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A framework for regional ecosystem authenticity evaluation–a case study on the Qinghai-Tibet Plateau of China

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ABSTRACT

Ecosystem authenticity is a concept for understanding the status of an ecosystem and provides useful information for making environmental management plans. However, approaches for quantitative ecosystem authenticity evaluation over large area are still rare. In this study, a conceptual framework of "Pattern-Process-Function-Resilience" is proposed to quantitatively evaluate regional ecosystem authenticity. Firstly, a composite index is calculated to estimate the self-adjustment ability and the level of biodiversity of the ecosystem. Then, the ratio between the composite indices are computed at the final and initial periods, and used to determine whether the ecosystem authenticity is protected or damaged, as well as the degrees to which the authenticity is protected or damaged by categorizing the ratio into five levels. A case study was conducted to quantify and evaluate the ecosystem authenticity over the Qinghai-Tibet Plateau (QTP) and the alternative locations of its twenty national parks from 2000 to 2015. Results show that regions with protected or damaged ecosystem authenticity cover about 95% and 5% of the entire QTP, respectively. Five of the twenty national parks alternative locations have damaged ecosystem authenticity. Areas with damaged authenticity are mainly distributed over the southeastern QTP, which suffered from deforestation and increased frequency of mountain hazards, including debris flow, flash flood, landslide, collapse, and snow avalanche. The approach presented in this study is instrumental to support future case-specific management and restoration strategies.

1. Introduction

Authenticity, a concept rooted in philosophy, refers to the quality of a person to act "wholly by the laws of his/her own being"

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despite huge external pressures (Erickson, 1995). During the past decades, the concept of authenticity has expanded into other fields of research interests, including geographical and ecological sciences. Currently, geographical and ecological studies on authenticity mostly focused on tourisms (Taylor, 2001; Rickly-Boyd, 2012; Park et al., 2019; Gupta and Duggal, 2021), heritage protection (McIntosh and Prentice, 1999; Chhabra et al., 2003; Gao and Jones, 2021; Prayag and Del Chiappa, 2021), and food quality (DeSoucey, 2010; Krajnc et al., 2021; Marianela et al., 2021). Ecosystem authenticity is usually proposed in terms of conservation protection, but associated research studies are still rare. Does ecosystem authenticity mean the naturalness is untouched by human activities? If so, there will be limited authentic places left in the world since the Earth has entered the Anthropocene (Lewis and Maslin, 2015), as human activities have affected 75% of the global ice-free land (IPCC, 2019). Human started destructing nature about 2 million years ago by burning and hunting, causing the disappearances of 25 million square kilometers of grasslands and 12 million square kilometers of forests (Naeem, 2011). The impacts of human settlement and manipulation are complicated and vary from one place to another (Hu et al., 2021; McElwee et al., 2020). Some impacts are subtle, while others are obvious. Therefore, whether the nature has encountered human interferes cannot be considered as one of the main criteria to evaluate ecosystem authenticity. Both pristine and altered ecosystems can be described as "authentic". Authenticity should be more focused on the change of the ecosystem's inherent characteristics, and the evaluation criteria should be selected accordingly.

Clewell (2000) suggested that ecosystem authenticity is consisted of natural authenticity and historical authenticity. Natural authenticity refers to the ability of an ecosystem to achieve a healthy state through self-regulation processes, regardless whether its composition or structure match a certain historical moment. Historical authenticity refers to the status of a restored ecosystem, if it is consistent with a reference historical state or not. Typically, ecological restoration activities can protect the natural authenticity of an ecosystem. However, historical authenticity cannot be obtained because it is almost impossible to protect historical authenticity by creating an identical ecosystem with the reference historical state for the following reasons. Ecological processes are complicated and hard to predict, it is almost impossible to create a well-functioning ecosystem by simply assembling ecosystem constituent parts (Naeem, 2011), let alone some constituent parts (e.g., natural, migrant, and invasive species) may distinct or emerge. In addition, the naturalness of the ecosystem can get lost during the assembling process. Dudley (2012) raised a new definition of ecosystem authenticity: "an authentic ecosystem is a resilient ecosystem with a level of biodiversity and range of ecological interactions that can be predicted as a result of the combination of historic, geographic and climatic conditions in a particular location". Therefore, we think that ecosystem authenticity indicates that during a period of time, an ecosystem performs well in self-regulating and self-adjusting, and its biodiversity level can be retained under ecological processes. Based on this theory, ecosystem authenticity can be assessed by its changes in self-adjustment ability and predictability, which take care of both natural and historical authenticities. The ecosystem authenticity can be evaluated by comparing the initial and final states during a specific period.

