Analysis of Changes in Water Body Area in Southwest, China Based on GEE

Zhouhe Gege, Ke Liang, Boao Li *

School of Geography and Remote Sensing Science, Xinjiang University, Xinjiang, China, 830000

* Corresponding Author Email: 15660161898@163.com

Abstract. It is of great significance for policymakers to develop management strategies for water resource regulation, habitat protection and wetland restoration. Based on the Google Earth Engine platform, this study extracted remote sensing data of water quality change in Southwest China in the past 20 years, combined with ArcGIS for spatial analysis, and used M-K trend test and mutation test to analyze the long-term temporal variation of water bodies in Southwest China. The analysis shows that the water area in Southwest China increased every five years from 2000 to 2020, but the growth rate changed, while the growth rate slowed down from 2010 to 2020, and the increase mainly occurred in the central and western regions. The results show that in the past 20 years, the water surface area in Southwest China has shown a statistically significant increasing trend, especially after 2020, this trend is more statistically significant. This study can provide a theoretical basis for the protection of water environment in Southwest China.

Keywords: Google Earth Engine, Southwest, Changes in the area of water bodies, Spatiotemporal analysis.

1. Introduction

The change of lake area will have a significant impact on the surrounding ecological environment and social economy. The biodiversity, habitat area, species resource distribution, and water resource utilization of wetland ecosystem are closely related to water level and water body area[1]. Located among many glacial lakes, Southwest China is the source of the Yellow River, Yangtze River, Ganges River, Indus River and other rivers, known as the "Asian Water Tower". There are 1171 lakes with an area of more than 1 km2 in Southwest China, with a total area of more than 46500 km2, accounting for about 57% of the total lake area in China [2]. Over the past two decades, global climate change has had a significant impact on the spatial area of lakes and rivers in Southwest China, and these changes reflect broader environmental and climate trends [3]. With the intensification of global climate change, the lakes and rivers in the Southwest are facing unprecedented changes. These changes not only affect local ecosystems and biodiversity, but also have far-reaching impacts on human societies [4]. Zhang et al. analyzed the variation of lakes larger than 1 km2 in Southwest China, focusing on the relevant elements of lakes in Southwest China, and found that the number of lakes in Southwest China has been increasing continuously since 1995, which is in good agreement with the temperature change trend [5].Guo Fengjie et al. analyzed the area change of Qinghai Lake based on meteorological data, and concluded that the change of lake area is closely related to the change of precipitation [6]. It can be seen that climate change is an important influencing factor for the change of related factors such as the area and number of lakes. However, there have been many studies on typical lakes on the Tibetan Plateau in the past, but the study of the overall water area change in Southwest China still needs to be further explored.

Based on the Google Earth Engine (GEE) platform, this study obtained the dataset of water changes in Southwest China from 2000 to 2020. Process the relevant data, calculate the long-term data of the water body, and draw and analyze the vector map of the water area. The Mann-Kendall trend test was used to complete the mutation test and periodic analysis of water area change, and the main law and spatial distribution of water body change in Southwest China were obtained, so as to achieve accurate estimation of water body, so as to provide theoretical basis and guidance for ecological environment restoration in Southwest China.

2. Methodology

2.1. JRC Global Surface Water Products

JRC Global Surface Water Products are global surface water-related data and products developed and provided by the European Commission's Joint Research Centre. JRC studies and monitors the Earth's water resources to support decision-making and policy making in areas such as water management, environmental protection, climate change research, and more. It extracts surface water based on multi-spectral and multi-time attribute Landsat satellite data from 1984 to 2019, and constructs an expert system by constructing multi-spectral ground object database and spatial transformation based on NDVI and HSV. The expert system improves its classification results through visual analysis and verification reasoning, combined with the powerful computing power of GEE cloud platform[7].

This article focuses on using the JRC Global Surface Water product Monthly History, a monthly scale product that records observations of water bodies for each month. In this data set, the band "water" represents the monthly observed water body, and three values are rendered after the unique value :0,1, 2,0 represents no observed data,1 represents data that is not a water body, and 2 represents data that is a water body.

