QUANTITATIVELY IDENTIFYING THE DOMINANT HUMAN DRIVING FORCES OF VEGETATION VARIATION IN THE THREE GORGES RESERVOIR REGION, CHINA

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Abstract. Quantitatively analyzing the role of human activity in vegetation change has been a hot topic in the field of ecological research. Taking the Three Gorges Reservoir Region (TGRR) of China as study area, under the support of the geographic information system (GIS) technology and residual trends method (RESTREND), the spatial-temporal characteristics of vegetation change and its human driving forces in the TGRR from 2000 to 2020 were quantitively explored. It was found that, the vegetation cover had shown an overall increasing trend and strong spatial heterogeneity over the past 20 years. The vegetation restoration trend in the north-eastern region of the TGRR were more obvious than that in the south-western region. RESTREND analysis showed that human activity produced an overall positive effect on vegetation change. The areas persistently covered by forested land and farmland contributed the most to the vegetation change (83.3% in total), whereas the contribution of returning farmland to forest was only 3.92%. In the persistent forested land, there was a highly significant positive correlation ($R^2 = 0.84$) between the implementation area of the ecological restoration project called “closing hillsides to facilitate afforestation” (CHFA) and the change amount of normalized difference vegetation index (NDVI). The implementation of the project CHFA could proximately explain the change of residual between the observed and estimated NDVI. This paper quantitatively revealed the important role of the CHFA project on vegetation restoration and conducted the first attempt to specify the residual of the RESTREND method. Achievements could provide valuable references for regional study on the driving mechanism behind vegetation cover change.
Keywords: *human activity, RESTREND, remote sensing, closing hillsides to facilitate afforestation, spatial-temporal analysis*

Introduction

Vegetation cover is not only the main portion of the ecosystem (Parmesan and Yohe, 2003; Piao et al., 2003; Hilker et al., 2015), but it is also an important indicator of changes in the ecological environment (Peng et al., 2012; Lamchin et al., 2015). The changes in vegetation cover are the combined result of climate change and human activity (Xiao et al., 2015; Delgado-Fernandez et al., 2019). Studying the impact of human activity on vegetation cover change has become a hot topic in the global change research (Pessoa and Lidon, 2013; Huang et al., 2020; Gao et al., 2022). Since the mid-20th century, a series of ecological and environmental problems, such as land degradation and soil erosion, have been occurring frequently, and vegetation cover has been degraded to a certain extent owing to increasing disturbance of the natural environment by human activity (Dotterweich et al., 2013; Chu et al., 2014; Hosseini et al., 2022). To effectively address ecological problems in the region, the Chinese

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government has been implementing a series of ecological restoration projects since 1999 (Zhao et al., 2017). The most commonly applied projects include the closing hillsides to facilitate afforestation (CHFA), natural forest protection (NFP), returning farmland to forest (RFF), and reforestation. Today, the latest NASA satellite data show that the Earth is greener than it was 20 years ago, with China accounting for 25% of the total increase in global vegetation (Chen et al., 2019). It can be said that vegetation cover change is a profound reflection of human activity.

There has been numerous research on the relationship between human activity and vegetation cover change at the national or regional scale (Zhang et al., 2022). Zhao et al. (2017) used the Hurst index and the non-parametric trend methods (Sen’s test) to calculate changes in vegetation cover on the Loess Plateau before and after the implementation of the returning farmland to forest (grass) project. Cheng et al. (2020) adopted the methods of dichotomous image segmentation and correlation analysis to study the spatial and temporal variation of vegetation cover and its driving factors in terms of topography and demography in the Yuanjiang River Basin of Guizhou province. Li et al. (2011) developed an NDVI-climate response model to analyze the role of human driving forces (e.g. returning farmland to forest project) in the vegetation cover restoration in the Bijie area of Guizhou province. Using a PCSE-modified panel data model, Cheng et al. (2020) studied the effect of the returning farmland to forest project on vegetation restoration in Shaanxi Province. It can be summarized that, although a considerable number of ecological restoration projects have been implemented, most of the studies have focused on returning farmland to forest. Research on the impact of other projects (e.g. closing hillsides to facilitate afforestation) is still at the level of qualitative understanding, and no quantitative research has been reported (Shen et al., 2020).

As a unique geomorphological region all over the word, formed by the world-famous Three Gorges Dam, the Three Gorges Reservoir Region (TGRR) has complex topography and fragile ecological environment with a challenging task of vegetation restoration (Shao et al., 2018). However, TGRR has been also now enjoying rapid economic growth, which inevitably lead to the conflicts between the rapid development and ecological protection. For the past 20 years, vegetation cover in the region has undergone a profound evolution owing to rapid urbanization development, industrial restructuring, population movements, and implementation of a series of ecological restoration projects. Therefore, the TGRR is considered a typical test area for conducting research on the role of human activities in vegetation cover change. However, there has been relatively little relevant research conducted in the TGRR.

