sustainability

Article

Conservation Value of World Natural Heritage Sites' Outstanding Universal Value via Multiple Techniques—Bogda, Xinjiang Tianshan

Hui Shi [1], Tiange Shi [2], Fang Han [1,*], Qin Liu [1,3,*], Zhi Wang [1,3] and Hulan Zhao [1,3]

[1] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China; shihui@ms.xjb.ac.cn (H.S.); hanfang@ms.xjb.ac.cn (F.H.); liuqin115@mails.ucas.ac.cn (Q.L.); wangzhi115@mails.ucas.ac.cn (Z.W.); zhaohulan17@mails.ucas.ac.cn (H.Z.)

[2] Department of Economics, Xinjiang University of Finance and Economics, Urumqi 830012, China; stg@xjufe.edu.cn

[3] College of Natural Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

* Correspondence: hanfang@ms.xjb.ac.cn (F.H.); liuqin115@mails.ucas.ac.cn (Q.L.); Tel.: +86-991-788-5356 (F.H.); +86-991-788-5354 (Q.L.)

Received: 24 September 2019; Accepted: 22 October 2019; Published: 25 October 2019

Abstract: The protection of World Natural Heritage Sites (WNHSs) has become a global undertaking, wherein Outstanding Universal Value (OUV) is an important aspect of heritage protection. Focusing on the protection of the aesthetic and bioecological values of Bogda (one component of Xinjiang Tianshan WNHS), 17 indicators are selected to construct a Heritage Value Protection Significance Index (*HVPSI*) and a related Heritage Value Protection Index (HVI). From these, the level of OUV conservation is obtained according to the five aspects of integrity, vulnerability, sensitivity, degree of human impact and environmental factors. The spatial autocorrelation analysis method was applied to the OUV conservation indices to comprehensively reflect the spatial-pattern characteristics of the heritage value in the study area. According to the spatial-division of the *HVPSI*, the plant community composition and diversity characteristics of different *HVPSI* zones are analyzed by a field survey (July 2018 and 2019). To verify the rationality of space partition and identify the OUV elements in each *HVPSI* district, a spatial-econometric model is then used to explore the relationship among *HVPSI*, HVI and community diversity. This study provides a scientific basis for management of heritage sites and a theoretical basis for further investigation into heritage site indicators.

Keywords: Outstanding Universal Value; spatial distribution; plant community diversity; correlation analysis; management; nature conservation; assessment; World Natural Heritage Site

1. Introduction

World Natural Heritage Sites (WNHSs) are natural areas with outstanding scientific and aesthetic value developed during the evolution of the earth [1]. The establishment of a WNHS effectively protects the world's most important ecosystems, rare and endangered species, natural monuments and the essence of the landscape [2]. A WNHS is distinguished by several characteristics, including global relevance, its non-renewable resources, its diversity and its unique ness [2]. A site must satisfy one of ten potential criteria for designation as a WNHS; in particular, the last four criteria are: (vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance [aesthetics]; (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms or significant geomorphic or physiographic features [geology]; (ix) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals [bioecology]; and (x) to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation [habitat standards] [3]. Since the adoption of the 'Convention Concerning the Protection of the World Cultural and Natural Heritage' by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on November 16, 1972, many countries have actively attempted to protect their cultural and natural heritage through declaration of world heritage sites [2]. To qualify as a WNHS, a heritage site must contribute Outstanding Universal Value (OUV). OUV is defined as 'cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity' [3]. Acknowledging and satisfying the requirements of OUV is an important part of heritage conservation and at the core of the standards of heritage value. The refinement of a WNHS's OUV standards is a key aspect in the declaration and protection of WNHSs. Furthermore, refining OUV requirements has important scientific and practical significance in the formulation of relevant protection and management policies [4].