Some studies have already made attempts to develop methods in evaluating ecological authenticity. Dudley (1996) suggested to assess authenticity of forest ecosystems from aspects of composition, pattern, functioning, and process. Angelstam et al. (2003) assessed the authenticity of some European villages by identifying and comparing their landscapes using time-series satellite images. Based on these studies, Dudley (1996) suggested to break authenticity down into several constituent parts (including but not limited to species composition, vegetation pattern, functioning ecological processes, resilience, area, connectivity, etc.) and apply weights to each of them. Qualitative analyses were performed in evaluating the authenticity in Serengeti national park, Attenborough nature reserve, and Snowdonia national park. Generally, current studies have two main limitations. First, most of them are theoretical or qualitative, and quantification analyses of ecosystem authenticity are still rare. Second, these studies are mostly focused on small regions like villages and conservations using inconsistent indicators, and their results were not comparable. Due to the lack of ripe theory, methods, and the difficulty in collecting relevant data, a uniform quantification framework capable of evaluating ecosystem authenticity over regional scale is still missing.

The main purpose of this study is to propose a quantitative framework to evaluate ecosystem authenticity at a regional scale. First,

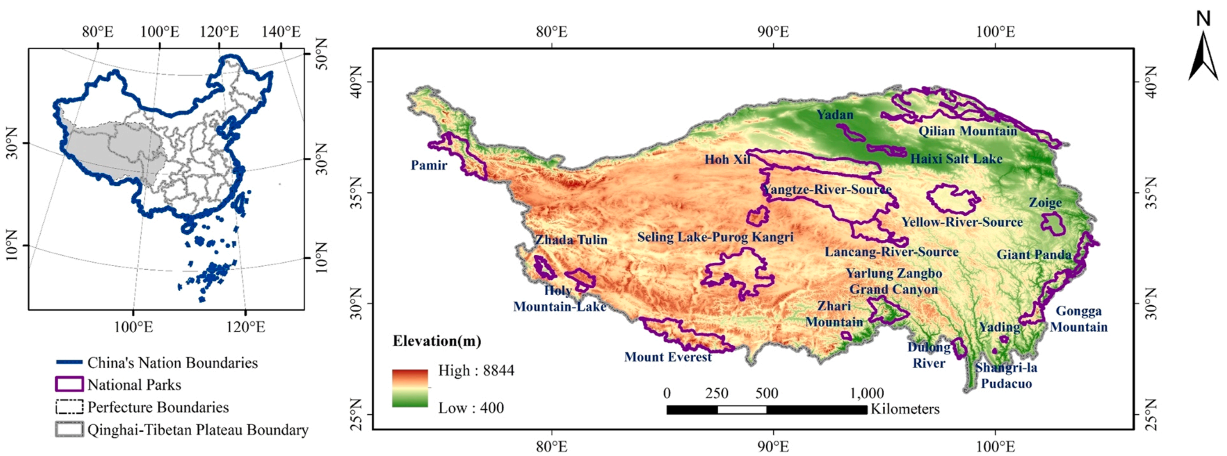

Fig. 1. Study area of Qinghai-Tibet Plateau (QTP) and the distribution of the national parks.

we propose a conceptual framework based on four ecosystem constituent parts: pattern, process, function, and resilience to calculate the ecosystem authenticity index reflecting the self-adjustment ability of the ecosystem. Representative indicators are selected for each part, and remote sensing data are adopted to quantify each indicator over the regional scale. Then, the ecosystem authenticity is determined during a specific period by comparing ecosystem authenticity indices at the initial and final states. Finally, a case study on evaluating ecosystem authenticity in the Qinghai-Tibet Plateau (QTP) and its twenty national parks from 2000 to 2015 is performed to investigate the feasibility of the proposed framework.

2. Study area

In this study, the QTP is selected as an experimental area to perform ecosystem authenticity evaluating. The QTP (Fig. 1), known as "the third pole" (Liu et al., 2018), is a giant geomorphic unit with the highest altitude (an average over 4000 m) on the Earth. The uplift of the QTP has profoundly influenced its environmental conditions and those of its surroundings. Under the dynamic and thermodynamic effects of atmosphere circulation, a unique climate with strong radiation and low temperature is formed. Over the past decades, the temperature over the QTP has been rising faster than other regions in the world (Dong et al., 2012). The precipitation has also showed an overall increasing trend with obvious spatial variance, with the northern regions increasing while southern decreasing (Yao et al., 2012). Forest, grassland, desert and other (bare land and bare rock) ecosystems spread from southeastern to northwestern, with wetlands located among them. The ecosystems on the QTP are extremely sensitive and vulnerable to human activities and climate change (Chen et al., 2013; Xia et al., 2021). In addition, accelerated social-economic development and fallen resource carrying capacity is also threatening the livelihood of QTP's wildlife (Zhang et al., 2021b). Understanding the ecosystem authenticity has become a crucial issue to ensure the sustainable development and making future management plans of the QTP. Therefore, the National Forestry and Grasslands Administration of China and the Tibetan People's Government have recently promoted a project to construct a national park cluster on the QTP for conservation and sustainable purposes. Conservation, the care and protection of natural resources for future generations, includes maintaining diversity of species, genes, ecosystems, and functions of the environment. Twenty-one alternative sites with high ecological, recreation, academic, and educational values were selected as national parks (Guo et al., 2021). Except for the West Tianshan, twenty of the national parks lie within our study area. These national parks are categorized into three groups: transnational, flagship, and distinctive national parks. Scientific analysis about the ecosystems of these alternative sites of national parks are important in providing the governors with information for decision making.

