Effects of Ecological Water Transfer on Fractional Vegetation Cover in the Surrounding Area of Qingtu Lake (Postprint)

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Abstract

Water transfer through artificial intervention to restore degraded ecosystems represents an effective approach for alleviating ecological problems. Qingtu Lake, the terminal lake of the Shiyang River, serves as a typical application case, with considerable attention focused on how ecological water transfer influences various regional environmental mechanisms. This study utilizes Landsat imagery of Qingtu Lake from 1987 to 2016 to retrieve Fractional Vegetation Cover (FVC), first examining the overall dynamic characteristics of FVC, and subsequently analyzing the relationship between its changes and ecological water transfer, in addition to climatic factors. The research demonstrates that over the past 30 years, the average vegetation cover in the Qingtu Lake surrounding area has increased from approximately 10% to over 20%; the vegetation cover change trend differed significantly before and after 2010. Employing trend analysis to compare vegetation cover change characteristics before and after the September 2010 ecological water transfer, the results reveal that although climate change constitutes the primary factor influencing large-scale vegetation cover, its impact on the vegetation cover increase around Qingtu Lake was relatively weak in this study; vegetation cover increased significantly primarily in areas proximal to the lake region, with ecological water transfer serving as the main influencing factor for this increase. Prior to the 2010 ecological water transfer, the annual average vegetation cover exhibited no significant trend, whereas following the 2010 ecological water transfer, it displayed a significant upward trend.

Full Text

Effect of Ecological Water Conveyance on Vegetation Coverage in the Surrounding Area of Qingtu Lake

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Abstract: Ecological water conveyance represents an effective human intervention approach for alleviating ecological problems and regenerating degraded ecosystems. This method has been implemented in the surrounding area of Qingtu Lake, the tail-end lake of the Shiyang River in Minqin County, Gansu Province. The impact of ecological water conveyance on the regional ecology and environment has attracted considerable attention. This study reconstructed the fractional vegetation coverage (FVC) in the Qingtu Lake area using Landsat images from 1987 to 2016. The characteristics of overall FVC dynamics were first explored, followed by an analysis of the relationship between these changes and ecological water conveyance. Results demonstrated that the average vegetation coverage in the Qingtu Lake area increased from approximately 10% to 20% over the past 30 years. The change trend of vegetation coverage before and after 2010 showed obvious differences. Trend analysis was employed to compare vegetation characteristics before and after the ecological water conveyance in September 2010, revealing that while climate change was the main factor affecting large-scale vegetation coverage, its effect on vegetation in the study area was slight. Vegetation coverage increased primarily in areas near the lake, with ecological water conveyance being the main driving factor. The annual vegetation coverage change before the 2010 ecological water conveyance was not obvious, but it showed a significant increasing trend thereafter.

Keywords: ecological water conveyance; vegetation coverage; climate change; Qingtu Lake

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1. Introduction

Qingtu Lake, located in the lower reaches of the Shiyang River basin, represents a critical ecological barrier in the Minqin area. The lake has experienced severe degradation due to water scarcity and environmental stress. In response, ecological water conveyance projects have been implemented since 2010 to restore the degraded ecosystem. Understanding the response of vegetation coverage to these interventions is essential for evaluating the effectiveness of restoration efforts.

2. Data and Methods

2.1 Study Area

The study area encompasses the Qingtu Lake region in Minqin County, Gansu Province, situated in the lower reaches of the Shiyang River basin. The geographic coordinates range from 39°04 to 39°09 N and 103°36 to 103°39 E, with an elevation between 1292 m and 1310 m. The region is characterized by a mean annual temperature of 7.8°C and receives limited precipitation concentrated in the summer months.

2.2 Data Sources

The primary data source consisted of Landsat TM/OLI imagery spanning the period 1987-2016. Images were acquired during the growing season (June–September) from the USGS Global Visualization Viewer (https://glovis.usgs.gov/). The spatial resolution of the imagery was 30 m, with a temporal resolution of 16 days. Additionally, Sentinel-2A data with 10 m resolution were used for validation. Hydrological data including lake inflow, water area, and groundwater depth were obtained from local water resource management agencies.

