elevation. Journal of Natural Resources, 2014, 36(3): 603-611.
[19] F. Sedano, P. Kempeneers, G. Hurtt, A Kalman Filter-Based Method to Generate Continuous Time Series of Medium-Resolution NDVI Images [J]. Remote Sensing, 2014, 6(12): 12381-12408.
[20] Y. C. Tian, X. Y. Bai, S. j Wang, et al., Spatial-temporal changes of vegetation cover in

Guizhou Province, Southern China [J]. Chinese Geographical Science, 2017, 27(1): 25-38.
[21] X. Y. Bai, S. j. Wang, K. N. Xiong, Assessing Spatial-temporal Evolution Processes of Karst Rock Desertification Land Indications for Restoration Strategies [J]. Land Degradation & Development, 2013, 24(1): 47-56.