3. Method

3.1. The evaluating framework of ecosystem authenticity

The evaluating framework of "Pattern-Process-Function-Resilience" is constructed (Table 1) and its change over a certain period is adopted to depict the ecosystem authenticity. Fig. 2 shows the workflow of the proposed framework. As the definition indicates "an authentic ecosystem is a resilient ecosystem with a level of biodiversity", a stable level of biodiversity is an important representation of ecosystem authenticity. However, biodiversity data (e.g., number of natural, migrant, and invasive species) are hard to be acquired. Measuring and collecting such data are extremely time and effort consuming. Therefore, all the indicators selected in the framework may strongly influence biodiversity to some extent. By synthesizing the four ecosystem constituent parts of pattern, process, function, and resilience, it is capable of evaluating an ecosystem with its ability of self-adjustment and self-regulation.

Pattern refers to the landscape pattern reflecting the spatial structure heterogeneity of a specific region. Landscape provides useful

Table 1
"Pattern-Process-Function-Resilience" framework.

Objective	Criterion	Indicators	Explanation
Composite Index	Pattern	Shannon's Diversity Index (SHDI)	Higher SHDI values indicate higher landscape heterogeneity, thus higher levels of biodiversity and self-adjustment ability.
		Contagion Index (CONTAG)	High CONTAG indicates better connection within the prior landscape, which supports higher biodiversity and self-adjustment ability.
		Patch Cohesion Index (COHESION)	High COHESION indicates high aggregation degree of a patch type in the landscape, which supports higher biodiversity and self-adjustment ability.
	Process	Gross Primary Productivity (GPP)	GPP determines the energy and material entering the energy flow of the terrestrial ecosystem. High values of GPP indicate the ecosystem has high self-regulation abilities, especially for atmospheric carbon content.
	Function	Habitat Quality (HQ)	Regions with high HQ may better support biodiversity at all levels, and thus enhance the population persistence.
		Soil Retention (SR)	Higher SR may reduce the risk of soil erosion, and enhances soil conservation ability of an ecosystem.
		Water Yield (WY)	Higher WY means more runoffs per unit basin area in a given period, indicates stronger water conservation ability of an ecosystem.
		Crop Supply (CS)	Higher CS implies higher crop yields and stronger self-adjustment ability of the ecosystem.
		Livestock Supply (LS)	Higher LS implies the ecosystem is capable of providing more livestock and has stronger self-adjustment ability.
	Resilience	Resilience Coefficient (RC)	RC represents the restoration difficulty of different land use types, the higher the value is, the stronger the resilience is.

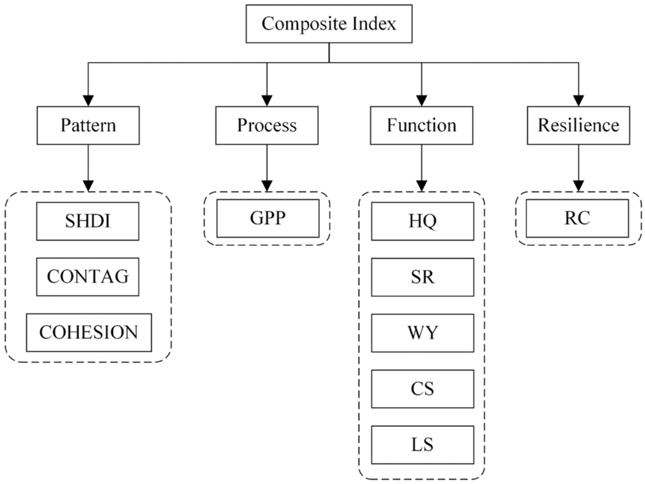

Fig. 2. Workflow of the "Pattern-Process-Function-Resilience" framework.

