

# Spatial-temporal Changes of NDVI and Their Relations with Precipitation and Temperature in Yangtze River Basin from 1981 to 2001

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**Abstract** Multitemporal NOAA/AVHRR NDVI images and monthly temperature and precipitation data were obtained across Yangtze River basin covering the period 1981–2001. The spatial and temporal patterns of NDVI are the same, while spatial analysis shows that the NDVI is influenced by the vegetation types growing in the study regions, and NDVI presents an increasing trend during the study period in the whole basin. The climate indicators play an important role in the changes of vegetation cover in the river basin. In the two Indicators, temperature has a significant effect on the NDVI values than precipitation in the whole basin. However, in the 11 subbasins, the different rules are shown in different subbasins.

**Keywords** Yangtze River basin; NDVI; temperature; precipitation; time series

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## Introduction

The vegetation can typically show the seasonal and annual dynamics. The daily temporal resolution and globe coverage of satellite sensors NOAA AVHRR makes it possible to monitor vegetation at different spatial and temporal resolutions globally.<sup>[1]</sup> Normalized difference vegetation index (NDVI) data collected by AVHRR sensor have been widely used to study vegetation dynamics on the earth. The investigation for the long-term variations in both vegetation condition and climate change is a good method to monitor the changes of the environment of the globe. Research on

the NDVI dynamics in a long time series and relationships between the vegetation and meteorological factors in the regional scale is of significance to monitor the environmental changes in a basin.

Many research works have focused on the dynamic relations between vegetation and the climatic factors in large regional scale. Herrmann *et al.* analyzed the trends in vegetation dynamics in the African Sahel and their relationship to climate.<sup>[2]</sup> Li *et al.* and Sun *et al.* chose the typical vegetation types and representative areas in China that is sensitive to the regional environment to do the analysis.<sup>[3, 4]</sup> Chen *et al.* studied the driving force of the meteorological factors to NDVI values.<sup>[5]</sup> Ma *et al.* analyzed interannual vari-

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ability of vegetation cover and the relation of NDVI and meteorological parameter in Heihe River basin in China.<sup>[6]</sup> Li and Yang divided Yellow River basin into 16 subregions to analyze the relations between NDVI and precipitation and runoff values.<sup>[7]</sup>

In this paper, a time series of 8 km×8 km 15 days NOAA NDVI from 1981 to 2001 is selected, and the monthly precipitation and temperature data is collected from the China Academic of Sciences (CAS) website. Spatial and temporal analysis and statistical analysis are employed in the study to do the change analysis in the long time series. The author analyzes the annual changes of vegetation in these areas by NDVI, as well as the relations between the NDVI value and meteorological factors in different sub-basins in the Yangtze River basin.

## 1 Study area

The Yangtze River, also called Changjiang in Chinese, is the longest (also the largest) river in China, and the third longest river in the world. It originates in Tibetan Plateau, crosses the country from the west to the east and eventually flows into the East China Sea. The Yangtze River (Fig.1) flows about 6300 km in distance and has 1.8 million km<sup>2</sup> of drainage area. Nearly 440 million people live in this river basin. The upstream of the Yichang gauge (near the Three Gorges Dam site), called the upper Yangtze River, has a drainage area of about 1.0 million km<sup>2</sup> and contains four major tributaries, namely, Jinsha River, Mintuo River, Jialing River, and Wu River. The middle part of the upstream is the Sichuan basin where the elevation is lower than 1000 m. The region between the Yichang gauge and Jiujiang gauge is called the middle-stream, which includes Han River tributary and two large lakes, namely, Dongting Lake and Poyang Lake. Below the Jiujiang gauge is the lower Yangtze River. The long-term mean of the annual precipitation in the Yangtze River basin is about 1070 mm, but its spatial and temporal distribution is highly uneven. The annual spatial precipitation ranges from 500 mm in the west to 2500 mm in the east, and more than 60% of annual precipitation is concentrated in summer (June, July, and August). The climate causes frequent floods as well as droughts, sometimes, in the river basin.