Given the above background, taking the TGRR as the study area, this paper aimed to analyze the spatial and temporal variation characteristics of vegetation cover in the TGRR from 2000 to 2020, calculate the contribution of each land use conversion type to vegetation cover change, and quantitatively assess the effect of CHFA project on vegetation restoration. Our study is expected to quantitatively identify the dominate human driving forces of vegetation variation in the Three Gorges Reservoir Region.

Materials and methods

Study area

The Three Gorges Reservoir Region (TGRR) of China lies between 28°56′ - 31°44′ N latitude and 106°16′ - 111°28′ E longitude (*Fig. 1*), with a total area of 57,900 km^2. This

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area is located at the end of the upper reaches of the Yangtze River, or the meeting point between the Sichuan basin and the plain of the middle and lower reaches of the Yangtze River. The region consists of 22 districts (counties) under the jurisdiction of Chongqing City and 4 counties under the jurisdiction of Hubei Province. The landscape is generally mountainous and hilly, with complex topographic features. The altitude is between 16 m and 2778 m. The TGRR has a monsoon-influenced humid subtropical climate, with a multi-year average temperature ranging from 15 to 18 °C. The multi-year average annual precipitation is 1,150.26 mm. In the course of the year, precipitation is mainly concentrated in the summer, when the high temperature weather also occurs frequently. The activities of atmospheric circulation systems, such as the western Pacific subtropical high, markedly vary from year to year, resulting in a high variability of precipitation and frequent flooding in the TGRR during the summertime (Liu et al., 2010). The land use is dominated by forested land, farmland, construction land. The forested land is dominated by evergreen coniferous, evergreen broadleaved, and deciduous broadleaved forests; the farmland is dominated by arable land (paddy and dryland).

