

Chapter 2

Spatial–temporal Variation of Vegetation Cover in the Dadu River Basin and the Impact of Cascade Hydropower Development



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Abstract The spatial–temporal variation characteristics of NDVI in the whole Dadu River basin and the affected area of the cascade hydropower during the 22 years were studied based on the SPOT/VEGETATION dataset and precipitation and temperature data from 1998 to 2019 using pixel by pixel one variable linear regression and correlation analysis. The results showed that (1) The mean annual NDVI of the Dadu River basin maintained fluctuating growth, with an increase rate of 0.00476/a ($p < 0.05$) from 1998 to 2019. (2) The NDVI growth trend of vegetation in all areas of basin during the study period was significant, with 92.11% of the pixels showing a growth trend and of which 82.18% was significant. (3) The correlation between NDVI and temperature and precipitation in basin showed obvious regional differences. In the downstream area near the Chengdu Plain, NDVI is negatively correlated with precipitation and positively correlated with temperature while NDVI is positively correlated with temperature and precipitation in the northern area of Jinchuan County. (4) Comparing the NDVI changes before and after the construction of the hydropower plant, it shows that the hydropower plant may lower the NDVI value in the early stage of construction, but the vegetation will recover rapidly with the completion of the plant and will not change the original change trend. The above results show that the NDVI changes are mainly influenced by meteorological conditions, and the negative impacts of the hydropower plant construction on the basin level are limited and recoverable.

Keywords Dadu river basin · NDVI · Spatial–temporal features · Cascade hydropower · Correlation analysis

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The development of hydropower plants can have huge social and economic effects, but it also changes the structure and function of terrestrial and aquatic ecosystems to a certain extent. When hydropower plants are built and impounded, they will inevitably inundate part of the land leading to the loss of upstream terrestrial habitats (Botelho et al. 2017), and the increase in upstream water surface will also create microclimates, which in turn will affect the structure and diversity of upstream vegetation (Zhang et al. 2020). In addition, hydropower plant construction and operation alter the natural flow of rivers and directly lead to changes in sediment hydrology, resulting in the loss of rapids and longitudinal watercourses, affecting historical channel dynamics and alluvial geomorphology downstream. In many cases, as these changes may have a noticeable impact on riparian vegetation, leading to changes in structure and distribution, decreases in species richness and invasion of exotic species (Liu et al. 2022a), therefore, there is a lot of interest in the overall ecological impact on the basin.

Normalized Difference Vegetation Index (NDVI) is constructed by using the reflection characteristics of vegetation in visible and near-infrared wavelengths, and is often used as the best biophysical indicator of vegetation growth status and cover change, which especially the time series NDVI can better reflect the temporal evolution and spatial variability of vegetation activities on land surface. In particular, a time-series NDVI can better reflect the temporal evolution and spatial variability of vegetation activities on land surface (Chu et al. 2019; Peng et al. 2019), which has been widely used in vegetation change studies at different scales (Yang et al. 2019). For example, when Liu et al. studied the spatial and temporal variation of NDVI in various terrestrial ecosystems in China over the past 30 years, it was found that the vegetation activity in China has increased significantly over the past 30 years (Liu et al. 2018). Ma et al. studied the karst landscape area in southwest China and found that the response of NDVI to climate factors is spatially and temporally heterogeneous (Ma et al. 2021). Ouyang et al. found that the severely affected vegetation areas were concentrated within 5 km from the reservoir by comparing the interannual NDVI around reservoirs (Ouyang et al. 2010). Yi et al. showed that the construction of the dam trapped a large amount of water, sediment and nutrients in the upstream area, and the increase in air humidity and nutrients favored vegetation growth (Yi et al. 2019).

The environmental impact assessment of hydropower plants in general tends to focus on a small area and a short time span, lacking long-term studies and judgments on the extent of disturbance and overall impact results at the whole basin level (Li et al. 2012), while the longer duration and higher degree of development of the Dadu River basin is a good case to explore this issue. In addition, the current remote sensing data for assessing terrestrial vegetation cover can basically cover the pre and post time periods of the Dadu River basin development, and the application conditions are available.

Based on the above reasons, this paper takes the Dadu River basin as an example and tracks the long time series data from 1998 to 2019 in terms of NDVI, precipitation, temperature and other latitudes to comprehensively analyze the vegetation cover changes and spatial distribution characteristics of the Dadu River basin and

further investigate the impact of hydropower gradient development on the vegetation cover. The results of the study will reveal the impact of the Dadu River basin on vegetation cover. The results of the study will reveal the spatial–temporal variation characteristics of NDVI in the Dadu River basin and its influencing factors, and provide theoretical support for the development of ecological protection and sustainable development of the Dadu River basin.