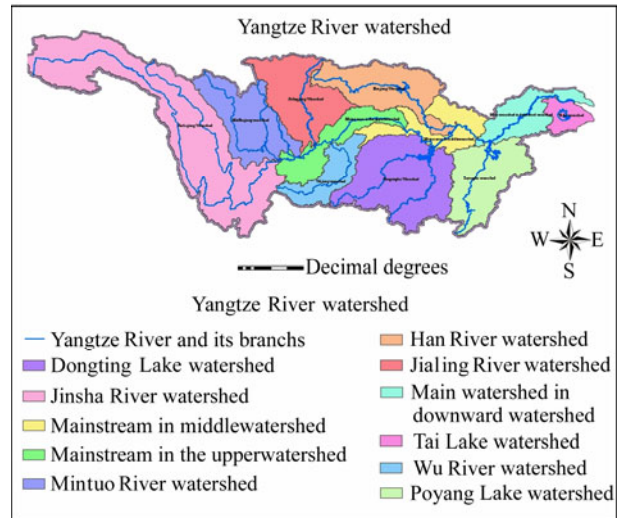


Fig. 1 Yangtze River basin

## 2 Data and methods

### 2.1 Data preparation

#### 2.1.1 NDVI dataset

NDVI data used in this study were processed by the GIMMS group at NASA's Goddard Space Flight Center, as described by Tucker *et al.* (1994).<sup>[8]</sup> For this research, NDVI monthly data at 8 km spatial resolution were generated from an already processed 15-day NDVI composites using the maximum value compositing (MVC) procedure to minimize effects of cloud contamination, varying solar zenith angles, and surface topography,<sup>[9]</sup> and reconstruct the time series of NDVI data to monthly data.

#### 2.1.2 Climate variables

Climate variables were downloaded from the 1 km resolution yearly and monthly rainfall dataset and 1 km resolution yearly and monthly temperature dataset in China, which is produced by the CAS using the Austin 4.3 software to interpolate the 680 points' precipitation and temperature data from the meteorological stations to 1 km resolution raster dataset. The interpolation method used in the Austin 4.3 software is thin plate smoothing splines (TPS), which is confirmed to be the fittest interpolation method in dealing with the meteorological data.

#### 2.1.3 Vector data of subbasin range

SRTM (shuttle radar terrain mission) data and

ArcGIS 9.0 hydro tools were used to do the basin segmentation to divide Yangtze River basin into 11 subbasins. SRTM data is the DEM data with 90 m resolution downloaded from the CIAT (The International Center for Tropical Agriculture) dataset.

## 2.2 Spatial and statistical analysis methods

### 2.2.1 Spatial analysis method

There are 21 years mean NDVI map and yearly anomalies maps from 1981 to 2001 to show the NDVI spatial patterns and trends generated by the ArcGIS 9.0. Yearly anomalies maps are calculated by the Eq.(1):

$$NDVI_{\sigma} = [((NDVI_{\alpha}) / (NDVI_{\mu}) - 1)100] \quad (1)$$

Where  $NDVI_{\sigma}$  are yearly percent anomalies,  $NDVI_{\alpha}$  are individual annual means, and  $NDVI_{\mu}$  is the long-term yearly NDVI mean.

### 2.2.2 Statistical analysis method

Several statistical methods, including multiregression analysis, correlation analysis, and GIS spatial calculation, were employed to analyze the relationships between NDVI and meteorological factors in the whole basin and its 11 subbasins.

## 3 Results

### 3.1 Spatial patterns and trends of NDVI

Mean NDVI distribution map and yearly anomalies series maps in the 21 years are generated to show the spatial distribution and changes of NDVI in the study period. According to Fig.2, NDVI values in the spatial distribution are largely dependent on the vegetation types and land use covered in the ground. NDVI shows low value in the area along the headstream of Jinsha River subbasin covered with poor soil conditions for the nature environment while Sichuan basin and the areas along the downstream covered by farmland and cities for the human activities. NDVI shows high value in the areas along the downstream of Jinsha River subbasin, upstream of Mintuo River and Jialing River subbasin, upstream and midstream of Han River subbasin, the western and southern part of Dongting Lake subbasin, and most part of Poyang Lake subbasin for land cover in most of these areas are forests.

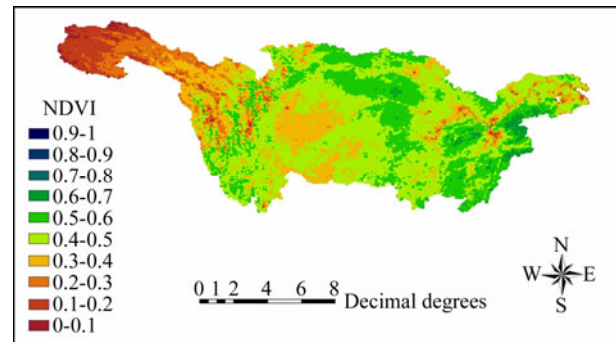


Fig. 2 Yangtze mean NDVI from 1981 to 2001

Fig.3 shows the spatial NDVI anomaly patterns for Yangtze River basin from 1981 to 2001. The series maps shows that the vegetation cover is increasing in the basin in the study period and most of the areas have no obvious changes, while the upstream basin shows an upward trend from 1981 to 2001 especially for the JingShajiang subbasin because of the government's water and soil protection measures after 1989. Moreover, the vegetation cover in downstream areas shows a fluctuation trend of the NDVI values because of the highly developed economy in these areas. Areas in the midstream show no obvious changes fluctuating with the meteorological factors' change. In 1995, it shows a better vegetation cover in all the subbasins except for the Jinsha River subbasin. It may be because of the high temperature and low precipitation in the Jinsha River subbasin, but other areas in the basin have good water and temperature conditions.