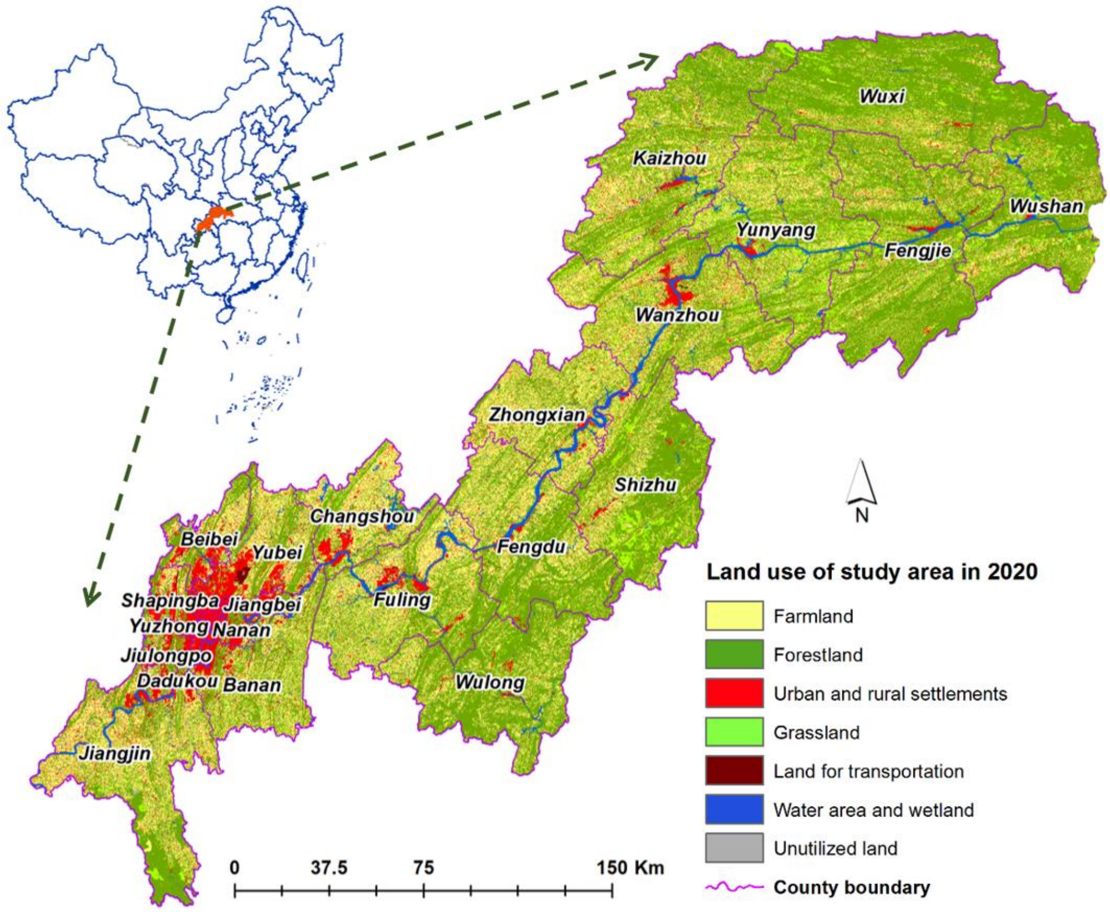

Figure 1. *Location and land use of study area*

Data sources

The basic data required for this study included remote sensing data (*Table 1*), land use data, and meteorological data. A series of moderate resolution imaging spectroradiometer (MODIS) vegetation index products could be obtained from the NASA

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(https://modis.gsfc.nasa.gov/). The normalized difference vegetation index (NDVI) based on the red and near-infrared (NIR) portions of the electromagnetic spectrum (NDVI = (NIR-RED)/(NIR + RED)), one of the most important vegetation indices measuring the amount of green vegetation, was adopted in this study. The original NDVI data with 500 m spatial resolution and 16-day temporal resolution was processed into monthly maximum NDVI data using the maximum synthesis method with spatial resolution unchanged. Daily rainfall and temperature data from 19 meteorological stations located in the TGRR was obtained from Chinese Meteorological Science Data Center (http://data.cma.cn). Land use data of the 2000 and 2020 were obtained from the National Earth System Science Data Center (NCSSD) (http://www.geodata.cn), in the grid format with a spatial resolution of 30 m including seven land use types. Based on the land use data of 2020, we created the spatial distribution map of land use by assigning different colors to each land use type in the GIS environment (*Fig. 1*). Digital elevation model (DEM) data were derived from the Geospatial Data Cloud of China (http://www.gscloud.cn), with a spatial resolution of 90 m. Data on the implementation area of closing hillsides to facilitate afforestation project were collected from statistical yearbooks which were provided by Chongqing Bureau of Statistics (http://tjj.cq.gov.cn).

Table 1. *Descriptions of remote sensing data*

Dataset	Satellite/Senor	Format	Time
NDVI	Terra and Aqua/Moderate Resolution Imaging Spectroradiometer (MODIS)	Grid	2000-2020
DEM (SRTM)	Space Shuttle Endeavour/Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR)	Grid	2000

Methodology

Mann-Kendall method

The overall trend of NDVI was analyzed by using the Mann-Kendall method, which is a non-parametric statistical test with the advantages of wide applicability, low artificiality, and a high degree of quantification, and performed well in trend testing over long-term series (Gocic and Trajkovic, 2013). We assumed the time series (x_1, x_2, ..., x_n) to be samples of *n* independent and identically distributed random variables. The alternative hypothesis, H1, was a bilateral test. The distributions of X_i and X_j were not the same for all $i < j \leq n$ and $i \neq j$. The test statistic, S, is thus defined as *Equation 1:*

$$S = \sum_{i=2}^{n} \sum_{j-1}^{i-1} sign\left(X_i - Y_j\right) \quad \text{(Eq.1)}$$

where *sign()* is the sign function mainly for discriminating the values of X_i-X_j within the parentheses, with the following provisions (*Eq. 2*):

$$sign\left(X_i - Y_j\right) = \begin{cases} 1 \cdots\cdots X_i - Y_j > 0 \\ 0 \cdots\cdots X_i - Y_j = 0 \\ -1 \cdots\cdots X_i - Y_j < 0 \end{cases} \quad \text{(Eq.2)}$$

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The values of Z corresponding to the M-K statistical test at S > 0, S = 0, and S < 0, respectively, were calculated using *Equation 3:*

$$Z=\begin{cases}(S-1)/\sqrt{Var(S)}\cdots\cdots S>0\\ 0\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots S=0\\ (S+1)/\sqrt{Var(S)}\cdots\cdots S<0\end{cases} \quad \text{(Eq.3)}$$

where a positive Z value represents an increasing trend, and a negative value represents a decreasing trend. Absolute values of Z greater than or equal to 1.28, 1.96, and 2.32 pass the significance test at 90%, 95%, and 99% confidence, respectively.