2.1 Overview of the Study Area

The Dadu River is the largest tributary of the Minjiang River system in the upper reaches of the Yangtze River, originating from the southeastern foot of Goluo Mountain in Qinghai Province, with two sources: the eastern source is the Foot Muzu River and the western source is the Choshujia River, with the eastern source being the main source. The two sources from the mouth of the double river (i.e. Aba Malcom County, Baiwan Township) after the confluence began to be called Dadu River. Its latitude and longitude are between 99°42'E and 103°48'E, and its latitude is between 28°15'N and 33°33'N. The total length of the main river is 1062 km, with a natural drop of 4175 m, including 852 km in Sichuan Province, with a natural drop of 2788 m; the total river basin area is 77400 km² (excluding the Qingyi River), with an annual runoff of 47 billion m³, including a basin area of 70,821 km² in Sichuan Province, accounting for 91.5% of the total basin (He et al. 2021).

Dadu River main stream hydropower planning is mainly power generation, taking into account downstream flood control, navigation, water supply, etc. The development of Dadu River main stream basin lasted for a long time from 1965 when Gongzui hydropower plant was built, through planning adjustments and optimization studies of downstream and local river development methods, the whole basin was developed with 28 stages, at present, among the planned hydropower plants of Dadu River main stream, Monkey Rock, Changhe Dam, Jinjiping, Luding, Dagangshan, Longtoush, Waterfall, etc. Dagangshan, Longtou Shi, Waterfall Gorge, Shenxigou, Pillow Dam I, Shaping II, Gongzui, Tongjiezi, Shawan and Angu are built hydropower plants, Shuangjiangkou, Jinchuan, Hard Liangbao, Pillow Dam II and Shaping I are under construction, and most of the remaining steps are in pre-feasibility or feasibility study stage. The construction and spatial distribution of the main-stream stages are shown in Fig. 2.1.

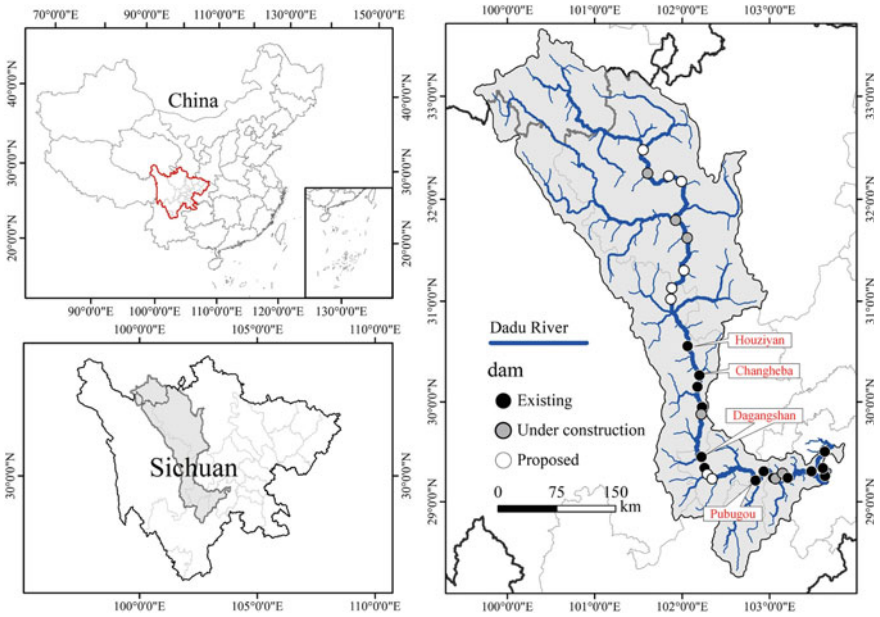


Fig. 2.1 Location of study area

2.2 Data and Study Method

2.2.1 Data Information

2.2.1.1 NDVI data

At present, NDVI time-series data obtained from satellite remote sensing images based on SPOT/VEGETATION and MODIS have been widely used in studies of vegetation dynamics monitoring, cover change detection, macroscopic vegetation cover classification and net primary productivity estimation in various scales (Liu et al. 2022b). The NDVI dataset used in this study is an annual vegetation index dataset generated based on the SPOT/VEGETATION (<http://www.vito-eodata.be>) decadal 1 km vegetation index data, using the maximum synthesis method to reduce the effects of the atmosphere, clouds, and solar zenith. index dataset (Holben 1986). This dataset effectively reflects the distribution and change of vegetation cover in spatial–temporal scales in all regions of the country, and is a very important reference for monitoring vegetation change status, rational use of vegetation resources and other ecological and environmental related fields of research. The data can be obtained from the Data Center for Resource and Environmental Sciences, Chinese Academy of Sciences (<http://www.resdc.cn/>).