2.2. Mann-Kendall trend test

Mann-Kendall trend test is a non-parametric statistical test of time series, which considers the relative size relationship of all data point pairs, does not depend on the actual value of the data, and does not require specific distribution test of the data series. In this paper, the method is used to analyze whether there is a monotonically increasing or decreasing trend in the time series of water area. Suppose that the time series of the elements is X = (,,... ... ,), where n is the number of sample sequences, and the calculation formula of detection statistic S is as follows[8]:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\left(x_j - x_k\right) \tag{1}$$

S is the statistic, subject to mean E(S)=0, variance, where n is the number of groups of equal data and the number of group j equal data. The standardized statistic Z is further obtained as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, S > 0 \\ 0, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, S < 0 \end{cases} \tag{2}$$

At the given α significance level, if, then the null hypothesis is negated, that is, the sequence shows a significant trend at the confidence level α; If the statistical variable Z > 0, the series shows an upward trend. If Z < 0, the trend is downward.

2.3. Mann-Kendall mutation test

Mann-Kendall mutation test is one of the most effective methods to test time series mutation, which can identify the moment when the mutation starts[9]. For a time series with n sample sizes,... ... Construct an order column:

$$\boldsymbol{S_k = \sum_1^k R_i \ , k = 2, 3 \ldots, n} \tag{3}$$

Where, represents the cumulative number greater than (1≤i≤j). Under the assumption that the time series is randomly independent, the statistics are defined:

$$UF_k = \frac{|S_k - E(\boldsymbol{S_k})|}{\sqrt{Var(\boldsymbol{S_k})}}, k = 2,3, \ldots n \tag{4}$$

Where, and respectively represent the mean and variance of the cumulative count.

Performing the above operation on the reverse sequence of the original time series yields the statistical time change of the reverse sequence, denoted as, such that:

$$UB_K = -UF_k, k = n, n-1, \dots, 1 \tag{5}$$

Finally, the graph of sum is drawn. If the two curves intersect and the intersection point is between the critical line, then the moment corresponding to the intersection point is the mutation point [10].

3. Results

3.1. The dynamic characteristics of water body area changes in Southwest China.

After conducting automatic water body extraction and visual interpretation of the data, the annual dynamics of water body area changes in Southwest China over the past two decades were statistically analyzed, as shown in Table 1 and Figure 1.

Table 1. Changes in area growth during different time periods

Period of time	Growth area/ (km^2)	Annual growth rate/ (%)	Average annual growth area/ (km^2)
Frist time period	7.07	39.33	12.96
Second time period	7.42	32.68	4.19
Third period	4.25	15.7	1.73
The fourth period	1.4	4.83	-0.25

(Note: Based on the growth rate of lake area, the period from 2000 to 2020 is divided into four stages, namely 2000–2004, 2005–2009, 2010–2014, and 2015–2020.)