To define OUV, scholars have compared and analyzed the multiple values of landscapes, ecology, science, technology, economic benefits and aesthetics of heritage sites via global comparative analyses [5–11]. Additionally, they have studied the practical functions, interests and compositional characteristics of a sites' OUV and proposed relevant protection measures for targeted protection [8,12,13]. Among these components, the aesthetic component of OUV (criterion vii) for a WNHS is incorporates aspects of its geological and bioecological values [14,15], the integrity of the landscape (scale, shape) [16,17], characteristics of the landscape group (richness, combination, difference) [18] and the landscape's attributes (uniqueness, rarity, typicality, originality) [19,20]. The bioecological component of OUV (criteria ix, x) for a WNHS reflects the ecological processes and characteristics of plants and animals in the ecosystem of the respective biogeographical area, the habitat and biodiversity. Biodiversity incorporates aspects such as species diversity, species composition, flora, vegetation type, fauna, vertical natural zone, International Union for the Conservation of Nature Species Survival Commission (IUCN/SSC) habitat type, habitat integrity, species richness, endangered species and endemic species [22–25].

IUCN natural heritage experts comprehensively evaluate potential heritage areas to determine whether they satisfy the WNHS criteria in terms of the integrity, originality and threats to the OUV [6,12]. Integrity requires that OUV elements and areas with heritage values have uncompromising and regional holistic characteristics [13,26]. Threats to the OUV reflects the situation in which the OUV is subject to human and natural impact or influence, such as building construction and development, transportation infrastructure, utilities or service infrastructure, biological resource use or modification and sudden ecological or geological events [27–30]. Ecosystem processes and the characteristics of animals and plants play significant roles in the aesthetic and bioecological components of OUV [24,31]. Ecosystems have some degree of resilience and possess an ability to recover after disturbance [28,32]. The species diversity component of OUV includes features such as: the number and distribution of rare and endangered species and species richness [22,33]. Animal species, under the stress of external disturbances, are typically sensitive to changes in living habitats, foraging sites, migration routes and so forth [29]. At the same time, environmental factors such as altitude, slope, temperature and precipitation are root causes of regional formation and thus contribute to the formation of the environmental component of OUV [21,25,31,34]. Therefore, in the assessment of heritage value, OUV elements should be comprehensively evaluated according to the objective resource situation (integrity and specificity) and the actual social and environmental conditions [14,22,24].

Currently, research surrounding OUV mostly involves explanations of the significance of OUV to a WNHS; the methods used to study this are relatively simple [7,9,35]. The research methods is based on a combination of quantitative and qualitative explanations to identify, classify, describe and score heritage according to different attributes [12,36]. Through the evaluation of landscape features, detailed outlines of heritage resources, public preference statistics, questionnaires and interviews, scholars often conduct a comprehensive assessment of the heritage site value from the natural factors, environmental conditions, historical social factors, aesthetics and factors [8,11,14,24,26]. They also analyze the environmental capacity and sensitivity of the different landscape features to develop the most suitable protection and development strategies for the WNHS [15,20].

There are many relevant studies on ecological security, ecological sensitivity, ecological vulnerability and ecological health in WNHSs [28,37–41]. From the perspective of natural resource protection and sustainable development, scholars select indices that represent geographical features, landscapes, land-use type and species diversity; these are then used to construct a comprehensive assessment model to study the characteristics of the temporal and spatial evolution and the influencing factors. Such characteristics are then studied using a variety of methods, including the Pressure-State-Response framework model [36], comprehensive index method [42], Radial Basis Function neural network model [43], multi-objective decision model [44], the Grey Model (GM (1,1)) [45]. Research methods for index weighting include objective methods, such as the entropy weight method, mean square error method and principal component analysis method, as well as subjective weighting methods, including the analytic hierarchy process, grey correlation degree analysis and the Delphi method [15,21,39,46]. Additionally, scholars often use field plot survey methods to record basic information at a given location (altitude, slope, aspect, slope-direction, geographic location, etc.) as well as the characteristics of the vegetation within that plot (species, quantity, average height, relative abundance, coverage, etc.) [22,23,47]. For areas that are listed as WNHS by bioecological value standards (ix, x), the recorded information can then be used to demonstrate a WNHS's OUV with regard to its species biodiversity, species composition, flora and vegetation type [24,25,28,33].