Linear regression analysis

At the grid level, for more convenient calculation, we used linear regression to analysis the trend of NDVI and residual (see RESTREND method section) over time series. The formula is as *Equation 4:*

$$\text{slope}=\frac{n\times\sum_{i=1}^{n} i\times c_i-\left(\sum_{i=1}^{n} i\right)\times\left(\sum_{i=1}^{n} c_i\right)}{n\times\sum_{i=1}^{n} i^2-\left(\sum_{i=1}^{n} i\right)^2} \quad \text{(Eq.4)}$$

where c_i is the actual NDVI value observed in the *i*-th year, and *n* is the total number of years. When *slope* > 0, the vegetation cover is increasing; when *slope* < 0, the vegetation cover is decreasing; and when *slope* = 0, the vegetation cover is unchanged.

We used the *t*-test to calculate significance level in the trend analysis of the linear regression, as shown in *Equations 5–6:*

$$t=\frac{\widehat{b}}{\widehat{\sigma}}\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\ \sim t_{1-a}(n-2) \quad \text{(Eq.5)}$$

$$\widehat{\sigma}=\sqrt{\frac{1}{n-2}\sum_{i=1}^{n}(y_i-\widehat{y}_i)^2} \quad \text{(Eq.6)}$$

where $\widehat{b}$ represents the linear regression coefficient (the *slope*), y_i is the observed NDVI value in year *i*, $\widehat{y}_i$ is the regression value of NDVI in the *i*-th year, x_i is the time independent variable, and *a* represents the significance level.

RESTREND method

The widely applied method of RESTREND (Li et al., 2012; Gedefaw et al., 2021; Irisarri et al., 2021) was selected to quantify the impact of human activity on vegetation. The principle of RESTREND is to distinguish the effect of human activities on vegetation cover change by removing the effect of climate changes. In this study, we established regression model of annual mean NDVI and climatic factors (rainfall and air

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temperature) for each grid and obtained the estimated annual mean NDVI values. Then, the residual between the observed and estimated NDVI value was used as proxy for the impact of human activity on vegetation change. The formula of residual is expressed as *Equation 7:*

$$\varepsilon = NDVI_{observed} - NDVI_{estimated} \quad \text{(Eq.7)}$$

where ε (residual) is the vegetation variation unexplainable by climate factors, thus could be considered as the results of human activity. If $\varepsilon > 0$, it represents a positive impact of human activity on vegetation change, vice versa.

Results

Temporal and spatial variation characteristics of vegetation cover

The vegetation cover in the Three Gorges Reservoir Region (TGRR) showed a significant upward trend from 2000 to 2020, with an increase rate of 0.06/10a (*Fig. 2a*). The Z value of the M-K test was 2.39 at a confidence level of 2.33, passing a 99% significance test. From the perspective of the spatial variation over the last 20 years, areas experiencing the increase in vegetation cover account for more than 91% of the total area, with a maximum increasing trend of 0.03/10a, which was mainly concentrated in the northeast region of TGRR (*Fig. 3a*). Areas experiencing the decrease in vegetation cover mainly concentrated in the southwest region, with a maximum decreasing trend of -0.02/10a.

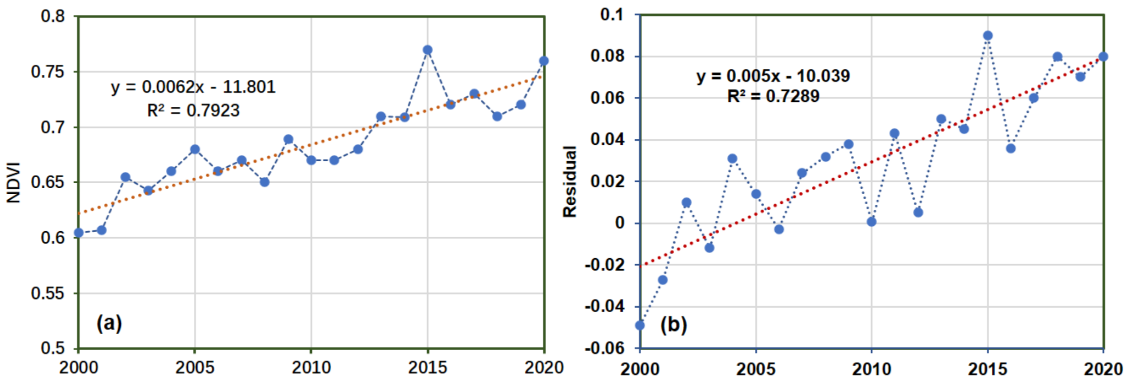

Figure 2. *(a) Change trend of observed NDVI from 2000 to 2020. (b) Change trend of residual between the observed NDVI and estimated NDVI from 2000 to 2020*

For more details, areas with the vegetation increase at the significant level constituted most of the study area (46.23%), and those at the extremely significant increase level account for 24.77%. Areas experienced the extremely significant decrease of vegetation cover constituted the least (0.39%), and those with significant decrease level were yielded as 0.61%. Approximate 28% of the study area experienced the insignificant change of vegetation whatever increase or decrease. Overall, the areas with the vegetation increase at the significant level and above accounted for 71% of the study area, showing an obvious vegetation restoration in TGRR from 2000 to 2020.