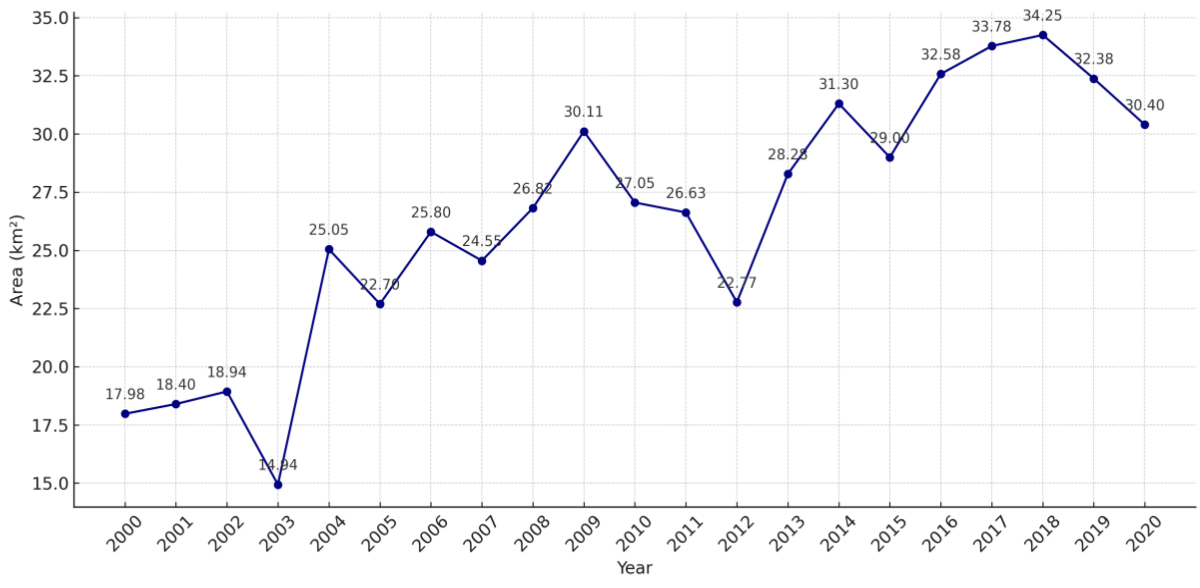

Figure 1. Annual Average Water Surface Area in Southwest China (2000-2020)

The analysis indicates that from 2000 to 2020, the water area in Southwest China increased by 12.42 km^2, with a change rate of 69.1%, reaching 30.398 km^2 in 2020. In the first period, from 2000 to 2004, there was a significant increase in water area in the region, expanding from 17.976 km^2 in 2000 to 25.046 km^2 in 2004, with an expansion of 7.07 km^2 over five years. In the second period, from 2005 to 2009, the water area continued to show a significant growth trend, with an average annual growth rate of 32.68%, breaking through 30 km^2 in 2009. Compared to the first two periods, the expansion rate of water area in the third period, from 2010 to 2014, slowed down, with an increase of 4.25 km^2 over five years. In the fourth period, from 2015 to 2020, the water area in Southwest China generally stabilized, with some fluctuations in area over the six years, culminating in a water area of 30.4 km^2 by 2020.