Xinjiang Tianshan WNHS was listed in the Natural World Heritage List in 2013. It satisfied two criteria from WNHS's declaration guide: aesthetic value (vii) and bioecological value (ix) [14]. The Xinjiang Tianshan heritage site comprises four components: Tomur, Kalajun-Kuerdening, Bayinbuluke and Bogda. The heritage value of Bogda lies in the complete vertical zone spectrum on the northern slope of Xinjiang Tianshan, mountain lakes, glaciers and species diversity of rare and endangered animals and plants [48]. Currently, research on Bogda includes forest fire prevention measures [49], ground lichen community characterization [50], vertical natural band spectrum extraction [51], glacial thickness and reserve variation characterization [52], lake ecosystem service function value evaluation [53], tectonic belt and orogenic mechanism analysis [54], tourism landscape resource assessment and protection [55], ecological security differentiation and driving mechanism identification [48], geological ecological risk assessment [21] and multi-target monitoring system construction [44]. Scholars have analyzed the characteristics of a certain value element and also comprehensively evaluated the heritage site from the perspective of ecological security, ecological risk, landscape security and ecosystem function [48,56]. There is less research on the OUV of Bogda in terms of heritage declaration standards such as integrity, originality and influence on WNHS. The area of the Bogda site is vast, at 387 km^2; to protect the forest, grassland and other endemic species. There are six designated staff, with their horses, to protect and management the study area. Even with these, the scope of the management problems is large [14]. The area is maintained by the designed staff who must contend with poor road accessibility. Therefore, delimiting the key protection zones and screening out the OUV characterization elements are of great significance to the protection of this WNHS.

This study draws on the comprehensive index evaluation research methods pertaining to ecological security, sensitivity, ecological health and other research and constructs a Heritage Value Protection Significance Index (*HVPSI*) and a related Heritage Value Protection Index (HVI) from the five aspects of integrity, vulnerability, sensitivity, degree of interference and environmental factors. The study provides a theoretical basis for confirming the monitoring indicators and provides a scientific basis for the development of conservation management measures to achieve sustainable development of the WNHS.

2. Materials and Methods

2.1. Study Area

As one of the four components of the Xinjiang Tianshan Heritage Site, Bogda is in Urumqi city and Fukang city in Xinjiang. The geographic coordinates are 87°59′59″–88°31′13″ E, 43°42′26″–44°5′12″ N. The study area includes the heritage site and the buffer zone of Bogda as the study area (747 km²). The overall terrain rises steeply from north to south, with an altitude ranging from 1,380 m to 5,445 m. Bogda is located in the continental temperate climate zone and is the 'wet island' of the arid desert center. The climate is warm in winter and cooler in summer, with abundant rainfall and deep snow. The highest temperature in summer is 28.4 °C and the lowest temperature in winter is −28.2 °C, the relative humidity is 70%–85% and the average annual precipitation is 443.9 mm [21,48].

The study area comprises a typical representation of the natural vertical zone on the northern slope of the Xinjiang Tianshan Heritage Site. It rises from 1380 m to 5445 m in a horizontal distance of less than 30 km on the northern slope of Bogda Peak. In this zone, there are seven natural vertical belts: the temperate desert zone (TDZ, 700–1100 m), the mountain steppe zone (MSZ, 1100–1650 m), the montane conifer-forest zone (MCZ, 1650–2700 m), the sub-alpine meadow zone (SMZ, 2700–2900 m), the alpine meadow zone (AMZ, 2900–3300 m), the alpine cushion vegetation zone (ACVZ, 3300–3700 m) and the ice-snow zone (IZ, 3700–5445 m). The Tianchi Scenic Area is in the MCZ, which was rated as a 5A-level scenic spot in 2007 [51,57].

