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Development and Analysis of the Water and Soil Conservation Function Dataset across the Tibetan Plateau (2001–2023)

Cong, N.[1, 2]

1. Lhasa Plateau Ecosystem Research Station, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;
2. Key Lab of Hydraulics and Mountain River Engineering, Sichuan University, Chengdu 610065, China

Abstract: The intensive development of base installation over the TibetPlateau (TP) for the past few years seriously challenges the local fragile ecological environment. This study makes use of the MODIS NPP dataset and the soil science database of China and calculates the capability index of water and soil conservation of the whole TP based on the quantitative index method. We further evaluate the water and soil conservation function and classify it according to the Technical Guidelines of Ecological Conservation Red Line Delineation. The grade assessment dataset of water and soil conservation function across the Tibetan Plateau (2001–2023) is finally produced. The dataset contains two parts the capability index of water and soil conservation and the grade assessment of water and soil conservation function. They indicate the spatial distribution of the capability of water and soil conservation, and the degree of importance of the function, respectively. The format of this dataset is .tif with 46 senses and the total data size is 568 MB (compressed into one package with 180 MB).

Keywords: water and soil conservation; the Tibetan Plateau; capability index; function assessment

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Author Information: Cong, N., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, congnan@igsnrr.ac.cn

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1 Introduction

The intensive developments of base installations have been carried out in the Tibetan Plateau (TP) in recent years. On one hand, the large-scale project disturbs or even destroys the circumjacent vegetation. On the other hand, the project will interfere with the ecological environment via multiple approaches such as impacting the balance of soil moisture and soil fertility. Therefore, the projects hinder vegetation growth and affect the community dynamics, which challenges the stability of the alpine ecosystem and the engineering. In addition, the alpine ecosystem is extremely fragile because of the bad weather, it thus hardly recovers once destroyed[1]. At the same time, the ecological environment of TP suffers a relatively larger stress under ongoing global warming. Therefore, construction is easy to break the ecosystem balance. It is necessary to pay more attention to the ecological effect of engineering construction. However, rare studies are dropped in this field.

The government gradually increased the investment in base installation in the middle and western regions of China since the new century followed by the engineering constructions. These major projects will break the vegetation growing around the engineering area and further affect the plant community dynamics. Hence, it could threaten the functional roles of the alpine ecosystem and the construction stability[2]. The weather shows the features of high elevation, coldness, and dryness across the TP. And the vegetation growth is closely related to soil moisture[3]. Water and soil conservation plays a crucial role as a primary evaluative factor in the functionality of ecosystem services. It becomes one of the important indicators for ecological environment assessment in TP with dryness and strong wind. According to the Technical Guidelines of Ecological Conservation Red Line Delineation[4], this study evaluates the water and soil conservation function of TP derived from NPP data via the quantitative index method.

2 Metadata of the Dataset

The metadata of the yearly 1-km raster dataset of water and soil conservation function across the Tibetan Plateau (2001–2023)[5] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

Water and soil conservation is one of the essential functions of ecosystem regulation. It is achieved through the inherent structure and processes of the ecosystem to mitigate soil erosion caused by water, thereby reducing the impact of water erosion on soil. The water and soil conservation function in high-cold and ecologically fragile areas is primarily influenced by factors such as the local soil, topography, and vegetation. The capability index of water and soil conservation is used as the evaluation criteria for the grade assessment of water and soil conservation in the research area. Three parameters are input into the capability index calculation model as NPP, the Soil Erodibility Factor and the Topography Slope Index. They are obtained from the NPP dataset[1], the soil science database of China with a 1:1,000,000 scale[2], and the DEM dataset[3], respectively. The quantitative index method is employed in this study[7,8].