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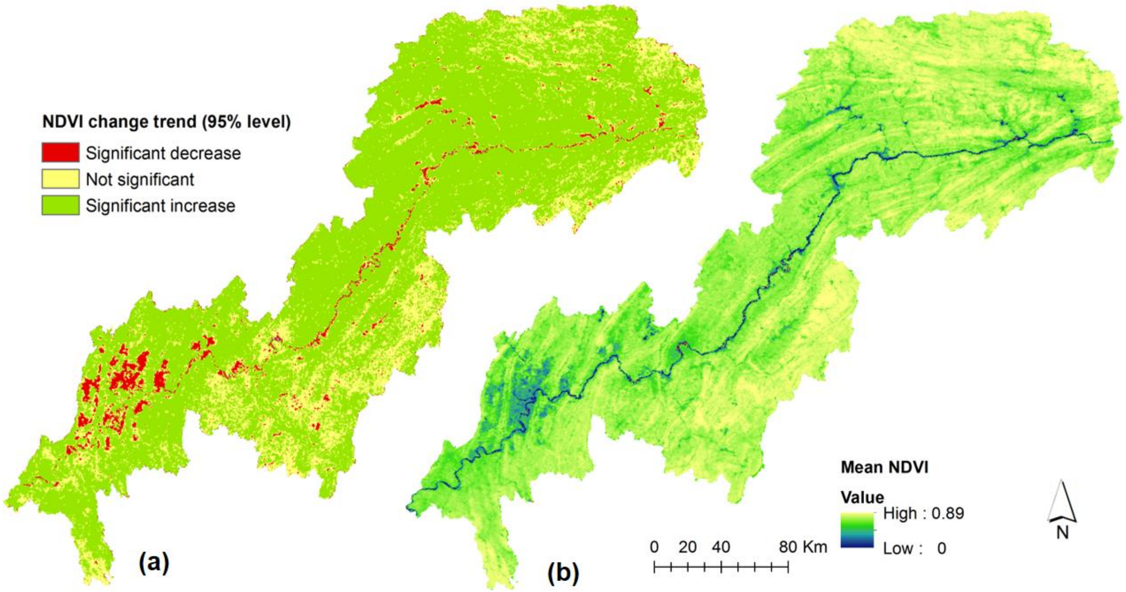

Figure3. *(a) Change trend of NDVI from 2000 to 2020. (b) Annual mean of NDVI from 2000 to 2020*

Spatial and temporal characteristics of the impact of human activity on vegetation cover

In this study, we found that the correlation coefficients between the annual mean NDVI and the annual mean temperature as well as annual rainfall in the study area from 2000 to 2020 achieved 0.52 and 0.76, respectively, both reaching significant correlation level. Based on the regression analysis on each grid, the NDVI-climate model was developed with rainfall and temperature factors as independent variables and NDVI as the dependent variable. Then, residuals were obtained by subtracting the estimated NDVI by NDVI-climate model from the observed NDVI.

It was found that the average NDVI residual from 2000 to 2020 was 0.005, indicating that the impact of human activity on vegetation change was predominantly positive. In terms of temporal variation, the NDVI residuals showed an increasing trend year by year, with a growth rate of 0.04/10a, and the maximum value occurring in 2015 (0.09) (*Fig. 2b*). In terms of spatial distribution, there were both positive and negative impacts of human activity on vegetation cover in the study area from 2000 to 2020, with the positive impacts being dominant (*Fig. 4*). The areas with positive impact of human activities on vegetation cover were mainly concentrated in the north-eastern part of the study area, with the most obvious impacts in the counties of Fengjie, Zhongxian, Wanzhou, and Kaizhou. The areas with negative impact of human activities on vegetation cover were mainly concentrated in the main urban areas of TGRR, such as Yubei, Jiangbei, Shapingba, Banan, and Jiulongpo. These places have high population density and rapid urbanization process, where large areas of farmland, grassland, and forested land have been converted to construction land resulting in a reduction in vegetation cover.