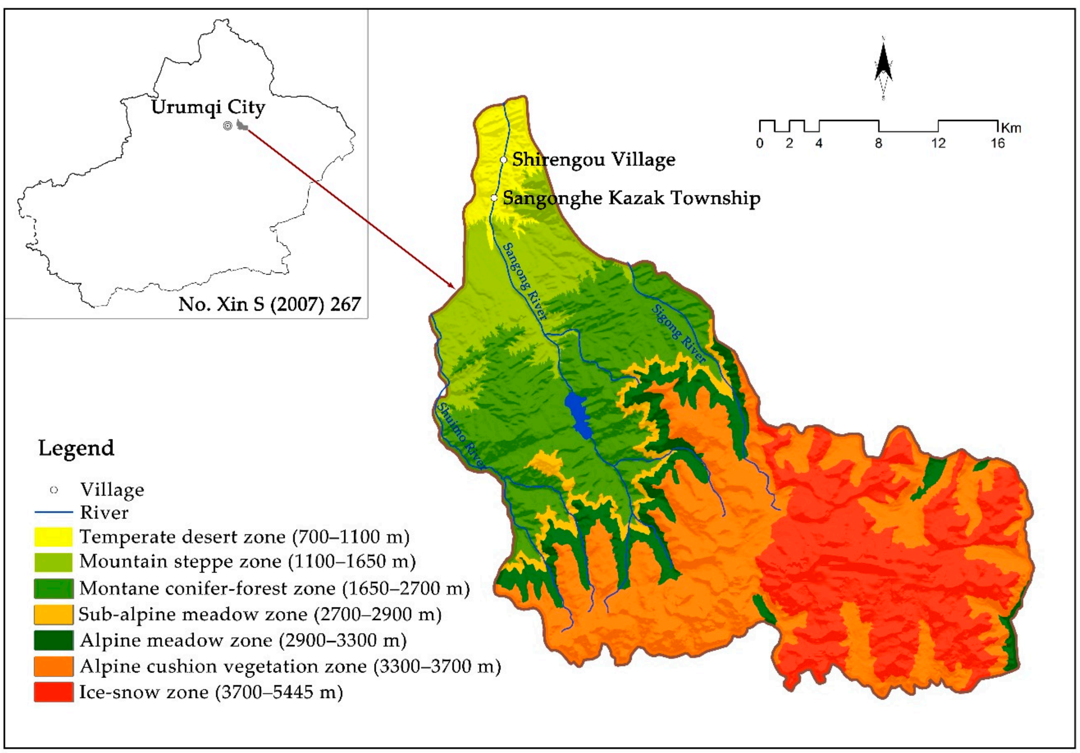

Figure 1. Location and natural vertical belts of the Bogda heritage site.

2.2. Data Sources and Processing

The data used in this study includes Landsat 8 OLI_TIRS images with a resolution of 15 m in good weather and cloudless states, from September 2010 and 2015 (Geospatial Data Cloud, http://www.gscloud.cn) , Digital Evaluation Model (DEM) data, a soil distribution map, a vegetation distribution map and precipitation and temperature raster data of the Xinjiang Territory International Exchange Station from 2015, the Xinjiang Tianshan heritage declaration document, Tianshan Tianchi

Scenic Area master plan (2004–2020), the Geological Survey Report of Tianchi Scenic Area and the Xinjiang Statistical Yearbook (2000–2010). Data sources are shown in Table 1.

Table 1. Data source and description.

Type of data		Year	Resolution	Data Source	Purpose
Remote sensing data	Landsat TM remote sensing image	2010–2015	15 m	Geospatial Data Cloud	Calculating the landscape type functional dominance, landscape type degradation degree, landscape fragmentation degree, NDVI
DEM data	DEM	2015	30 m	Geospatial Data Cloud	Calculating altitude and slope
Pictures data	Landscape photos	2010–2015	-	Filed Survey and Document of Xinjiang Tianshan Heritage Declaration	Calculating degree of landscape beauty
Maps data	Map of vegetation types in China	2010–2015	1:1,000,000	Peking University Open Research Data	Calculating richness of community structure
	Map of soil types in China	2010–2015	1:1,000,000	Peking University Open Research Data	Calculating soil types
Table data	List of endangered, endemic species and scenic properties	2010–2013	-	Document of Xinjiang Tianshan Heritage Declaration	Calculating degree of protection of endangered species, degree of diversity of endemic species, degree of beauty
Space vector data	Road data	2010–2015	-	Filed Survey	Calculating road density
	Location data of tourist gathering area	2015	-	Filed Survey	Calculating tourist recreation space
	Location of landslide and debris flow	2010–2015	-	Geological Survey Report of Tianchi Scenic Spot	Calculating natural disaster occurrence area
Raster data	Temperature and precipitation data	2015	1 km×1 km	Resource and Environment Data Cloud Platform	Calculating temperature and precipitation

Envi 5.1 software was used for image processing. The bands 5, 4 and 3 were initially used as the R, G and B modes, of Landsat images. Then, the Universal Transverse Mercator projection N45 band and WGS1984 ellipsoid geospatial information registration were used to process the images. Finally, the image data and field survey data were combined to enable classification of the study area's landscape types. According to the 'Chinese Classification of Land Use Status' (GB/T21010-2017) classification criteria and the status of the study area, the area was divided into the following types: glaciers/permanent snow, bare land, alpine meadows, alpine grassland, evergreen coniferous forest, deciduous broad-leaved forest, warm grassland, warm meadow, sparse grassland, lake, construction land, transportation land, dry land and mining sites.