### 3.2 Temporal patterns of NDVI

Average annual NDVI from 1981 to 2001 are shown in Fig. 4. They show that the NDVI is increasing in the study period and achieve the maximum value in 1995 and minimum value in 1984.

### 3.3 Correlation analysis with NDVI and meteorological factors

Multiregression among NDVI, precipitation and temperature, correlation coefficients with NDVI and precipitation, NDVI with one month lag precipitation, and NDVI with temperature are respectively calculated in Yangtze River basin and its 11 subbasins.  $R$  squares and correlation coefficients are shown in Table 1, where  $P$  represents precipitation,  $P(\text{lag})$  represents the one month lag precipitation, and  $T$  represents temperature.

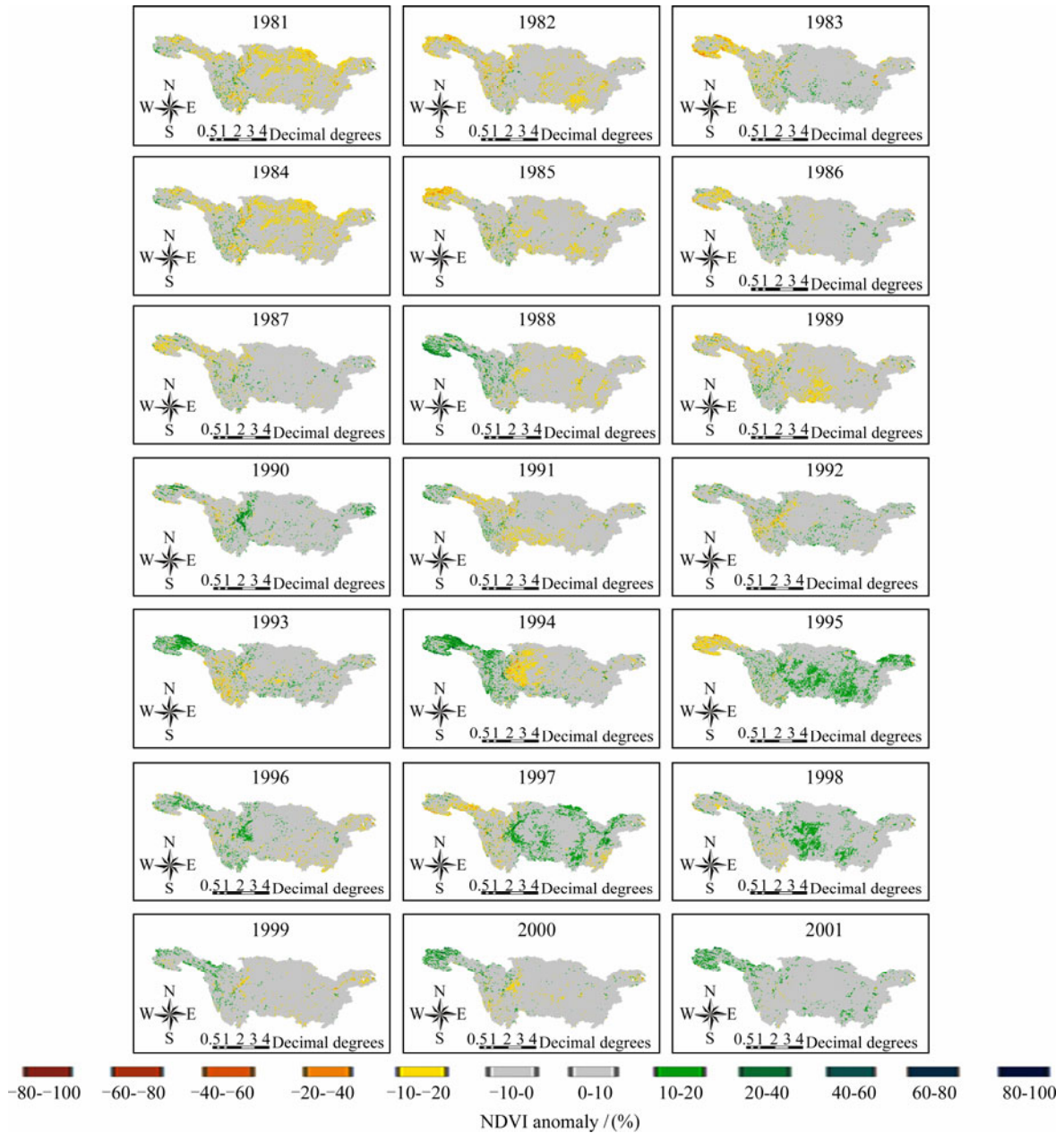


Fig. 3 Yangtze NDVI anomaly map (1981-2001)