Contribution of different land use conversion types to vegetation cover variation

In the RESTREND analysis, residual was used to characterize the extent to which human influenced vegetation cover change on each grid cell, but it could not identify

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the specific ways of human influence. In general, land use conversion is treated as the crucial way of human activity to intervene the vegetation cover (Yuan et al., 2019; Wu et al., 2022). In the GIS environment, we summed up the grid-values of NDVI change for each land use conversion type (LUCT) from 2000 to 2020 as well as residual change. If we write the total change of NDVI (TCN) for the *i*-th LUCT as TCN_i. The contribution rate of *i*-th LUCT to the total NDVI change of the study area was calculated using $\mathrm{C_i} = |TCN_i| / \sum_{i=1}^{n} |TCN_i|$. The corresponding contribution of the total residual change was calculated in the same way. There are various types of land use conversion in TGRR, such as farmland-forested land and grassland-farmland. If the land use type had not been changed, for example farmland-farmland, we express it as persistent farmland.

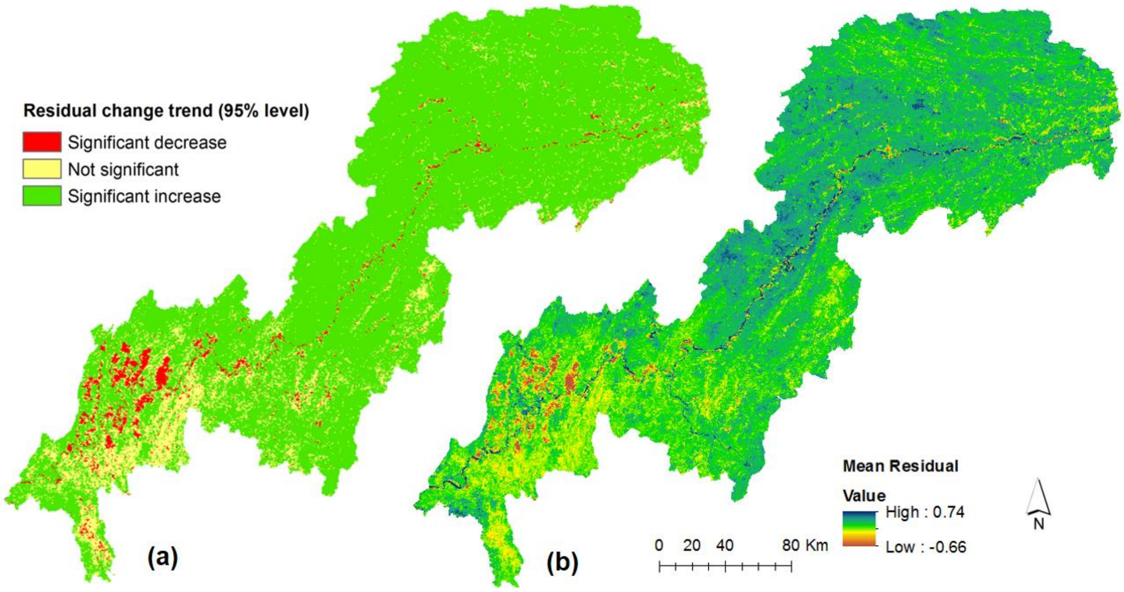

Figure 4. *(a) Change trend of residual from 2000 to 2020. (b) Annual mean of residual from 2000 to 2020*

As shown in *Table 2*, the largest contribution to vegetation change was from persistent forested land (61.25%) and persistent farmland (21.05%), which together accounted for 83.3% of the total change in vegetation cover of study area, followed by persistent construction land and persistent water regions. The areas experiencing the conversion of land use type all had very low contribution to vegetation cover change, with the largest contribution being only 3.92% from the conversion of farmland-forest land (the returning farmland to forest project). It was obvious that the returning farmland to forest project contributed substantially less to the overall changes in vegetation cover of the study area, despite great attention it has attracted. Farmland is a product of human activity, vegetation cover of which is controlled by human planting behavior (Lasanta et al., 2015; Fan et al., 2021). Therefore, vegetation cover change in the persistent farmland can be entirely attributed to human activity. As for the persistent forested land, vegetation change is the combined result of climate change and human activity. In the TGRR, persistent forested land contributed 61.25% to the total NDVI change, the corresponding value of residual is 50.76%, which merits further exploration.