Table 1 Metadata summary of the yearly 1-km dataset of water and soil conservation function across the Tibetan Plateau (2001–2023)

Items	Description
Dataset full name	Yearly 1-km raster dataset of water and soil conservation function across the Tibetan Plateau (2001–2023)
Dataset short name	Water&SoilConserv_TP2001-2023
Authors	Cong, N., Lhasa Plateau Ecosystem Research Station, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, congnan@igsnrr.ac.cn Zheng, Z. T., Lhasa Plateau Ecosystem Research Station, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhengzt@igsnrr.ac.cn Wang, D. L., Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science, wangdl@@igsnrr.ac.cn
Geographical region	The Tibetan Plateau
Year	2001–2023
Temporal resolution	1 year
Spatial resolution	1 km
Data format	.tif
Data size	568 MB
Data files	It contains 2 groups of data: (1) capability index of water and soil conservation, (2) the grade assessment of water and soil conservation function. Four senses are included in each data
Foundations	Chinese Academy of Sciences (West Light Foundation 2022); the National Natural Science Foundation of China (42071133)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten per cent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[6]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3.1 Algorithm Principle

The capability index of water and soil conservation is used as the evaluation indicator of the ecological environment. The formula is listed below:

$$S_{Pro} = \mathrm{NPP} \times (1-K) \times (1-F_{slo}) \tag{1}$$

where S_{Pro} indicates the capability index of ecological environment water and soil conservation. NPP indicates the value of annual NPP. F_{slo} is the Relief Index and K indicates the soil erodibility. The unit of original MODIS NPP dataset is kg C/m^2, while in this study we transfer the NPP unit to g C/m^2. Meanwhile, the capacity index S_{Pro} keeps consistent with NPP in this study (g C/m^2).

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1 MODIS NPP dataset. NASA. https://ladsweb.Nascom.nasa.gov.

2 The soil science database of China with a 1:1,000,000 scale. CAS-LASON. http: // westdc.westgis.ac.cn.

3 The DEM dataset. Geospatial Data Cloud. https://www.gscloud.cn.

3.2 Data Processing

The grade assessment of water and soil conservation is produced based on the core algorithm in section 3.1 and the classification is evaluated by the capability index of water and soil conservation. The capability index calculation model includes three primary input parameters such as NPP, the soil erodibility factor, and the topography slope index. Here, the soil erodibility factor *K* indicates the complexity of soil particle separation and carrying by waterpower. It is mainly related to the physical and chemical properties of soil such as soil texture, soil structure, organic content, and permeability. The Topography Slope Index shows the local topographic variability and indirectly affects the local water and soil erosion.

3.2.1 Data Collection

According to the Technical Guidelines of Ecological Conservation Red Line Delineation[4], the assessment of water and soil conservation function grade consists of NPP data, soil data, and DEM data. NPP data is from MODIS NPP dataset with a spatial resolution 500 m. Soil data comes from the soil science database of China with a 1:1,000,000 scale and 1-km spatial resolution. DEM data is derived from the website of geospatial data cloud with a spatial resolution 90 m. We unify the above grid datasets to the coordinate system of WGS84, and spatial resolution of 1/120° (≈1 km).

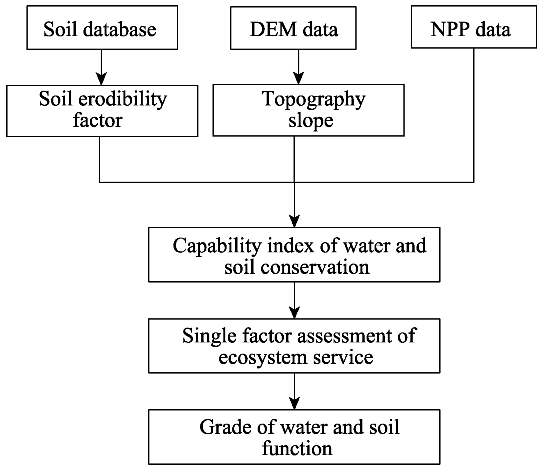

Figure 1 Technology roadmap of grade assessment of water and soil conservation in TP

3.2.2 Data Pre-processing

The capability index of water and soil conservation is obtained by NPP, soil erodibility factor, and topography index (Figure 1). We need to calculate the soil erodibility factor and relief index before inputting parameters into the model. The equations are as follows.