information about ecosystem dynamics (O'neill et al., 1999), its composite and structure greatly influence the richness of plant species (Honnay et al., 2003). Landscape pattern metrics, the quantification of landscape structure characteristics (McGarigal, 2014), are often adopted in biodiversity studies and habitat analyses (Uuemaa et al., 2009). So far, hundreds of landscape pattern metrics have been developed to represent different aspects of landscape structure. However, many of the metrics established strong correlations and they are inappropriate to be used at the same time (Plexida et al., 2014). In this study, three metrics with low correlation, including Shannon's Diversity Index (SHDI), Contagion Index (CONTAG), and Patch Cohesion Index (COHESION), were selected to measure the richness and evenness of landscape diversity (McGarigal, 2014), aggregation levels of spatial patterns (He et al., 2000), and the physical connectivity of the corresponding patch type (Ferreras, 2001), respectively. Higher SHDI values indicate higher landscape diversity and hence plant diversity (Honnay et al., 2003). CONTAG and COHESION reveal the fragmentation process of habitats. The fragmentation of habitats may reduce the inter-patch dispersal of species and hence lead to smaller and more isolated patches with less biodiversity. Overall, pattern reflects the ability of the landscape to support biodiversity in the ecosystem and protect ecosystem authenticity.

Process refers to the ecological processes of energy flows, which is represented by Gross Primary Productivity (GPP) in this study. GPP is the total amount of CO_2 fixed by plants in photosynthesis. GPP dominants the total amount of material and energy entering the ecosystem energy flow, adjusts the anthropogenic carbon fractions in the atmosphere, and regulates future climate warming trends (Raupach et al., 2008). GPP also provides societal services including food, fiber, and energy (Cai et al., 2014). Therefore, GPP is a crucial indicator for monitoring the abilities of self-adjustment and livelihood supply of an ecosystem under climate change.

Function refers to the ecosystem services. Ecosystem services are the outputs, conditions, or processes of natural systems that directly or indirectly benefit humans or enhance social welfare. Wallace (2007) suggested to categorize ecosystem services into four groups: adequate resources, protection from predators/disease/parasites, benign physical and chemical environment, and socio-cultural fulfilment. In this study, our focus on ecosystem authenticity evaluation is more tended to the natural aspects. Therefore, we selected the ecosystem services to represent the ecosystem's adequate resources and benign physical and chemical environment. Factors may overlap for these two groups. However, a service is often considered adequate resources when its value is below a certain quantity, and considered benign physical and chemical environment when its values are lying within a specific range (Wallace, 2007). Thus, services of Habitat Quality (HQ), Soil Retention (SR), Water Yield (WY), Crop Supply (CS), and Livestock Supply (LS) are adopted to measure the function aspect of ecosystem authenticity. HQ measures the "ability of the environment to provide conditions appropriate for individual and population persistence", and is considered "a continuous variable in the model, ranging from low to medium to high, based on resources available for survival, reproduction, and population persistence, respectively" (Hall et al., 1997). Generally, regions with high HQ will better support biodiversity at all levels, and HQ decreasing indicates declining biodiversity persistence, resilience, breadth, and depth (Sharp, 2018). SR shows the ability to reduce soil erosion through the structure and process of an ecosystem. WY refers to the runoff per unit basin area in a given period, which reflects the water conservation ability of ecosystem. Higher SR and WY values reveal greater self-adjustment ability of an ecosystem. CS and LS provide estimations for crop yield and livestock weight in the study area, respectively. Higher CS and LS values indicate more crop and livestock can be provided by the ecosystem. The selected services can well represent the natural aspects of ecosystem services and measure the self-adjustment ability of an ecosystem.

Resilience measures the capacity of an ecosystem to recover its original structure and functions after external disturbances (Peng et al., 2015). Resilience is strongly influenced and dominated by the underlying land use types (de Vries et al., 2012; Foster et al., 2003). Generally, land use type closer to natural conditions owns higher resilience, e.g., unused land has the highest resilience since it can quickly recover to its original status after disturbance. In this study, the resilience coefficient (RC) is introduced to quantify the resilience at pixel scale. The resilience coefficient over the j-th land cover type (RC_j) is determined first (Table 2) (Peng et al., 2017).

The RC at the i-th pixel (RC_j) is obtained using RC_j modified by Normalized Difference Vegetation Index (NDVI) as:

$$RC_i = \frac{NDVI_i}{NDVI_{mean_j}} \times RC_j \quad (1)$$

where $NDVI_i$ indicates the NDVI at the i-th pixel, and $NDVI_{mean_j}$ indicates the arithmetic mean NDVI over the j-th land use type of the i-th pixel.