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Table 2. *The degree of various types of land use conversion contributing to vegetation change*

Original type	Converted type	Area (km^2)	Observed NDVI		Residual	
			Total change	Contribution rate (%)	Total change	Contribution rate (%)
Farmland	Farmland	18130.99	14271.22	21.05	55419.23	23.65
	Forested land	642.64	572.02	3.92	1996.23	0.87
	Grassland	2.29	2.16	0.02	9.9146	0.01
	Water	18.21	-13.53	0.03	64.65	0.03
	Construction	511.72	-404.59	0.88	4132.18	2.03
Forested land	Farmland	25.80	-22.44	0.02	97.02	0.1
	Forested land	26194.67	24417.01	61.25	98260.86	50.76
	Grassland	1.40	-0.29	0.01	0.9612	0.03
	Water	6.35	-4.93	0.02	48.54	0.01
	Construction	179.14	-140.21	0.12	1265.38	0.65
Grassland	Farmland	36.33	-39.87	0.08	112.56	0.02
	Forested land	14.74	12.57	0.01	69.80	0.04
	Grassland	2115.12	2114.88	2.36	7861.68	0.03
	Water	1.22	-1.40	0.89	10.66	0.01
	Construction	8.62	-6.55	0.02	81.35	0.04
Water	Farmland	0.53	-0.44	0	4.094	0
	Forested land	0.46	0.20	0	0	0
	Grassland	0.01	0	0	0	0
	Water	1467.09	1511.02	4.01	15001.04	6.52
	Construction	26.17	22.41	0.03	324.06	0.12
Construction land	Farmland	103.74	86.60	0.25	334.06	0.23
	Forested land	13.93	9.93	0.01	87.43	0.05
	Grassland	0.11	0	0	0.15	0
	Water	-2.88	2.02	0	14.15	0.01
	Construction	3314.40	2298.36	5.02	22394.35	14.79

The impacts of human activity on vegetation restoration in persistent forested land

The areas persistently covered by the forest from 2000 to 2020 were mostly concentrated in the north-eastern of TGRR, where the terrain is dominated by the mountainous landscape with high elevation and high vegetation cover (*Fig. 3b*). In the persistent forested land, human activity generally had a restorative effect on vegetation cover, which is more obvious in northeast part of TGRR than the southwest. At the county scale, the five counties with largest residual in the decreasing order are Wushan, Fengjie, Wuxi, Kaizhou, and Yunyang.

Closing hillsides to facilitate afforestation (CHFA) is an important ecological restoration project implemented by local government, and it is a landmark human activity in the persistent forested land. We collected the data concerning the implementation area of CHFA project, and summed up the grid-values of NDVI change occurring in the persistent forested land for each county of TGRR from 2000 to 2020, as well as residual. Then the regression analysis was conducted among CHFA, NDVI and

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residual at the county level (*Fig. 5*). We found a highly significant positive correlation between the implementation area of CHFA project and the total change of NDVI ($R^2 = 0.84$). This suggests that the CHFA project has played an important role in promoting the recovery of vegetation cover in persistent forested land. The highly significant correlation between the implementation area of CHFA project and the residuals ($R^2 = 0.76$) convinced us that the physical interpretation of the residual in the persistent forested land is the CHFA project to a certain extent. This finding also confirms the effectiveness of RESTREND method in quantifying the impact of human activity on vegetation change.

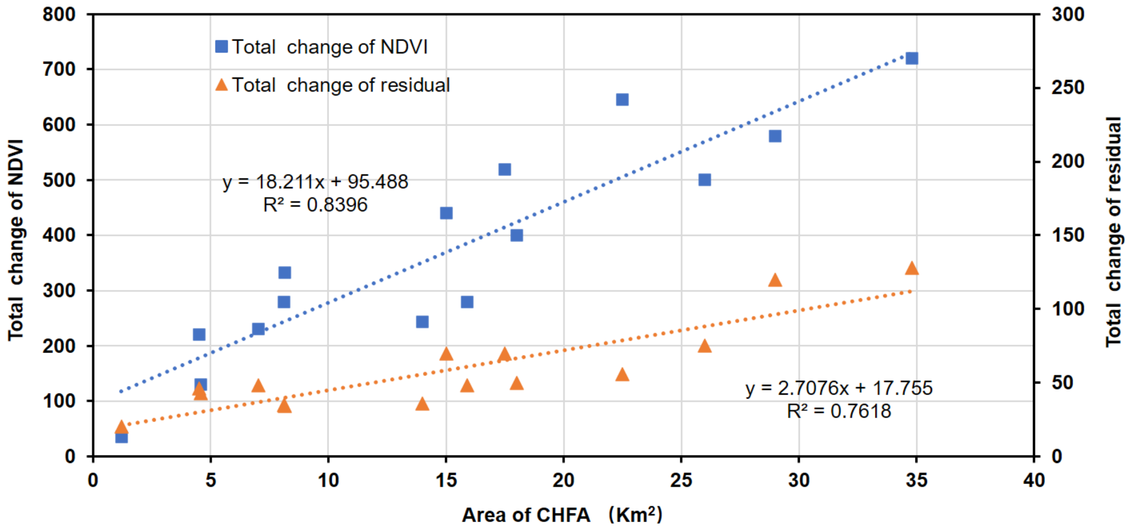

Figure 5. *The relationship between area of CHFA and total change of NDVI as well as residual at the county level*