$$K = (-0.01383 + 0.51575K_{EPIC}) \times 0.1317 \tag{2}$$

$$K_{EPIC} = \left\{0.2 + 0.3exp\left[-0.0256m_s\left(1 - \frac{m_{silt}}{100}\right)\right]\right\} \times \left[\frac{m_{silt}}{(m_c + m_{silt})}\right]^{0.3} \times \\ \left\{1 - 0.25orgC / \left[orgC + exp(3.72 - 2.95orgC)\right]\right\} \times \\ \left\{1 - 0.7\left(1 - \frac{m_s}{100}\right) / \left\{\left(1 - \frac{m_s}{100}\right) + exp\left[-5.51 + 22.9(1 - m_s / 100)\right]\right\}\right\} \tag{3}$$

where K_{EPIC} indicates the soil erodibility factor before correction and *K* indicates the soil erodibility factor after correction. m_c, m_{silt}, m_s and orgC indicate the clay (<0.002 mm), silt (0.002−0.05 mm), sand (0.05−2 mm), and the fraction of soil organic carbon content (%), respectively. The indexes are derived from the soil science database of China with a 1:1,000,000 scale. Then we join *K* to the base map (the soil type map) in ArcGIS working environment. The grid map of soil erodibility is transformed by conversation tools in

ArcGIS, which could match the NPP grid data.

The Relief Index (F_{slo}) is calculated by the difference between the maximum and minimum DEM values of the local region. And the grid map of F_{slo} is also converted in spatial model of ArcGIS.

In this study, we firstly calculate the relief index F_{slo} with the difference value between maximum DEM and minimum DEM based on every 3×3 window. Then the relief index F_{slo} and soil erodibility factor K are normalized between 0–1, and the capability index of ecological environment water and soil conservation S_{Pro} is calculated by Equation (1). Finally, we sort the F_{slo} in descending order and calculate the accumulative value of F_{slo} and accumulative ratio. We choose the values corresponding to the accumulative fraction of 80% and 50% as the thresholds and divide them into very important, important, and normal by the thresholds.

4 Data Results and Validation

4.1 Data Composition

The format of this dataset is .tif. The coordinated system is WGS84 and the data cover the Tibetan Plateau of 23°N–43.5°N, 73°E–105°E. We evaluate the water and soil conservation grade every five years since it has little interannual change. The dataset contains two groups of data. The first one is the grade assessment dataset of water and soil conservation function, and the second one is the capability index dataset of water and soil conservation which belongs to an important processing data. Both of the two datasets consist of 23 senses yearly grid data from 2001 to 2023. For the two datasets, the capability index dataset of water and soil conservation indicates the spatial pattern of capability of water and soil preservation on the TP (Figure 2), and the grade assessment of water and soil conservation shows the spatial distribution of function importance which could assist us to extract the key area for water and soil conservation.

4.2 Data Products

We derive the water and soil conservation function into three grades normal, important, and very important based on the Capability Index of Water and Soil Conservation (Figure 3). The grade of water and soil conservation function increases from the west toward the east of TP. The east region of TP suggests a very important grade. The area shows a complex terrain with plentiful precipitation where geological disaster frequently occurs and lead to the increased stress of water and soil conservation. We further detect the unaltered regions of function grades during the 23 years (Figure 4) and the water and soil conservation function shows stability in most areas of TP. 80% of the pixels indicate changelessness in the function grade. The long-term very important regions in the east of TP indicate that we should pay attention to this area. Conservation for both the surface soil and underground water is a key attention point during the site selection and construction development.

