Spatial-temporal variation of NDVI and its responses to precipitation in the upper of Heihe from 2000 to 2019

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Abstract—As the direct result of climate change, Spatio-temporal variation of vegetation cover is an important index in regional ecological change. Based on Google Earth Engine, MODIS-NDVI and precipitation of TRMM from 2000 to 2019 were extracted. Trend analysis method and PCCs were applied to explore the different scales temporal and spatial change of NDVI and the relationship between NDVI and precipitation in the upper of Heihe River Basin. It was found that the annual change of vegetation increased slowly in the study area, and correlation of vegetation NDVI with precipitation are insignificant. On month scale, the vegetation change was cyclical, there was a noticeable increase from June to September, but from November to next February, the vegetation coverage was the lowest, the change of precipitation had the similar variation pattern, and there was a strong positive correlation between precipitation and NDVI. In terms of spatial change, the NDVI rose generally from northwest to southeast, vegetation coverage in northwest was improved.

1. Introduction
Vegetation is an essential component of terrestrial ecosystems, it thereby represents a natural link among the atmosphere, water, and soil, thereby playing important roles in the energy exchanges, biogeochemical cycles, and hydrological cycles at the land surface[1, 2]. With the influence of climate change, vegetation variation is important indicators of changes in the regional ecological environment[3, 4]. Among existing vegetation indices, the normalized difference vegetation index (NDVI) can reflect the growth activities and basic condition of vegetation[5-7]. Thus, NDVI is widely used in monitoring vegetation.

Located in the Northwest China, the upstream of Heihe river basin is an ecological fragile area[8]. It’s significant for the balance of oasis ecosystem in the lower reaches of inland rivers to study vegetation changes in this area, which efficiently curb the development of desertification[9]. Li et al.[10] found that the vegetation coverage in Heihe River Basin has improved from 1999 to 2010, and it gradually changes with the trend of desertification from the southeast to the northwest. Yuan et al.[11] found that precipitation was the dominant factor for the overall basin. In the upper basin, elevation was found to be the dominant factor in the Heihe River Basin during the period of 2000–2016.

The data were taken from Google Earth Engine (GEE) in this paper. GEE is a geospatial processing
service, and it is powered by Google Cloud Processing. As the boom of remote sensing, geospatial data gets more complex and diverse, and the storage and computation of remote sensing data becomes a challenge. The development of GEE has created much enthusiasm and engagement in the remote sensing and geospatial data science fields[12]. There is a wide variety of data in GEE. It includes common satellite data, and ready-to-use products. Additionally, GEE provides API with JavaScript and Python to process and calculate geospatial data more convenient.

This study based on the GEE to extract MODIS-NDVI data and precipitation production of TRMM in the upper of Heihe river basin. The purpose was to investigate Spatio-temporal variation of vegetation cover from 2000-2019 in this area, and explore the correlation of NDVI and precipitation on different scales.

2. Materials and Data

2.1. Study area
The Heihe River is the second largest inland river in the arid region of Northwest China, and it’s one of the important tributaries of the upper reaches of the Yellow River. The upper of Heihe River Watershed (figure 1), on the northeast edge of the Qinghai-Tibet Plateau, divides into BaBaoho River and Yeniugou. The two forks merge in Huangzangsi flowing north to Yingluoxia, which is the exit of Qilian Mountain. The average annual precipitation in this area reaches to 500mm, and the study area covers 2088 km2 with low temperature.

2.2. Data
The 16-day composite NDVI data of MOD13A2 was acquired in the period of February,2000 to December 2019, with a spatial resolution of 1km2. The monthly precipitation production of TRMM in the same period of February, 2000 to December 2019 with a resolution 0.25°were used. And above data were from GEE.