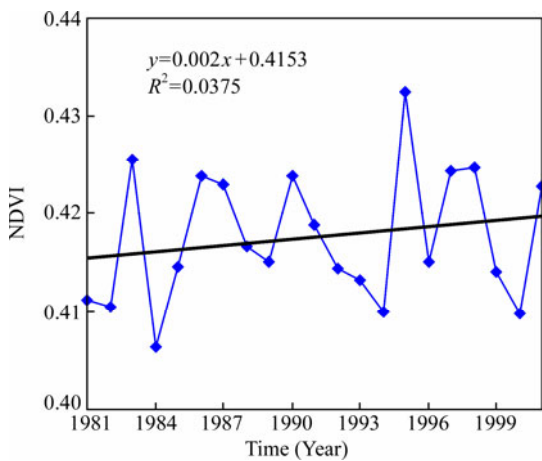


Fig. 4 Average annual NDVI from 1981 to 2001

In Table 1, NDVI shows a good correlation with the precipitation and temperature and the  $R$  square value gets to 0.888 in the whole basin. It means that the meteorological factors play an important role in changes of vegetation dynamics in Yangtze River basin. Except for the Jingshaji subbasin and Tai lake subbasin, the  $R$  squares in the other subbasins are bigger than 0.8, and its values also largely depend on the NDVI values in these subbasins. Han River, Poyang Lake subbasins show high  $R$  square value with high NDVI values in these areas, as shown in Fig.2. Jinsha River subbasin shows a low value because of its nature environment while Tai Lake subbasin for the highly developed economy.

**Table 1** Correlation coefficients

NDVI	Correlation coefficient			R Square
	P	P (lag)	T	
Jinsha River	0.770	0.911	0.729	0.600
Mintuo River	0.899	0.878	0.886	0.830
Jialing River	0.906	0.848	0.953	0.918
Wu River	0.827	0.887	0.932	0.869
Upper mainstream	0.528	0.550	0.959	0.921
Han River	0.811	0.817	0.969	0.940
Dongting Lake	0.725	0.861	0.932	0.876
Mid mainstream	0.718	0.839	0.967	0.936
Poyang Lake	0.722	0.838	0.968	0.938
Tai Lake	0.216	0.472	0.764	0.667
Down mainstream	0.589	0.791	0.959	0.920
All basin	0.836	0.926	0.942	0.888

Both precipitation and temperature showed a linear positive correlation with NDVI value in the whole Yangtze River basin, while temperature influence is larger than the precipitation.

NDVI shows a lag response to the precipitation, and the correlation analysis is operated between the precipitation data and the NDVI values that are suspended by a time interval. The result shows that the correlation coefficient is obviously increased when the interval is set to one month.

Precipitation and temperature have different effects depending on different subbasins. Temperature had more significant effects than precipitation on vegetation dynamics in the subbasins except for Jinsha River subbasin. In the subbasins along the downstream, precipitation shows small correlation with NDVI values for the reason that human activities play a big role in the vegetation cover in these areas. In the subbasins along the midstream and upstream, the precipitation plays an important role in vegetation dynamics in these areas especially in Jinsha River subbasin and is more sensitive to the vegetation dynamic than temperature.

## 4 Conclusion

In the period from 1981 to 2001, the NDVI values show an increasing trend based on the spatial and temporal analysis of the whole basin. Moreover, from the spatial analysis, NDVI distributions largely depend on the vegetation types and land use covered in the ground.

NDVI values from 1981 to 2001 in Sichuan Basin and areas along the downstream area show a de-

creasing trend with the development of the economies in this area, while the changes in part of upstream subbasins show an increasing trend as the water and soil protection measures taken by the government.

Vegetation dynamics in subbasins along the downstream and Jinsha River subbasin show a lower correlation to the climate changes than the other subbasins. This suggests that human activities, such as urbanization, play an important role in the vegetation cover along downstream, while the nature features have a more positive effect along the midstream and upstream.

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