4.3 Data Validation

We use the quantitative index method to evaluate the function of water and soil conservation according to the Technical Guidelines of Ecological Conservation Red Line Delineation[4]. The based datasets in this study can objectively reflect the background value of TP which

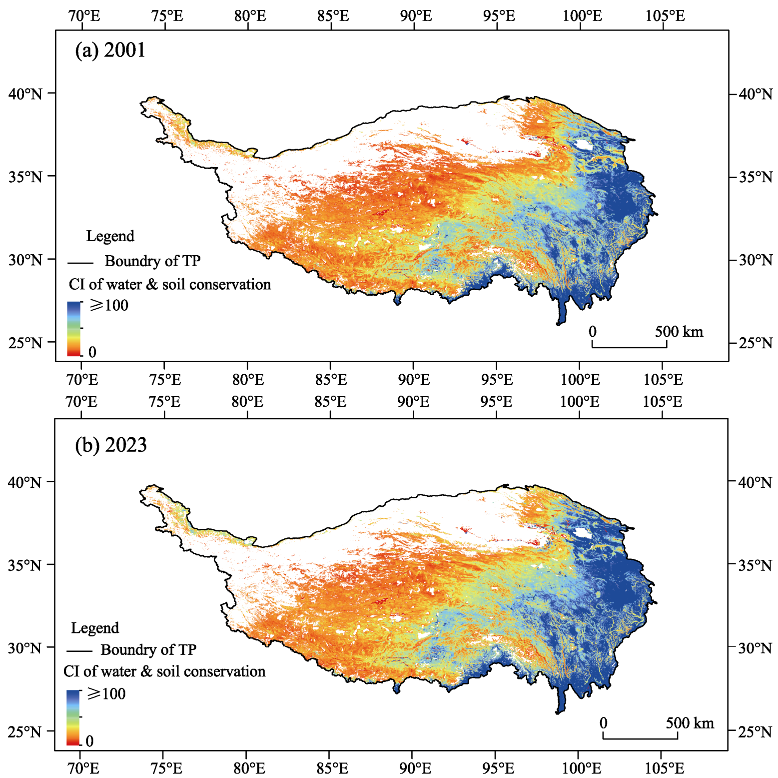

Figure 2 Maps of Capability Index (CI) of water and soil conservation in TP (2001, 2023)

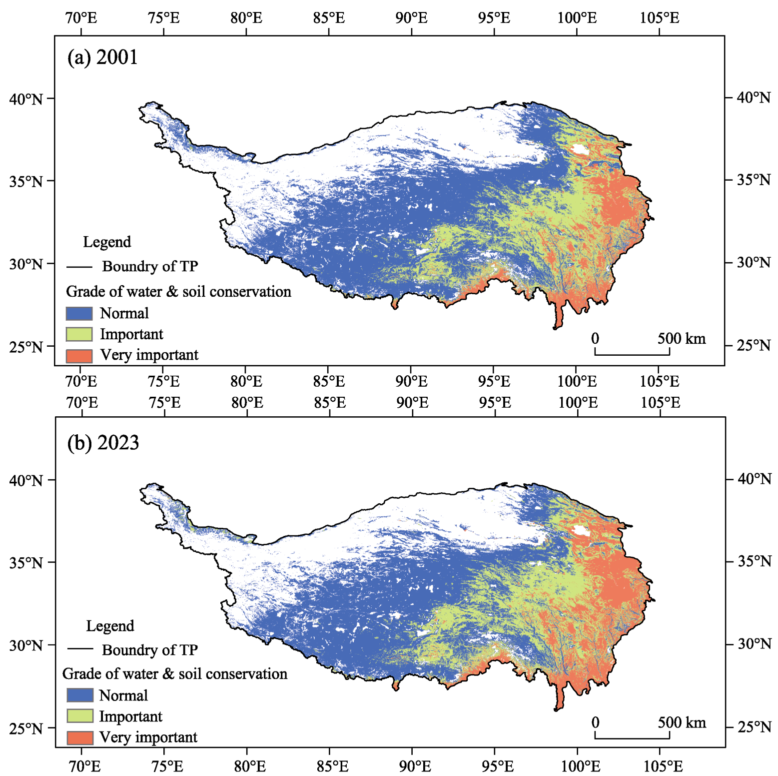

Figure 3 Maps of grade assessment of water and soil conservation in TP (2001, 2023)