3.2. Ecosystem authenticity evaluation

Based on the evaluating framework of "Pattern-Process-Function-Resilience", expert opinions were gathered from different aspects comprehensively and the Analytic Hierarchy Process (AHP) weighting method (Saaty, 1977) was applied to determine the weights for all the indicators. AHP is a simple yet powerful tool developed to help stakeholders making effective decisions by making pairwise comparisons about the importance between options or alternatives (Handfield et al., 2002). AHP brings qualitative and quantitative analysis together, and has been widely applied in ecological studies (Song et al., 2010; Xue et al., 2019). In this study, we consulted opinions from experts in geography, ecology, surveying and mapping, remote sensing, etc., and determined the final weights (Table 3). The composite index (A) is then calculated using the weighted sum of all the indicators.

During a study period, the composite indices for the initial and final years (A_1 and A_2) were firstly calculated and then the ratio K (K=A_2/A_1) between these two indices were calculated to show the change. When K>1 or K≈1 (A_2>A_1 or A_2≈A_1), the self-adjust ability of the ecosystem is improved or stays stable, indicating the ecosystem is authentic, or the ecosystem authenticity has been protected and retained during the period. When K<1, the self-adjustment ability of the ecosystem is reduced, indicating the ecosystem is not authentic, or its authenticity has been damaged. In this study, it is hardly possible that the values of A_1 and A_2 are exactly the same, a small difference does not indicate significant change in ecosystem authenticity. Therefore, an empirical threshold of 5% is set to tolerate the change in the composite indices, which means that $K \in [0.95, 1.05]$ is considered as K≈1. Once the ecosystem authenticity status is identified, K is grouped into 5 categories from level 1–5 representing the intensity of the protection or damage of the ecosystem authenticity. When $K \in [0.95, 1.05]$, the self-adjustment ability of the ecosystem stays stable and we designate it as level 3. For $K \in (0, 0.95)$ and $K \in (0.95, +\infty)$, we classify both intervals into two levels using the jenks natural breaks method (Jenks, 1963). Level 1, 2, 4, and 5 are assigned with K values increasing, implying the self-adjustment ability of an ecosystem is seriously reduced, reduced, enhanced, and strongly enhanced, respectively. Therefore, in this study, when the ecosystem self-adjustment ability reduces (Level 1 and 2), the ecosystem authenticity is considered to be damaged (the ecosystem is authentic); when the ecosystem self-adjustment ability is retained (Level 3) or enhanced (Lever 4 and 5), the ecosystem authenticity is considered to be protected (the ecosystem is not authentic).

3.3. Data acquisition

Data used in this study include land use and land cover (LULC), GPP, ecosystem services, and NDVI. LULC data were obtained from the Resource and Environment Science and Data Center (http://www.resdc.cn/). The classification system is consisted of 6 primary classes (farmland, woodland, grassland, water body, constructed land, and unused land) and 25 secondary types (paddy field, dry field, etc.). Global Land Surface Satellite (GLASS) GPP is one of the products belonging to the GLASS produce suite, which were generated based on robust algorithms (Liang et al., 2021). GLASS GPP was developed by integrating environmental factors of atmospheric CO_2 concentrations, direct and diffuse radiation fluxes, and atmospheric water vapor pressure deficit using the latest Eddy Covariance-Light Use Efficiency model (Yuan et al., 2019). GLASS GPP used in this study was acquired from National Earth System Science Data Center, National Science & Technology Infrastructure of China (http://www.geodata.cn). The ecosystem services data, including HQ, SR, WY, CS, and LS, were generated by Hou et al. (2020) using InVEST model based on environmental and social variables: land use maps, digital elevation model, evapotranspiration, net primary productivity, soil texture, temperature,

Table 2
Resilience coefficients (RC) for all the land cover types.

Land cover type	RC	Land cover type	RC
Paddy field	0.35	Intertidal zone	0.70
Dry field	0.30	Beach	0.70
Woodland (crown density: >30%)	0.85	Urban	0.20
Shrubland	0.80	Rural	0.25
Woodland (crown density: 10–30%)	0.75	Other construction land	0.15
Other woodland	0.60	Sand	1.00
Grassland (coverage: >50%)	0.50	Gobi	1.00
Grassland (coverage: 20–50%)	0.45	Saline alkali land	1.00
Grassland (coverage:5–20%)	0.40	Marshland	1.00
River and canal	0.85	Bare land	0.95
Lake	0.85	Bare rock	1.00
Reservoir pond	0.80	Other unused land	1.00
Permanent snow and ice	0.10		

Table 3
Indicator weights derived from AHP.