Discussion

This study analyzed the spatial and temporal characteristics of vegetation cover in the Three Gorges Reservoir Region (TGRR) from 2000 to 2020. It was discovered that the overall vegetation cover in the study area exhibited an upward trend. This is basically consistent with the findings of Liu et al. (2013), who had investigated the vegetation cover change from 2000 to 2011 in TGRR. In the last two decades, the vegetation cover of the world has shown a pronounced recovery, and human activity as the main driver of vegetation cover change have begun to receive global attention (Liu et al., 2018; Jahani and Saffariha, 2021; Li et al., 2022). In general, land use conversion is treated as an important manifestation of the change brought about by human activities on vegetation cover (Yuan et al., 2019; Wu et al., 2022). Under the support of the GIS technology and RESTREND method, we clarified the relative contribution of different land use conversion types to the variation of NDVI and residual. The areas covered persistently by forested land and farmland contributed the most to the change in vegetation cover (83.3% in total) from 2000 to 2020, whereas the contribution of farmland-forested land conversion (the project of returning farmland to forest) was only 3.92%. Although existing studies have quantitatively demonstrated the significant benefits of the project of returning farmland to forest on vegetation cover restoration (Qiao et al., 2021; Zhou et al., 2021), for the TGRR, there is a need for in-depth studies

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on areas experiencing no land use conversion but bearing overwhelming majority of the vegetation change. Vegetation cover change in the persistent farmland can be considered to be primarily driven by human activity, whereas that in the persistent forested land is influenced by a combination of human activity and climatic conditions (Liu et al., 2018; Haghverdi and Kooch, 2020). In the persistent forested land, the regression equation between the implementation area of CHFA project and the total change of NDVI as well as residual was established at the county level. The results showed that the CHFA project played a significant role in promoting vegetation restoration in the persistent forested land. Simultaneously, a high-fitting result was also found between CHFA project and the residual change. Therefore, it can be assumed that the role of human activity on vegetation restoration in the persistent forested land is closely related to the CHFA project. The residual employed to represent the impact of human activity on vegetation change could be specified as the CHFA to a certain extent. By contrast, physical interpretation of residual produced by RESTREND method is always ambiguous in previous research (Li et al., 2012; Gedefaw et al., 2021; Irisarri et al., 2021). This study integrated various analytical methods to analyze in depth the impact of human activity on vegetation change in the TGRR. We have first time revealed quantitatively the important role of CHFA project on vegetation cover restoration, as well as tried to instance the residual of RESTREND method. Our study can provide certain references for enriching regional studies on the human driving forces behind vegetation change.

Conclusion

Taking the Three Gorges Reservoir Region (TGRR) as study area, under the support of the GIS technology, RESTREND method and regression analysis, we conducted a combined analysis of land use conversion and the change of NDVI as well as residual. The spatial and temporal characteristics of vegetation cover change in the TGRR from 2000 to 2020 were explored, and its human driving forces were quantitively calculated. The specific conclusions of this study are as follows: (1) The overall vegetation cover in the study area showed an upward trend from 2000 to 2020, with significant spatial heterogeneity. The increasing trend of vegetation cover was more obvious in northeast region of TGRR than the southwest region. (2) The residual analysis showed that human activity in the study area from 2000 to 2020 had both positive and negative impacts on vegetation coverage, with the positive impact being dominant. The positive impact of human activity was mainly concentrated in the north-eastern part of the study area, and the negative impact was mainly concentrated in the main urban area of TGRR. (3) Among the different types of land use conversion, the persistent forested land contributed the most to the total vegetation cover change in the study area (61.25%), followed by the persistent farmland (21.05%). The project of returning farmland to forest (farmland-forested land conversion) contributed only 3.92%. There was a highly significant positive correlation between the implementation area of CHFA project and the total change of NDVI ($R^2 = 0.84$) as well as residual ($R^2 = 0.76$) in the persistent forested land. The CHFA project could significantly promote the vegetation restoration and provide the physical interpretation for the residual change to a certain context in the TGRR.

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