2.2.1.2 Meteorological data

Regarding the relationship between vegetation growth and climate, temperature and precipitation are usually considered to be the most important climatic factors affecting vegetation dynamics. The annual spatial interpolation dataset of precipitation and temperature in China used in this study is based on daily observations of meteorological elements at more than 2400 plants nationwide, which is available from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (<http://www.resdc.cn/>). Spatially interpolated data of precipitation and temperature for each year from 1960 to 2021 generated by interpolation based on Anuspl interpolation software using smooth spline function on the basis of calculating annual values of each meteorological element (Interpolating mean precipitation using thin plate smoothing splines 1995). The annual average temperature unit is 0.1 °C, and the annual precipitation unit is 0.1 mm, and the spatial resolution is 1 km. The meteorological data were aligned with NDVI data by projection and row number alignment using ArcGIS 10.8 software.

2.2.2 Research Methods

2.2.2.1 Linear regression and significance test

Least squares was used to analyze the temporal rate of change of each pixel in the study area, thus reflecting the characteristics of the evolution of NDVI during the 22 years starting from 1998 to 2019.

$$Slope = \frac{n \times \sum_{i=1}^n i \times NDVI_i - (\sum_{i=1}^n i) \times (\sum_{i=1}^n NDVI_i)}{n \times \sum_{i=1}^n i^2 - (\sum_{i=1}^n i)^2} \quad (2.1)$$

where Slope is the slope of the NDVI regression trend, n represents the duration in years, and $NDVI_i$ represents the corresponding NDVI value at year i. When Slope > 0, it indicates an increasing trend of NDVI in the study area during n years; on the contrary, it indicates a decreasing trend of NDVI; if Slope is close to 0, it means that the change is not significant.

2.2.2.2 Correlation analysis

Meteorological elements are important factors affecting vegetation cover, and the growth of plants and the composition of vegetation types cannot be separated from the role of temperature as well as precipitation. In order to obtain the pattern of NDVI changes with meteorological changes, two variables, precipitation and temperature, were selected as the unit of analysis, and the correlation between NDVI and these

two meteorological factors was determined, so as to obtain the mode of action of climate on vegetation. The correlation coefficient is used to quantitatively determine the closeness of the correlation between the geographic factors, and the simple correlation coefficient is calculated as follows.

$$r_{x,y} = \frac{\sum_{i=1}^n (x_i - \bar{x}) / (y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (2.2)$$

where, \bar{x} and \bar{y} are the average values of elements x and y , respectively. The value of simple correlation coefficient is $-1 \leq r_{xy} \leq 1$, $r_{xy} \geq 0$ means that the two judged are changing positively to each other, while if it is less than 0, it is showing a reverse change. The smaller the difference between the absolute value of the calculated data and 1, the greater the correlation, r_{xy} the closer it is to 0, indicating that the correlation between the elements is not strong. The significance test of NDVI and climate elements in different years was conducted using t -statistic, and the t -statistic was defined as.

$$t = \frac{r\sqrt{n-q-2}}{\sqrt{1-r^2}} \quad (2.3)$$

where r is the correlation coefficient, n is the number of samples, q is the order, and the statistic t obeys a t distribution with $n - q - 2$ degrees of freedom. By the t -value, the probability P -value corresponding to it is calculated.

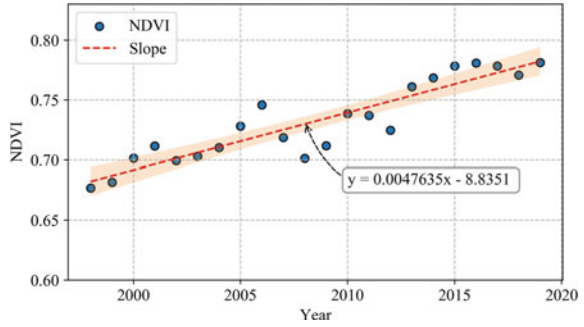
2.3 Results and Analysis

2.3.1 Overall Spatial Variation Characteristics of NDVI in Dadu River Basin

2.3.1.1 NDVI variation trend

The results of using one-dimensional linear regression analysis and least squares method to fit the annual maximum NDVI mean values over 22 years are shown in Fig. 2.2, the annual NDVI mean changes in the Dadu River basin during the study period showed an overall fluctuating upward trend Slope of $0.00476/a$ ($p < 0.05$), 1998–2001, 2002–2006, 2008–2010, and 2012–2016, the NDVI of the Dadu River basin showed a rapid increasing trend, and the NDVI of the Dadu River basin in 2001–2002, 2006–2008, and 2010 showed a rapid increasing trend, 2006–2008, and 2010–2012 NDVI values showed a decreasing trend followed by a rapid recovery. The average value of NDVI in the Dadu River basin during the study period was 0.732, where the maximum value occurred in 2019 with 0.781 and the minimum value occurred in 1998 with 0.677.