Indicator	Weight	Indicator	Weight
SHDI	0.07	HQ	0.22
CONTAG	0.05	SR	0.08
COHESION	0.05	WY	0.10
GPP	0.11	CS	0.05
RC	0.22	LS	0.05

precipitation, population density, and municipal statistical data. Landscape metrics of SHDI, CONTAG, and COHESION were calculated using Fragstats 4.2 software based on the LULC data. The NDVI data were collected from the Global Inventory Modelling and Mapping Studies (GIMMS) NDVI3g product, which was provided by the Goddard Space Flight Center of National Aeronautics and Space Administration (https://ecocast.arc.nasa.gov/data/pub/gimms). All the data were standardized to a range of 0–1 before further analysis because they were at various scales and units.

4. Ecosystem authenticity assessment

4.1. Regional ecosystem authenticity assessment

The ecosystem authenticity changes across the QZP QTP from 2000 to 2015 are shown in Fig. 3. In terms of the entire QTP, we found that the ecosystem authenticity has been protected over the majority of the places from 2000 to 2015. Statistically, locations with protected authenticity occupy about 95% of the QTP and damaged authenticity in the remaining 5%. Level 1, 2, 3, 4, and 5 accounted for 0.07%, 4.91%, 77.49%, 17.43%, and 0.10% of the total QTP, respectively. Areas with damaged ecosystem authenticity are mostly located over the southeastern QTP, where woodland and mountainous terrains are dominant. Severe deforestation and landscape fragmentation have taken places across these areas due to logging and intrastation construction in the past decades, which resulted the destruction of the forests and biodiversity (Hu et al., 2021; Miao et al., 2021). The ecosystem authenticity over other areas have been protected. The western QTP has the most severe environmental condition (high altitude, low temperature, and precipitation) and it showed a stable self-adjustment ability. This is because bare lands are usually high in physical stability, and they are

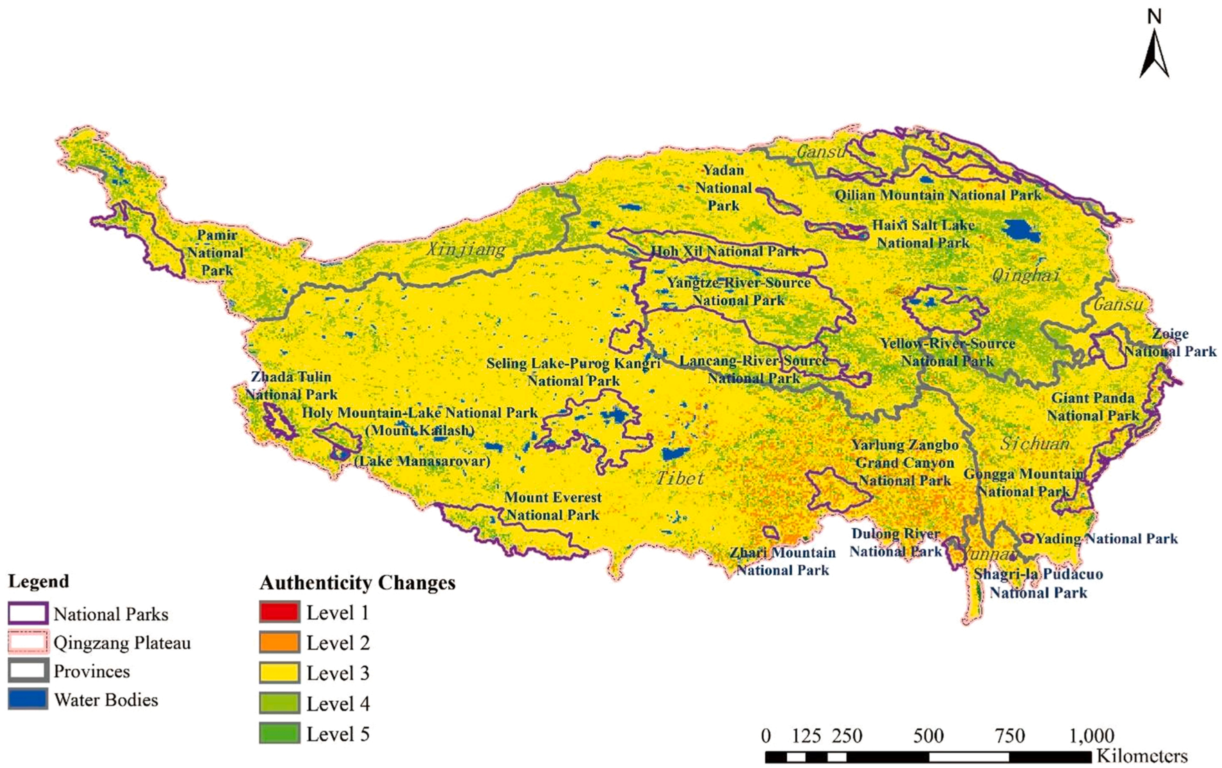

Fig. 3. Ecosystem authenticity changes from year 2000 to 2015 over the QTP. Level 1 and 2 indicate that the ecosystem self-adjustment ability is reduced and the ecosystem authenticity is damaged; level 3 indicates the ecosystem self- adjustment ability is retained and the ecosystem authenticity is protected; lever 4 and 5 indicate the ecosystem self- adjustment ability is enhanced and the ecosystem authenticity is protected.