Elevation and slope data for the study were obtained from the DEM. The data from the field survey were analyzed using Microsoft Excel, SPSS 20.0 and plotted using Sigmaplot 13.0 statistical analysis software.

2.3. Methods

2.3.1. Heritage Value Protection Significance Index (*HVSPI*) Construction

UNESCO's assessment of heritage sites is based on a comprehensive assessment of the value elements of heritage, the integrity of the values, originality and the degree of disturbance [12,24]. The selection of integrity indicators is mainly based on aesthetic and bioecological characteristics as well as on the integrity of elements of the natural vertical zones, including the alpine lakes, glaciers and rare and endangered animals and plants [15,22]. The landscape type's functional dominance index is comprehensively used to reflect the bioecological, aesthetic and ecological values of the different landscape types [17,24]. The degree of degradation and fragmentation of landscape types represents the integrity of the landscape's boundary on a spatial scale [40]. According to the self-recovery and anti-interference characteristics of the value elements of the study area, the vulnerability of the plant species can be measured from indicators such as the Normalized Difference Vegetation Index (NDVI) and community structure richness and soil type, which can directly or indirectly reflect the characteristics of vegetation [24,27,29]. The degree of protection indices for endangered species, as well as the endemic species, reflect the degree of protection and distribution of animal species and can directly or indirectly influence the distribution of animals after external disturbances [22,23]. Though reasonable grazing can ensure the natural succession of ecosystems and positively affect grassland regeneration and the nutrient supply for herbivorous wild animals, it can also indirectly affect the distribution of wild animals [58–60]. Therefore, by consulting relevant experts, indicators for the degree of endangered species protection, endemic diversity and theoretical carrying capacity are measured for their sensitivity in determinations of the OUV.

Interference reflects the situation in which the value elements are subject to human and natural interactions [61]; the degree of interference thus reflects the extent to which human or natural forces influence or alter the value elements. The main disturbance factors in the study area are tourism activities, road construction and landslides [48]; thus, they are comprehensively considered with regard to tourist recreation space, road density and the natural disaster occurrence area. The environmental maintenance factors are the specific environmental background features which contribute to the value of the OUV for the WNHS, such as altitude, slope, temperature or precipitation [47].

Through the consultation of experts and relevant research, this study selects 17 indicators to establish an *HVPSI* that incorporates the five aspects of integrity, vulnerability, sensitivity, degree of interference and environmental factors. The selection of such indicators is motivated by the aim to protect the aesthetic and bioecological values of the WNHS. Notably, HVSPI reflects the extent to which heritage value should be protected. The formula of the *HVPSI* construction is provided as follows:

- Indices

Overall, *HVPSI* represents the importance of heritage value protection. Component indices used in the construction of the *HVPSI* include integrity (*HI*), vulnerability (*VI*), sensitivity (*SI*), degree of interference (*DI*) and the environmental (*EI*); a, b, c, d and e are the weights of integrity, vulnerability, sensitivity, interference and environmental maintenance elements, respectively.

$$HVPSI = aHI + bVI + cSI + dDI + eEI \quad (1)$$

- Weight calculation

The 17 indicators of *HVPSI* are mapped by the unified projection coordinate system through ArcGIS 10.5. The raster data of each indicator is converted into the corresponding spatial point data through the central point. Then, the central points of the converted 17 indicators are spatially intersected. Third, the 747 spatial points of the data for the 17 indicators are obtained and the database is built. Finally, the weights of the 17 indicators of each of the 747 points are calculated by the entropy method. The weight of each indicator and formulas are shown in Table 2 and Figure 2.

Table 2. Weights, formulas and sources of HVSPI measurement for the component indices: integrity index (*HI*), vulnerability index (*VI*), sensitivity index (*SI*), degree of interference index (*DI*) and environmental elements index (*EI*).