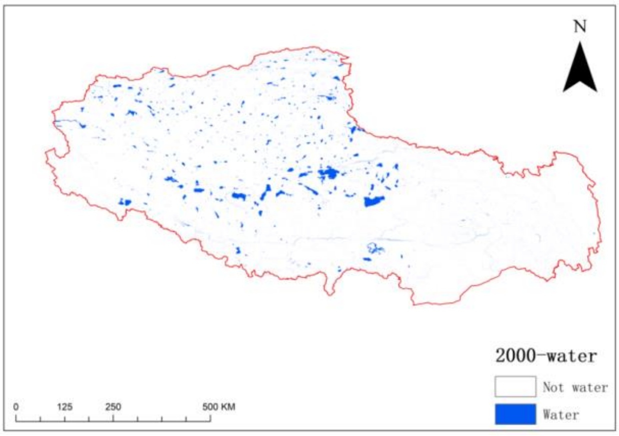

Figure 2. Distribution of water bodies in Southwest China in 2000

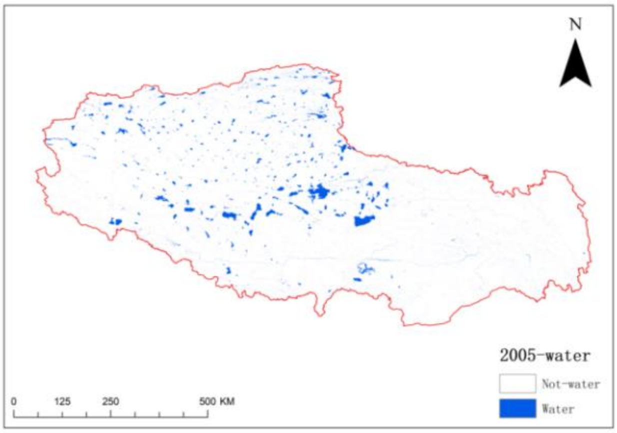

Figure 3. Distribution of water bodies in Southwest China in 2005

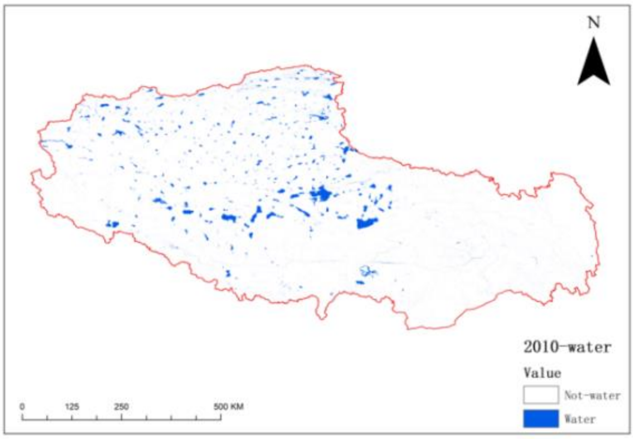

Figure 4. Distribution of water bodies in Southwest China in 2010

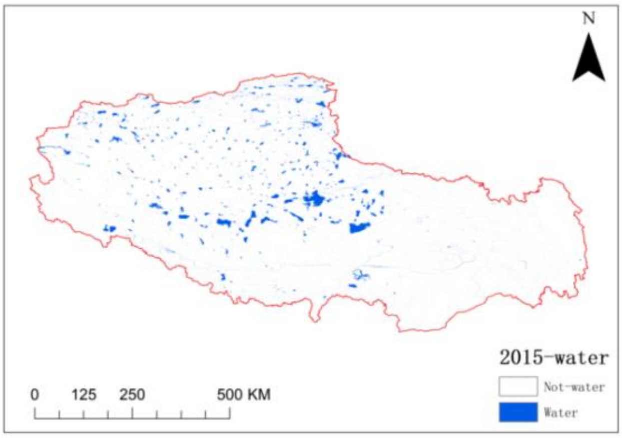

Figure 5. Distribution of water bodies in Southwest China in 2015

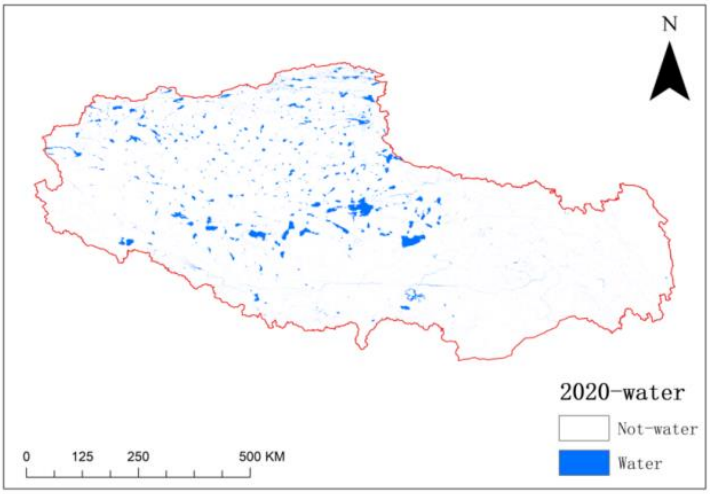

Figure 6. Distribution of water bodies in Southwest China in 2020

Table 2. Water surface area of Southwest China every five years

year	Water area/(km²)
2000	17.97617552
2005	22.69575002
2010	27.05449327
2015	28.99790796
1000	30.39831437

Combining the analysis of Figures 2-6 and Table 2, From 2000 to 2020, the water body area in Southwest China grew steadily, with notable expansions concentrated in central and northeastern regions. The area increased by 4.7196 km² from 2000 to 2005 and by another 4.3587 km² from 2005 to 2010, with significant growth in the west and center. The growth slowed down thereafter, with a 1.9434 km² increase from 2010 to 2015 and a 1.4004 km² rise from 2015 to 2020, indicating a more gradual and region-wide increase without specific area concentration. Overall, the most substantial growth occurred between 2000 and 2010, while the following decade saw a deceleration in the rate of water area expansion.