unlikely to be altered by external forces. Especially, the self-adjustment ability over Qinghai province has been greatly improved. This is mainly attributed to that the QTP has experienced the most significant vegetation growth over the past decades across the QTP (Zhao et al., 2015; Zhang et al., 2021a). Therefore, the process and resilience of Qinghai has been greatly enhanced, hence, improved its self-adjustment ability.

4.2. The alternative locations of national parks

Among the twenty alternative locations of national parks (referred to as parks hereafter) located within the QTP, fifteen parks established protected ecosystem authenticity, while five parks (Yarlung Zangbo Grand Canyon, Zhari Mountain, Dulong River, Gongga Mountain, and Haixi Salt Lake) have partially damaged ecosystem authenticity (Table 4). Haixi Salt Lake National Park is located in Qinghai province and mainly consisted of ponds and salt lakes. Saline water may lead to soil saline increase, which thereby may cast adverse effects on the stability and function of soil ecosystems by reducing microbial respiration, cellular physiology and metabolic processes (Chen et al., 2017). The saline water and low level of biodiversity made the ecosystem very vulnerable in this area. The other four parks are located in the mountainous region of the southeastern QTP, where the broken landscape and mountainous terrain have made the ecosystem authenticity harder to be protected. In addition, most of the national parks performed well in self-adjustment, some even improved self-adjustment abilities, including Pamir, Mount Everest, Yangtze-River-Source, Yellow-River-Source, Lancang-River-Source, etc.

5. Discussion

This study proposed a conceptual framework of ecosystem authenticity assessment integrating constituent parts of the ecosystem: pattern, process, function, and resilience. The main improvement of the framework is that it provided a method for quantitative evaluations on ecosystem authenticity over large regions.

5.1. The role of ecological projects in protecting authenticity

This study found that the ecosystem authenticity was protected over 95% of the QTP from 2000 to 2015. The ecosystem authenticity damaged places are mainly distributed over the southeastern QTP, containing Yarlung Zangbo Grand Canyon, Zhari Mountain, Dulong River, and Gongga Mountain National Parks. These areas contain one of the most botanically rich temperate forest ecosystems in the world, and were nominated as one of the global biodiversity hotspots (the Mountains of Southwest China). It is a significant reservoir of China's endemic species (Myers et al., 2000). Logging, infrastructure construction, large consumption of fuelwood, and illegal hunting have been threatening these areas over the past decades (Hu et al., 2021). The broken landcover, mountainous terrain, and increasing precipitation also increased the frequency of landslides. However, since the 21st century, the Chinese government has enacted several environmental protection projects to restore the vulnerable ecosystems on the QTP. Among which is the largest afforestation program in the world, the National Natural Forest Protection and Grain for Green (GGP), aiming to restore forest ecosystems. GGP was launched in 1999, and its primary goal is to restore ecology by turning cultivated lands into forests (Delang and Yuan, 2016).

Generally, the ecological impacts of GGP have been considered positive because afforestation has restored the green coverage over converted lands. The regional vegetation coverage, soil characteristics, and carbon sequestration reaction have been greatly improved (Delang and Yuan, 2016; Chen et al., 2009). The tree roots may also fix the soil and improve water balance, thus reduce the risks for mountain hazards and land degradation (Yang et al., 2006). However, some argue that the ecological effects of GGP are not always positive. Researchers suggested that in arid regions, the mortality rates of trees are high, and the evapotranspiration increase brought by afforestation may be higher than precipitation, which will further enhance the water shortages (Wang et al., 2007; Delang and Yuan, 2016). Moreover, exotic tree species introduced may disturb the local ecosystem. Therefore, for arid regions of the QTP, afforestation should be restricted to the planting of native species or other species that will not exacerbate soil water shortages. In addition, the vegetation density, level of biodiversity, and ecological values of these artificial forests (often monoculture plantations) are still lower than the natural forests. It may take a longer time for the forests to restore their original services and values through

Table 4
Ecosystem authenticity evaluation for the twenty national parks on the QTP.