Indices	Indicators	Weights	Formulas	Source
HI	Landscape Type Function Dominance	0.0495	Considering the ecological service value, aesthetic value and ecological value of different landscape types, each landscape type is assigned a functional advantage value, via f (landscape type) = functional advantage, that represents the respective level of a landscape type's contribution to the OUV of the site. The higher the degree of the functional advantage, the higher its ecological and aesthetic value and the more it should be protected: f (glaciers/permanent snow) = 8，f (evergreen coniferous forest, deciduous broad-leaved forest) = 7，f (warm grassland) = 6，f (warm meadow) = 5，f (alpine meadows) = 4，f (alpine grassland) = 3，f (Sparse grassland) = 2，f (bare land, lake, construction land, transportation land, dry land, mining sites) = 1.	[17,24]
	Degree of Landscape Beauty	0.0761	Tourists, managers, local residents, college teachers and undergraduates were selected to judge pictures of the study area. With these participants' evaluations, Scenic beauty estimation method (SBE) was then used to evaluate landscape beauty and to quantify the aesthetic value component that contributes to various landscape's OUV. The evaluation process is as follows: 1) The 10 most representative images of the important landscapes in Bogda were selected to form a PowerPoint. Participants were asked to score each image on a scale of 1 to 10.2) For resource points which received a beauty value greater than 70, spatial location	[15,59]

			information for landscape was extracted. A buffer zone with a 1 km radius as the spatial distribution of the landscape's degree of beauty was then analyzed.	
	Degradation of Landscape Type	0.0750	This index is the ratio of the difference between the area of each landscape type and the time after the interpretation of the two remote sensing data in the study area in 1990 and 2015. The formula is: $DLT = (A_f - A_b)/(Y_f - Y_b)$ (2) where DLT is the degree of degradation for the landscape type, A_f and A_b are the area of the landscape type in 1990 and 2015 and Y_f and Y_b are the year of 1990 and 2015, respectively. The higher the DLT is, the more obvious the degradation of the landscape type in the region is and the more it should be protected.	[48,62]
	Landscape Fragmentation	0.0610	This index considers the complexity of the spatial structure of the landscape and reflects the degree of human disturbance to the landscape. The formula is: $C_i = N_i/A_i$ (3) where, C_i is the fragmentation degree of landscape type i, N_i is the number of patches to landscape type i and A_i is the total area of landscape type i. The higher the degree of landscape fragmentation is, the more the area should be protected.	[17,63]
VI	Normalized Difference Vegetation Index (NDVI)	0.0456	NDVI is used to reflect vegetation growth status and vegetation coverage. The formula is: $NDVI = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}}$ (4) Where, NIR and VIS are the reflectance values in near-infrared and red bands, respectively. The higher the NDVI is, the better the vegetative state is and the more it should be protected.	[25,29]
	Richness of Community Structure	0.0483	This index is a comprehensive assessment of the habitat as a whole community structure. According to the type of vegetation, the richness of the community structure is defined as the proportion of the amount (area or quantity) of the niche vegetation type to the total amount in the vertical space with arbor layers, shrub layers, herb layers and quilt layers (moss lichen). The higher the value is, the more it should be protected.	[25,64]

			The vegetation types of the study area and their given heritage value scores (8) are: cold temperate zone and temperate mountain coniferous forest(8), subalpine deciduous broad-leaved shrubs (7), temperate grass and weedy meadow steppe (6), temperate cluster grass typical steppe (6), temperate semi-shrub and dwarf semi-shrub desert (6), temperate cluster dwarf grass and dwarf and semi-shrub desert steppe (5), temperate deciduous leafless sparse forest (4), Artemisia scoparia and weedy meadow (3), alpine sparse vegetation (2) and a glacier snow ecosystem (1).	
	Soil Type	0.0468	Soil is an important part of the ecosystem; it reflects the fertility level and utilization value of the soil. Soil fertility directly affects the production status of the vegetation. The higher the soil fertility is, the better the vegetation grows under the same conditions; thus, the higher its ecological value is and the more it should be protected. Therefore, according to the fertility level of the soil in the study area, different types of soil are assigned a value (6) that reflects their relative ecological value: grey cinnamon soil (6), chernozem (6), brown soil (5), light chestnut soil (5), chestnut soil (5), cultivated chestnut soil (5), chestnut alpine meadow soil (4), alpine meadow soil (3), alpine cold desert soil (2) and fluvo-aquic soil (1).	[27,65,66]
SI	Degree of Protection for Endangered Species	0.0493	This index refers to the proportion of different conservation grades of endangered animal species in a habitat to the total animal protection species. The greater the proportion is, the more the habitat should be protected. The formula is: $$C_s = \sum \lambda_j \frac{U_{sj}}{U_s} \quad (5)$$ where C_s is the animal species protection index of habitat type s, U_{sj} is the number of protected animal species of class j in habitat type s, U_s is the number of all protected animal species in s habitat, λ_j is the ecological weight of the j-class protected species in this area. The ecological weight value is a product of the ratio of j-class protected animal species to the total number of protected animal species in the whole region and the importance value of the j-class protected animal species. The higher	[66,67]