Fig. 2.2 Annual average of NDVI in the Dadu River Basin



The slope of each NDVI pixel by pixel was fitted to obtain the multi-year trend of NDVI spatial distribution, and the direction and rate of multi-year NDVI change in the basin were analyzed comprehensively. In, the NDVI change rates were divided into six categories: large decrease (<-0.008), medium decrease ($-0.008 \sim -0.004$), small decrease ($-0.004 \sim 0$), small increase ($0 \sim 0.004$), medium increase ($0.004 \sim 0.008$), and large increase (>0.008). The percentage of each change rate and spatial distribution as shown in Table 2.1 and Fig. 2.3. The percentage of the decreasing pixel only accounts for 7.89% of the total, and the large and moderate decreasing areas are mainly located in the eastern part of Xiaojin County and Markang City, the high altitude areas on both sides from Monkey Rock hydropower plant to Waterfall Gorge hydropower plant, the inundation area of Waterfall Gorge hydropower plant and around the downstream section from Gongzui hydropower plant to Hekou River, and the overall increasing trend of the basin NDVI, with the largest percentage of the moderate increasing area being 62.42%, followed by the small increasing area being 62.42%. The largest increase was 62.42%, followed by a small increase of 19.71%, and a large increase of 9.89%.

Table 2.1 NDVI change rate in the Dadu River basin from 1998 to 2019

Slope(/a)	Change rate	Number of pixel	pixel percentage (%)
<-0.008	Significant decrease	1084	1.42
$-0.008 \sim -0.004$	Medium decrease	1577	2.07
$-0.004 \sim 0$	Small decrease	3430	4.50
$0 \sim 0.004$	Small increase	15,038	19.71
$0.004 \sim 0.008$	Medium increase	47,629	62.42
>0.008	Significant increase	7548	9.89

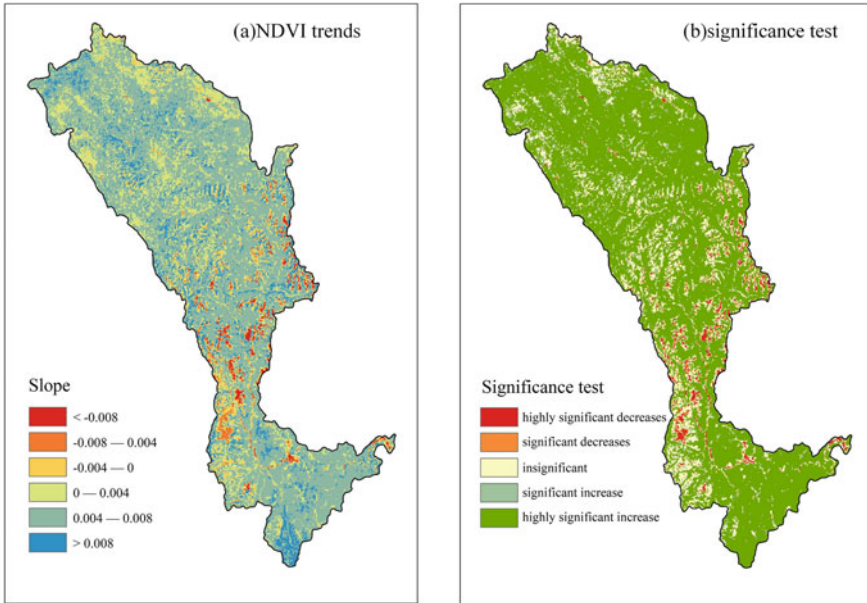


Fig. 2.3 Spatial distribution of NDVI trends and significance test

The significance test of pixel was conducted at $p = 0.05$ and $p = 0.01$ levels, and the results were highly significant for less than 0.01, significant for 0.01 ~ 0.05, and insignificant for more than 0.05. The results of are shown in Fig. 2.3. The majority of the areas in the basin showed a highly significant increase in NDVI, accounting for 76.01%, and 14.69% of the areas with insignificant changes, while the areas with significant and highly significant decreases accounted for only 3.14% of the basin area, with a similar distribution range as the areas with Slope < 0 .

In summary, the NDVI of the Dadu River basin from 1998 to 2019 showed a significant increasing trend, and the average value of Slope was $0.00476/a$. The NDVI of the basin only decreased in some high altitude areas from Luding to Jinchuan, but the rest of the areas showed a significant increasing trend.