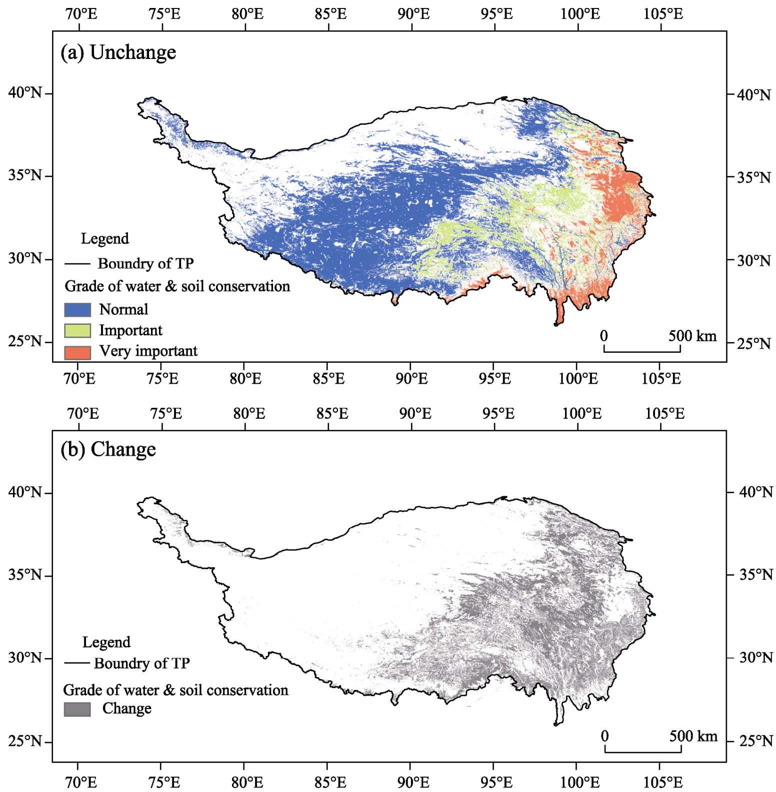

Figure 4 Maps of distribution of unchanged region (a) and changed region (b) in grade assessment of water and soil conservation (2001–2023)

provides robust input parameters for the calculation. This study confirms the previous research and continues the assessment until the 21st century[9]. For the new century, the water and soil conservation function still displays a spatial pattern with very important grad in the east and southeast. That means that the capability of water and soil conservation is relatively weak in the southeastern of TP. It is probably because of the relatively mild climatic environment, where vegetation does not need to be strong enough to escape from the hostile environment like vegetation located in the west dry area. Therefore, the government needs to pay high attention to preserving water and soil in these very important regions to prevent the damage of extreme climate events on the vegetation ecosystem.

5 Discussion and Conclusion

This study calculates the capability index of water and soil conservation of TP since the new century via a quantitative index method derived from MODIS NPP, the soil science database of China with a 1:1,000,000 scale, and DEM. We further evaluate the grade of the water and soil conservation and produce the grade assessment dataset of water and soil conservation function across the Tibetan Plateau (2001–2023). The calculation keeps to the technique process of Technical Guidelines of Ecological Conservation Red Line Delineation[4]. The quantitative index method is used to evaluate the parameters. The spatial pattern is related to the moisture gradient which matches the natural condition. The results confirm the previous study and further prolong the period with dataset updating. However, our satellite data source derives from remote sensing which is affected by cloud and ice snow during the Earth observation process. Therefore, the stability among inter-annual NPP probably slightly changes and further influences the function grad assessment. However, the limitation is tiny in impacting the results of this study.

The results show that over 80% of the area occurring changelessness in the grade of water and soil conservation. The spatial pattern indicates an increase in grades eastward from west of TP. However, the area of very important region is decreasing, indicating the enhancement of water and soil conservation ability in recent period. Our results confirm the previous study and extend the research period. It is beneficial for the local government to master the dynamic of alpine ecosystem in time[9]. Meanwhile, the spatial distribution can assist the construction designers present valid and effective measures. This study could provide a scientific guide for enhancing ecological construction efficiency, site selection, reducing construction disturbance, ecological environment recovery, and providing spatiality strategy suggestions[10–12].

Conflicts of Interest

The authors declare no conflicts of interest.

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