2.3. Method
Trend Analysis were widely used in the research of vegetation change, the slope of regression equation represents the intensity of vegetation growth change. The calculation formula is as follows:
\[
Slope = \frac{\sum_{i=1}^{n} (i - \bar{i}) (NDVI_i - \bar{NDVI})}{\sum_{i=1}^{n} (i - \bar{i})^2}
\]

(1)

\(n\) is the length of time, \(NDVI_i\) is NDVI in ith, \(\bar{NDVI}\) is the mean of NDVI in 20 years. When the value of slope more than 0, vegetation shows growth trend. Otherwise, it shows decrease trend.

Pearson correlation coefficient (PCCs) measures the linear correlation of two variables, and the calculation formula is as follows:

\[
R_{xy} = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})}{\left[\sum_{i=1}^{n} (X_i - \bar{X})^2 \sum_{i=1}^{n} (Y_i - \bar{Y})^2\right]^{1/2}}
\]

(2)

\(R_{xy}\) is the Correlation coefficient of \(X\) and \(Y\); \(n\) is the number of sample data; \(\bar{X}\) is the mean of \(X\), \(\bar{Y}\) is the mean of \(Y\).

3. Result

Figure 2 shows the change of annual NDVI. Generally, the NDVI in the study area rose slowly from 2000 to 2019. In 2003, NDVI was lowest, which indicates the minimal vegetation coverage. However, the value of NDVI increased from 2004 to 2006, and in 2014-2018, NDVI had been increasing, and comes to 0.273, the maximum value in 20 years.

Figure 3 is monthly NDVI variation in the study area. There was obviously periodic characteristic that had seasonality and a series of peaks and valleys. The changes in different cycle had similar trend. Generally, NDVI reached to the max in July that increased before July and decreased after July. During a year, NDVI was higher from June to September, which might be attribute to the maturity of plant and more precipitation. The fact that NDVI was in valley indicated that vegetation in the area covered with winter snow withered from November to February. The impact of precipitation on NDVI was limited.

Figure 4 shows the relationship between NDVI and precipitation in study area on year scale. With the R2 was 0.06, the linear correlation between NDVI and precipitation was weak. The impact of precipitation on NDVI was limited. According to figure 5, NDVI and precipitation were in Linear positive correlation, and the high Pearson's r was 0.908. Additionally, there was a similar period between NDVI and precipitation.
Figure 4. Relation of NDVI and precipitation

Figure 5. Pearson correlation coefficient of NDVI and precipitation

From the spatial trend change of NDVI in study area (figure 6, figure 7), the overall change in the northwest area was rapid from July to September, and in March to June, Slope reduced gradually, especially in low altitude areas. And the Slope rose rapidly, and started to decrease from November.

Figure 6. Spatial distribution of NDVI change trend from January to February

Figure 7. Spatial distribution of NDVI change trend from June to December

Figure 8 shows the distribution of NDVI in 2001, 2009, 2018. Compared to NDVI in 2001, NDVI increased significantly, and it represented the increase of the overall vegetation coverage level. The NDVI in southwest rose generally from southeast to northwest, and the coverage of vegetation in northwest was lower than in southeast.
Figure 8. Spatial distribution of NDVI in study region in 2001, 2009 and 2018

4. Conclusion
Using GEE, we obtained MODIS NDVI, TRMM precipitation data in the upper of Heihe in 20 years to explore the Spatio-temporal change of NDVI, and analyzed the impact of precipitation on vegetation NDVI.

Generally, vegetation in the area had experiencing a slow growth and the change showed periodicity[13]. Normally, NDVI increased significantly from June to September, and was low from November to February, which was consistent with the growth cycle of plant and as same as the change of precipitation data. According to the PCCS, NDVI and precipitation were in obviously positive correlation on month scale indicating that precipitation was one of the most important factors affecting vegetation variation[14]. However, on year scale, out of the weak correlation of NDVI and precipitation, there was limited influence of precipitation on NDVI. Additionally, there was higher NDVI in southeast compared to northwest, and in the northwest had improved modestly.

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