2.3.1.2 Factors influencing NDVI changes

Research results show that regional climate change is an important cause of NDVI increase, while temperature and precipitation are important indicators of climate change (Hao et al. 2023). The annual mean temperature with precipitation and NDVI variation of basin in the study period is obtained by calculating the pixel average of the study area from year to year as shown in Fig. 2.4. The multi-year average temperature of Dadu River basin is $4.72\text{ }^{\circ}\text{C}$, the maximum annual average temperature occurs in 2006 at $5.26\text{ }^{\circ}\text{C}$, and the minimum value of $4.14\text{ }^{\circ}\text{C}$ occurs in 2004.

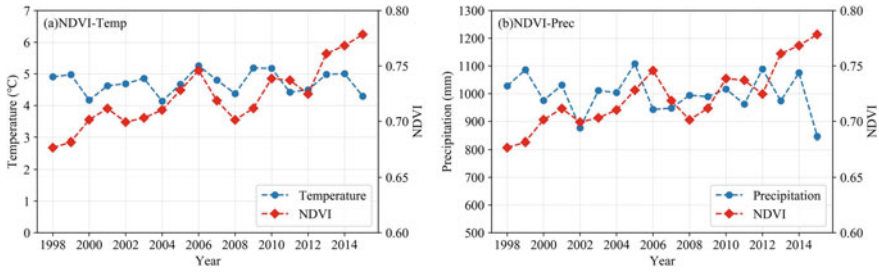


Fig. 2.4 Annual mean of NDVI and meteorological factors

The multi-year average precipitation is 997 mm, with the maximum annual average precipitation occurring in 2005 as 1108.03 mm and the minimum value occurring in 2015 as 845.71 mm. The coefficients of variation of annual mean precipitation and temperature are 6.79% and 7.21%, respectively, indicating that the annual mean precipitation and temperature of Dadu River basin have strong temporal stability.

The sliding correlation coefficient was used to check the stability of the correlation between NDVI and temperature and precipitation. The correlation coefficients between NDVI and temperature and precipitation were calculated for with a sliding window length of 9a, and the correlation coefficient series for each time period from 2002 to 2011 were obtained as shown in Fig. 2.5, according to which the stability characteristics of the correlation coefficients between NDVI and meteorological factors over time were analyzed. NDVI and temperature show a positive correlation with a mean correlation coefficient of 0.39, and the correlation shows an increasing trend from 2002 to 2004, and the correlation shows a more stable fluctuation from 2004 to 2010, and the correlation coefficient starts to decrease after 2010. The correlation coefficient between NDVI and precipitation is -0.021 , and the correlation coefficient increases gradually from 2002 to 2006, and becomes positive in 2004 and negative in 2007, and then becomes positive again in 2010, with no stable positive or negative correlation. In general, the overall vegetation NDVI of the Dadu River basin was positively correlated with temperature, but there was no stable correlation with precipitation.

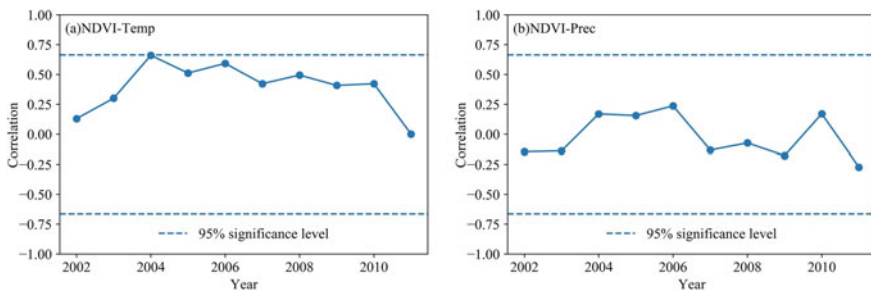


Fig. 2.5 Sliding correlation coefficient between NDVI and meteorological factors

In order to investigate the relationship between precipitation and temperature and vegetation NDVI in the Dadu River basin, pixel by pixel calculations were performed to analyze the relationship between vegetation NDVI and temperature in the Dadu River basin from 1998 to 2009. NDVI of vegetation in relation to precipitation and temperature from 1998 to 2019. The correlation coefficients of vegetation NDVI with precipitation (Fig. 2.6a) were $-0.87 \sim 0.71$, and the average value of correlation coefficient of all pixel was -0.103 . The positive correlation is mainly distributed in the north of Shuangjiangkou hydropower plant and the east side of the Dadu River main stream from Luding hydropower plant to Shuangjiangkou hydropower plant, as well as the area around Gongga Mountain itself with less precipitation, occupying 33.96% of the total area; the negative correlation area is mostly concentrated in most of the area downstream of Luding hydropower plant, as well as the west of the Dadu River main stream and other areas with more annual precipitation, occupying 66.04% of the total area. The spatial distribution of the correlation between precipitation and NDVI illustrates that the contribution of precipitation to vegetation growth is not necessarily positive but two-sided, with too much precipitation limiting vegetation growth and the right amount of precipitation promoting vegetation growth.