3.2. Analysis of MK Test Results

The MK (Mann-Kendall) trend test is a non-parametric statistical test method used to identify trends in a dataset. The Zc value indicates the strength and direction of this trend. A Zc value of 6.8659, which is greater than the critical value of ±1.96 (corresponding to the 95% confidence level), indicates that the test result is statistically highly significant. Furthermore, as the Zc value is positive, it signifies that there is a very significant increasing trend in the water surface area in Southwest China.

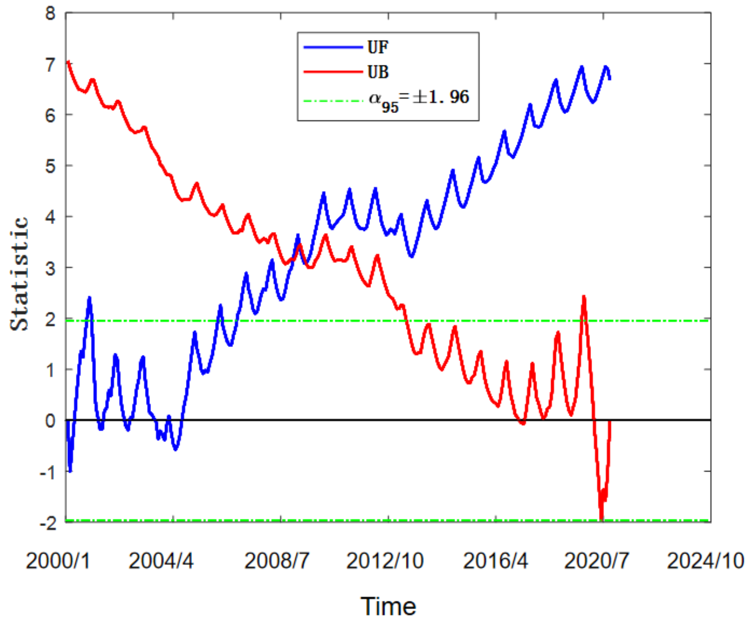

Figure 7. Results of mk mutation test

Figure 7 presents the UF and UB curves employed in the MK (Mann-Kendall) mutation test for identifying trend change points within a time series. The exceeding of the critical value of ±1.96 (which corresponds to a 95% confidence level) by the UF curve signifies a significant upward trend, while a downward crossing of the UB curve suggests a transition from a rising to a falling trend. The UF curve, which initially fluctuated below the zero line, began to ascend around 2004 and breached the confidence line significantly around 2008, indicating a notable increasing trend in the water surface area of Southwest China from that year onwards. The UB curve continued to decline, nearing the confidence line around 2020, but did not indicate a significant downward trend. A steep decline in the UB curve post-2019 may suggest a significant change in the growth trend of the water surface area during this period. The UF and UB curves indicate that the increase in water body area in Southwest China post-2008 is closely related to global warming. The rise in temperature has accelerated glacial melting and increased surface runoff, which may be the primary cause of the increase in water body area. In conclusion, our research demonstrates a significant growth trend in the water body area of Southwest China over the past twenty years. This trend became even more pronounced around 2020 and is consistent with global warming trends. Future studies need to further explore the complex relationship between climate change and changes in water body area, especially regarding the prediction and management of water resources.

4. Conclusion

In summary, our analysis of the past two decades' data has revealed an overall increasing trend in the water body area in Southwest China, with significant regional and temporal disparities. Particularly, the central and western regions experienced more pronounced growth between 2000 and 2010. Post-2010, the rate of increase slowed down, potentially due to changes in environmental protection and regional water resource management policies. The significant decline in the UB curve in the second half of 2020 indicates a crucial shift in the trend, necessitating further investigation. This could reflect the interplay of a range of factors, including extreme climatic events or policy-driven changes in land and water resource use.

Although our study provides some insights into the water body dynamics in Southwest China, it also highlights the complex interrelations between local environmental changes and broader global climatic patterns, particularly the need for further research into the connections with accelerated glacier melting and increased runoff. Future studies should incorporate a broader set of environmental variables, utilize longer time scales, and integrate more complex models to effectively predict and manage the region's water resources. This approach will be crucial to address the challenges posed by climate change and will offer a scientific basis for protecting biodiversity and supporting the sustainable development of local communities.

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