National Park	Type	Ecosystem Authenticity	National Park	Type	Ecosystem Authenticity
Pamir	Transnational	Protected	Lancang-River-Source	Distinctive	Protected
Mount Everest	Transnational	Protected	Hoh Xil	Distinctive	Protected
Holy Mountain-Lake	Flagship	Protected	Dulong River	Distinctive	Partial damaged
Seling Lake-Purog Kangri	Flagship	Protected	Yading	Distinctive	Protected
Yangtze-River-Source	Flagship	Protected	Gongga Mountain	Distinctive	Partial damaged
Yellow-River-Source	Flagship	Protected	Zoige	Distinctive	Protected
Yarlung Zangbo Grand Canyon	Flagship	Partial damaged	Shangri-la Pudacuo	Distinctive	Protected
Giant Panda	Flagship	Protected	Qiliang Mountain	Distinctive	Protected
Zhada Tulin	Distinctive	Protected	Haixi Salt Lake	Distinctive	Partial damaged
Zhari Mountain	Distinctive	Partial damaged	Yadan	Distinctive	Protected

ecological processes.

Haixi Salt Lake National Park, one of the national parks with partially damaged ecosystem authenticity, has a fragile ecosystem and low self-adjustment ability with low levels of aquatic life and tree species. Under the development pressure, salt mining has become one of the primary livelihoods of the residents for years, which greatly threatened the local environment. Therefore, local government has formulated laws to forbid such unsustainable behavior. Ecosystem authenticity over other regions of the QTP have been protected. Since the 21st century, multiple environmental protection and restoration activities have been launched, for example, the GGP, construction of Three-North Shelter Forest region, the establishment of nature conservations, and especially in 2016, the Ecological Protection and Restoration Projects for Mountain-River-Forest-Field-Lake-Grassland indicated that increasing attention had been raised concerning the relationships and interactions between landscape elements in the regional complex ecosystem (Zhang et al., 2021a). Under these protection and restoration projects, the ecosystems perform well in self-regulation and self-adjustment, and the ecosystem authenticity has been protected. Therefore, future ecosystem restoration strategies should be aiming at the southeastern QTP and around the northern salt lakes specifically. Environmental policies should be researched and implemented based on the sufficient scientific analysis, in which the ecosystem authenticity evaluation may play a crucial role. Our future studies will be focused on how to quantify the extent to which the ecological projects restore the ecosystem authenticity on the QTP.

5.2. Advantages and limitations

As Dudley (2012) stated, an authentic ecosystem should be self-sustaining and does not require constant or expensive management to maintain its values. The proposed method is capable of drawing the whole picture of ecosystem authenticity over the regional scale, such as the QTP, using the four constituent parts reflecting the self-adjustment ability of an ecosystem, as well as the level of biodiversity. Furthermore, the method is capable of providing information on developing future management strategies. For example, the ecosystem authenticity assessments on the QTP national park cluster may assist governors to understand the current status of the ecosystem and adjust future plans, since some of these alternative sites are still under consideration. The method focuses more on the appearances of the ecosystem, rather than the disturbances or restoration activities. The appearances can be regarded as the results of disturbances or restoration activities. Therefore, the management of protected areas are not included in the evaluating framework of ecosystem authenticity. However, it would be a key approach to achieve and protect ecosystem authenticity. More importantly, stakeholders should promote the idea of protecting the ecosystem with self-adjustment ability and authenticity to the local residence, whose daily activities to maintain livelihood are considered to be an embedded part of the ecosystem.

This study also has some limitations. Due to the lack of data, the level of biodiversity was reflected by its influential factors instead of actual biodiversity data. Future works should be planned and conducted systematically to collect valuable data on biodiversity, especially over large regions. Moreover, this study focused more on the natural aspects of the ecosystem. Factors like socio-cultural fulfilment of the residence and grazing should be taken into consideration in our future work. In addition, the future work will investigate the conservations using remote sensing data with high spatial resolution and perform evaluation more case-specifically.

6. Conclusion

In this study, a framework for evaluating ecosystem authenticity is proposed. This framework integrates constituent parts of the ecosystem, including pattern, process, function, and resilience, which can well reflect the level of biodiversity as well as the self-regulation and self-adjustment ability of the ecosystem. By using remote sensing data, the framework provides a useful tool in quantify and evaluating the ecosystem authenticity over a large region during a specific period. The case study conducted over the QTP indicates that the ecosystem authenticity over the 95% of the QTP has retained their ecosystem authenticity from 2000 to 2015. Environmental restoration projects have greatly protected the QTP's self-adjustment ability. However, the southeastern QTP has been partially damaged because of the deforestation and frequent mountain hazards like landslides. It requires more time for the effects of restoration activities to take place. Moreover, most national parks played positive roles in protecting ecosystem authenticity. For future studies, areas with damaged ecosystem authenticity should be investigated using data at higher spatial resolutions, and restoration strategies over these regions should be planed and designed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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