The distribution of correlation coefficients between NDVI and temperature is shown in (Fig. 2.6b), and the average correlation coefficient of all pixel is 0.0727.

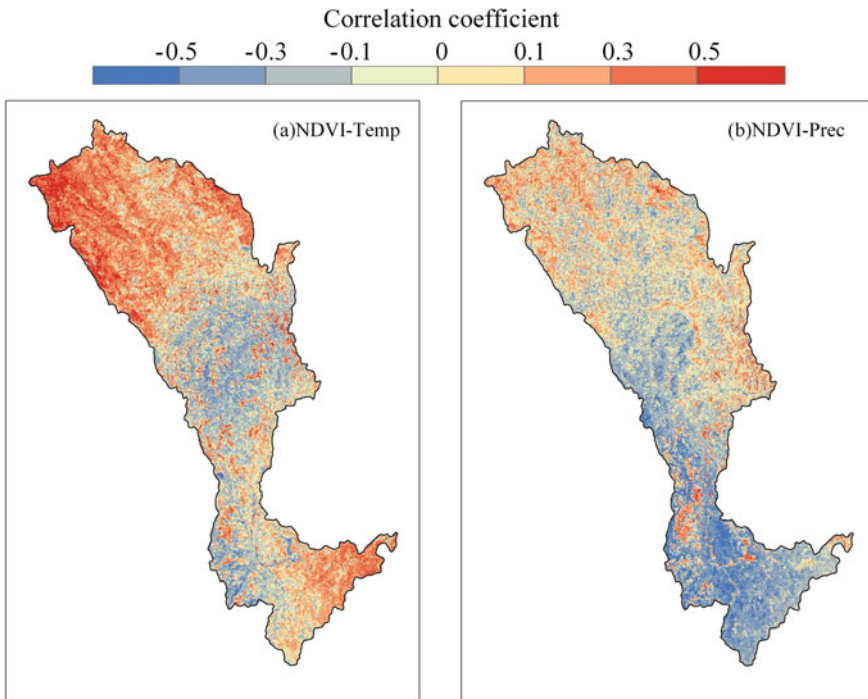


Fig. 2.6 Spatial distribution of the correlation between NDVI and meteorological factors

The positive correlation area is mainly distributed to the north of Shuangjiangkou hydropower plant and most of the area from Cascade Gorge hydropower plant to the downstream plain and the high altitude area within the area from Shuangjiangkou hydropower plant to Cascade Gorge hydropower plant, occupying 60.80% of the total basin area; the negative correlation area is mainly concentrated in most of the low altitude area from below Shuangjiangkou hydropower plant to Cascade Gorge hydropower plant, occupying 39.13% of the total area. Different from the correlation distribution of NDVI and precipitation, NDVI and temperature are still positively correlated in the plain areas where the annual average temperature is higher in the downstream, except for the area where the annual average temperature is lower in the upstream.

In conclusion, the correlation between temperature and precipitation and vegetation NDVI in the Dadu River basin is not completely positive but spatially heterogeneous. In areas with low temperature and precipitation, temperature and precipitation can promote vegetation growth, while excessive precipitation and temperature may lead to a decrease in vegetation NDVI. And in the area with abundant precipitation and low temperature like the Dadu River basin, temperature has a greater influence on NDVI than precipitation, especially for the higher elevation area in the northern part of the basin and the eastern part of the lower reaches, temperature has an obvious positive relationship on NDVI, and in the northern high elevation area, due to the original low precipitation and low temperature, temperature and precipitation together show a positive influence in this area.

a. Characteristics of the influence of hydropower plant construction on regional NDVI changes

In order to analyze the influence of hydropower plant construction on NDVI within the influence area of the plant, the four largest reservoir hydropower plants in the main stream of the Dadu River were selected and the slope of NDVI change within the influence area of the plant and the distribution of multi-year NDVI before and after the start of construction were calculated for 22 years. temporal and spatial distribution variation characteristics of NDVI.