2.3 Fractional Vegetation Coverage Calculation

Fractional vegetation coverage (FVC) was derived from the Normalized Difference Vegetation Index (NDVI) using the pixel binary model. The calculation followed the standard approach where NDVI values for bare soil (NDVI) and dense vegetation (NDVI g) were used as reference points. The FVC was computed as:

(*cid* : 143)(*cid* : 158)(*cid* : 159)*mn*1987—2016(*cid* : 129)(*cid* : 130)(*cid* : 131)(*cid* : 132)(*cid* : 133)*H*(*cid* : 151)(*cid* : 153)(*cid* : 140)*PKI* 82 *NDVI NDVIsoilNDVIveg NDVIsoil*× 100 *uCvw* 30*a*(*cid* : 157)(*cid* : 129)(*cid* : 130)(*cid* : 131)(*cid* : 132)(*cid* : 133)(*cid* : 137)(*cid* : 138)*Z*˘¥ „1987—2010(*cid* : 127)(*cid* : 153)*cdb*

where NDVI was set at the 0.5th percentile of the NDVI frequency distribution and NDVI g at the 99.5th percentile for each image. This method effectively reduces the influence of atmospheric conditions and soil background variations.

2.4 Trend Analysis

Temporal trends in FVC were analyzed using linear regression. The slope of the regression line indicated the rate of change, while significance was tested at the 95% and 99% confidence levels. The trends were categorized into five classes: significantly decreasing (slope < 0, $P < 0.01$), decreasing (slope < 0, $0.01 < P < 0.05$), stable ($P > 0.05$), increasing (slope > 0, $0.01 < P < 0.05$), and significantly increasing (slope > 0, $P < 0.01$).

3. Results

3.1 Temporal Variation of Vegetation Coverage

Figure 2 illustrates the temporal variation of vegetation coverage from 1987 to 2016. The average FVC showed a gradual increase over the 30-year period, with a notable acceleration after 2010. Before 2010, the vegetation coverage remained relatively stable at approximately 10%, with slight inter-annual fluctuations. Following the initiation of ecological water conveyance in September 2010, the FVC increased significantly, reaching approximately 20% by 2016.

[Figure 2: see original paper]

The trend analysis revealed distinct patterns before and after the intervention. During 1987-2010, the slope of the trend line was not significant ($R^2 = 0.0012$), indicating minimal change. In contrast, the period 2010–2016 showed a significant increasing trend, with the slope indicating an annual increase of approximately 2.8% in areas near water bodies.

3.2 Spatial Variation of Vegetation Coverage

The spatial distribution of vegetation coverage change exhibited clear patterns related to distance from water sources. Areas within 2000 m of the lake showed the most significant improvement, with FVC increasing by over 80% in some locations. The effect diminished with distance, with negligible changes observed beyond 5000 m from the water body.

[Figure 8: see original paper]

The significance test results (Figure 11) demonstrated that 94% of pixels within 1000 m of water showed significantly increasing trends ($P < 0.01$), while only 2.8% showed decreasing trends. This spatial pattern confirms that ecological water conveyance had a strong localized effect on vegetation restoration.

[Figure 11: see original paper]

4. Discussion

4.1 Impact of Ecological Water Conveyance

The ecological water conveyance initiated in 2010 marked a turning point in vegetation dynamics. The correlation analysis between FVC and hydrological factors (Table 3) revealed strong negative correlations between vegetation improvement and distance from water ($r = -0.97$), indicating that proximity to water was the primary determinant of restoration success. The water conveyance increased lake inflow, expanded water area, and raised groundwater levels, creating favorable conditions for vegetation establishment.

The effectiveness of water conveyance was most pronounced within a 2000 m buffer zone, where groundwater depth was raised above the critical threshold for plant survival. Beyond this distance, the influence of water conveyance diminished rapidly, suggesting limited lateral water migration in this arid environment.

4.2 Relative Importance of Climate Change

While climate change has been identified as a major driver of vegetation dynamics in northwest China at regional scales, its effect in the Qingtu Lake area was relatively minor compared to the impact of water conveyance. The slight increasing trend in temperature and precipitation over the study period could not account for the dramatic vegetation increase observed after 2010. The statistical analysis confirmed that the post-2010 vegetation change exceeded what would be expected from climate factors alone.

5. Conclusions

(1) Over the 30-year study period, vegetation coverage in the Qingtu Lake area showed an overall increasing trend, with a significant acceleration after 2010 when ecological water conveyance began. The average FVC increased from approximately 10% to 20%.

(2) The ecological water conveyance was the primary driver of vegetation restoration, particularly within 2000 m of water bodies. Areas near the lake experienced the most substantial improvements, with over 94% of pixels showing significantly increasing trends.

(3) Climate change had a limited effect on local vegetation dynamics, despite being a major factor at larger regional scales. The magnitude and spatial pattern of vegetation change were inconsistent with climate-driven change alone.

(4) The success of ecological water conveyance demonstrates that targeted human intervention can effectively restore degraded ecosystems in arid regions, provided that water resources are managed sustainably. Continued monitoring is recommended to assess the long-term sustainability of these restoration efforts.

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