Subscript 1 represents the multi-year NDVI average before the construction of the hydropower plant, subscript 2 represents the multi-year NDVI average after the start of the construction of the hydropower plant, and subscript 3 represents the slope of NDVI variation during the study period. Figure 2.7(a₁ ~ d₁) shows the multi-year NDVI mean values of each hydropower plant before construction. The largest NDVI mean value before construction is 0.794 at Dagangshan, the smallest is 0.736 at Cascade Gorge, 0.768 at Changhe Dam, and 0.747 at Monkey Rock. The river locations of Waterfall Gorge and Monkey Rock have relatively low NDVI values. Figure 2.7(a₂ ~ d₂) show the average multi-year NDVI values after the construction of the hydropower plant. After the construction of the hydropower plant, the NDVI difference between the river area and the reservoir perimeter increases significantly compared with that before the construction, and the change of NDVI mean value of all the hydropower plant influence areas is positive, at this time, the largest NDVI mean value is 0.827 in Dagangshan, the smallest mean value is 0.764 in Cascade Gorge, 0.818 in Changhe Dam, and 0.816 in Monkey Rock, where the multi-year

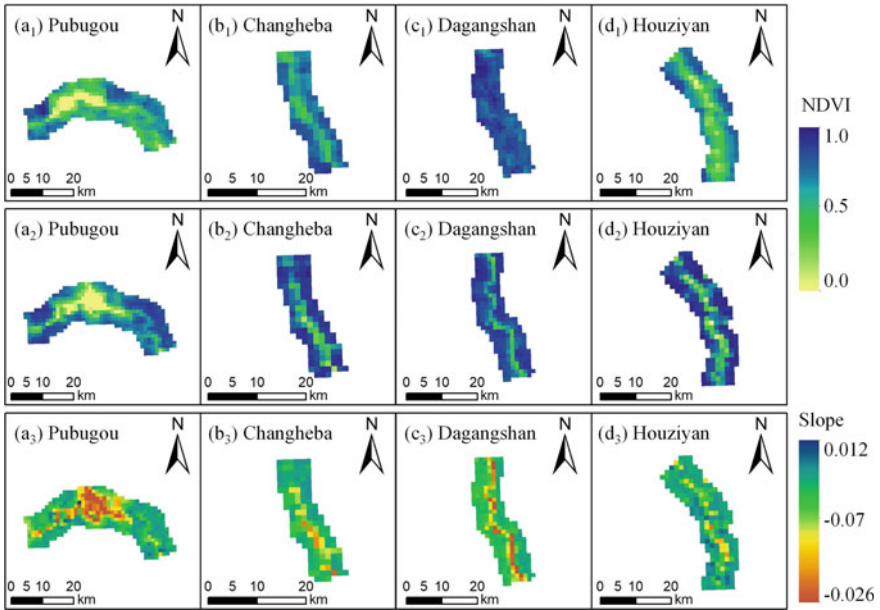


Fig. 2.7 Characteristics of NDVI changes in the area of influence of the plant

NDVI mean value of Monkey Rock increases The largest increase in NDVI was 0.0689 at Monkey Rock, and the least significant increase was 0.0282 at Waterfall Gorge. Figure 2.7(a₃ ~ d₃) show the direction and magnitude of NDVI changes in the influence range. The area of Slope < 0 of each plant is only distributed at the river, and the rest of the area shows an increasing trend, among which the waterfall ditch plant is the plant with the largest inundation area therefore it is also the largest area of Slope < 0 among the four plants, accounting for 25.27% of the total area.

The rate of change of NDVI in the area of influence of each plant before and after the construction of the dam Slope is shown in Fig. 2.8. From the trend, the NDVI change rate in the influence area of all hydropower plant s after the construction of dams still showed a significant increasing trend, among which the Slope values after the construction of Monkey Rock and Changhe dams started were larger than before the construction of dams, and the NDVI change rate increased from 0.0037/a ($p < 0.05$) to 0.0116/a ($p < 0.05$) and from 0.0024/a ($p > 0.05$) to 0.0093/a ($p > 0.05$), respectively. to 0.0093/a ($p < 0.05$); while the Slope values after the construction of Cascade Gorge and Dagang Mountain started were smaller than before the dams were built, and the rate of change of NDVI decreased from 0.0061/a ($p > 0.05$) to 0.0014/a ($p > 0.05$) and from 0.0050/a ($p < 0.05$) to 0.0021/a ($p > 0.05$), respectively. In the influence area of the selected hydropower plant s except for the Dagangshan hydropower plant, where the NDVI was not affected in the pre-construction period and still maintained an increasing trend, the NDVI of the other three hydropower plant s decreased in the pre-construction period. Among them, the NDVI of the

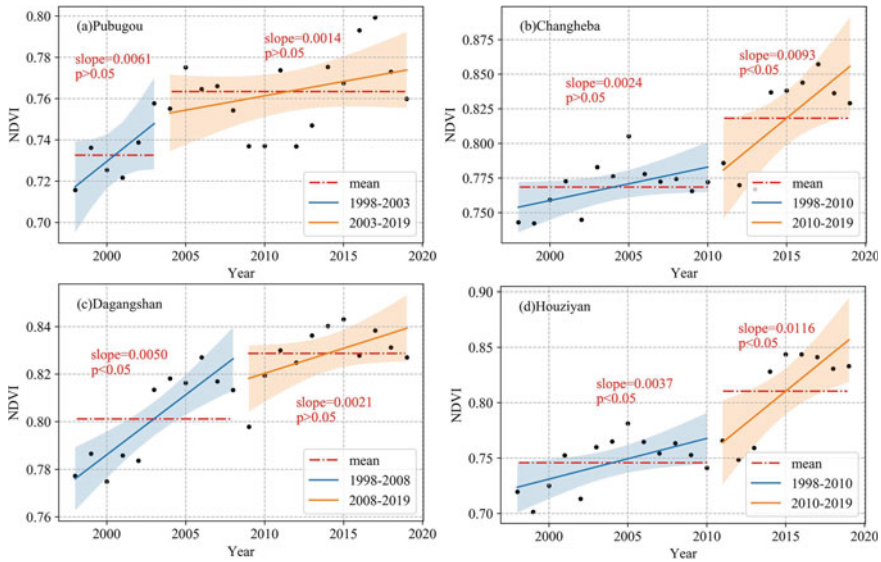


Fig. 2.8 NDVI change rate before and after dam construction

Cascade Ditch hydropower plant decreased continuously from 0.775 to 0.737 during the period from the cut-off in 2005 to the completion of the main project in 2011, and then recovered rapidly. Changheba hydropower plant had a small decrease in NDVI from 0.772 to 0.767 from the start of construction in 2010 to 2013, and then rapidly increased to 0.837 in 2014. Monkey Rock hydropower plant had a small decrease in NDVI from 2011 when it was cut off to 2012 and then recovered rapidly after 2013. The average NDVI in the impact area of Dagangshan hydropower plant did not change significantly in the first few years after the construction started, but started to decline continuously after all units were put into operation in 2015.

From the results of NDVI change in the influence area of the hydropower plant, the negative impact of dam construction on the NDVI of vegetation is mainly concentrated in the early stage of dam construction, which will cause a certain decrease in NDVI but the disturbance will recover quickly after the dam construction.

2.4 Conclusion

In this study, the NDVI change rate before and after dam construction was evaluated by using the synthetic data set based on SPOT/VEGETATION and the national meteorological interpolation data, selecting the Dadu River basin and the four hydropower plants on the Dadu River main stream as the study area, and studying the NDVI change characteristics and influencing factors from 1998 to 2019. basin cascade hydropower development on vegetation cover, and the study concluded the following.

- (1) The annual mean value of NDVI in the Dadu River basin from 1998 to 2019 maintained a fluctuating increase, with the maximum value occurring in 2019 at 0.781 and the minimum value occurring in 1998 at 0.677, with an increase rate of 0.00476/a ($p < 0.05$).
- (2) The correlation between NDVI and temperature and precipitation was spatially heterogeneous, with temperature and precipitation promoting vegetation growth in areas with low temperature and precipitation, while excessive precipitation and temperature could lead to a decrease in vegetation NDVI. Because of the abundant precipitation in the Dadu River basin, temperature becomes the main factor governing vegetation growth and has a greater impact on NDVI.
- (3) At the basin level, the impact of the construction of the step hydropower plant on the NDVI level of the entire basin is limited, and the NDVI decline caused by the construction of the hydropower plant is only distributed in the inundated area around the original river channel, and the rest of the impact area has a significant increase compared with the area before the construction.
- (4) The negative impact of dam construction on the NDVI of vegetation from the time scale is mainly concentrated in the early stage of dam construction, when the NDVI may decline to a certain extent, but not to a large extent, and will not affect the overall trend, and the disturbance will recover quickly after the construction of the dam.

The spatial resolution of the data used in this study is 1 km, and the use of low resolution data for analysis may overlook some more detailed results. NDVI is now widely used but NDVI also suffers from the problems of easy saturation in areas with high vegetation cover and incomplete correction of atmospheric effects, about which the problem of easy saturation exists in many studies (Song et al. 2017). Further selection of optimized vegetation index is needed to improve the sensitivity to high biomass areas and enhance the monitoring of vegetation. Previous studies in many regions have found lags in the response of NDVI to changes in meteorological elements, and the use of annual average data in this study may not accurately reflect the correlation between the two. Changes in vegetation and habitat climate due to hydropower development need to be studied with more detailed peripatetic data and longer time scales.

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