		the C_s is, the more the habitat type should be protected. In the study area, animal and plant species were selected and defined as endangered species according to the IUCN Species Red List (2010), the CITES Appendix (2010), the Chinese Species Red List (2004), the National Key Protected Wild Animals (1988) and the Xinjiang Uygur Autonomous Region Key Protected Wild Plants List (2007). According to the degree of endangerment of species, the degree of relative protection corresponding to the above listed sources is defined as 9, 7, 5, 3, 1.	
Endemic Diversity	0.0505	This index refers to the proportion of endemic species to total species within a habitat type, which reflects the complex relationship between organisms and environments. The higher the index is, the more the habitat type should be protected. The formula is: $$V_s = M_{st}/M_s \quad (6)$$ where, V_s is the endemic species diversity index of habitat type zone s, M_{st} is the number of endemic species in the habitat type zone s and M_s is the number of species in the entire habitat type zone s.	[66,67]
Theoretical Carrying Capacity	0.0588	This index is chosen as an indicator of grassland protection, to reflect the productivity of grassland and the theoretical grazing level of grasslands. Through calculation of the amount of livestock carried on the grassland in the heritage site, the degree of pasture grazing in the area is obtained and verified and a corresponding protection mode is adopted to facilitate different degrees and types of protection. In calculating this indicator, the research of the carrying capacity of Chinese counties and cities by existing scholars was referenced. According to different vegetation types of grassland, the grassland vegetation types were classified into 6 secondary grassland types (meadow grassland, typical grassland, desert grassland, alpine meadow, alpine grassland and shrub grassland). Mountain meadows, warm grasslands and warm meadows are all classified as meadow grasslands; warm grassland deserts and warm desert grasslands are classified as desert grasslands. According to the livestock	[68,69]

			carrying amount related research, the carrying amount is calculated.	
	Tourist Recreation Space	0.0926	This index reflects the degree of tourists' gathering in a certain period time. Considering the distance that visitors can reach, a buffer analysis is conducted with a radius of 1 km as the tourists' recreation space. The higher the index is, the more it should be protected.	[5,13]
DI	Road Density	0.0763	This index is the ratio of the total mileage of the road network to the area within a certain scope. Therefore, the road density of the center point of each grid is calculated as the total mileage of the road in grid sections with an area of 1 km × 1 km. The higher the index is, the more serious the impact on the value of the heritage is and the more area of the considered scope should be protected.	[29]
	Natural Disaster Occurrence Area	0.0827	According to the 'Specifications for Debris Flow Hazard Prevention and Control Engineering Survey' (DZ/T0220-2006), the vulnerability of debris flow should be evaluated. As per the situation of natural disasters in 'Tianshan Tianchi Scenic Area master plan (2004–2020),' a buffer analysis was conducted on the area in the study area where natural disasters are prone to occur, with a radius of 1 km.	[21,30]
	Altitude	0.0471	According to Digital Evaluation Model (DEM) data, the data was obtained by GIS10.5.	[37,70]
	Slope	0.0469	According to DEM data, the data was obtained by GIS10.5.	[71]
EI	Temperature	0.0471	According to the resource temperature data cloud platform, Xinjiang temperature raster data processing is obtained.	[21]
	Precipitation	0.0463	According to the resource data cloud platform, Xinjiang precipitation raster data processing is obtained.	[21]

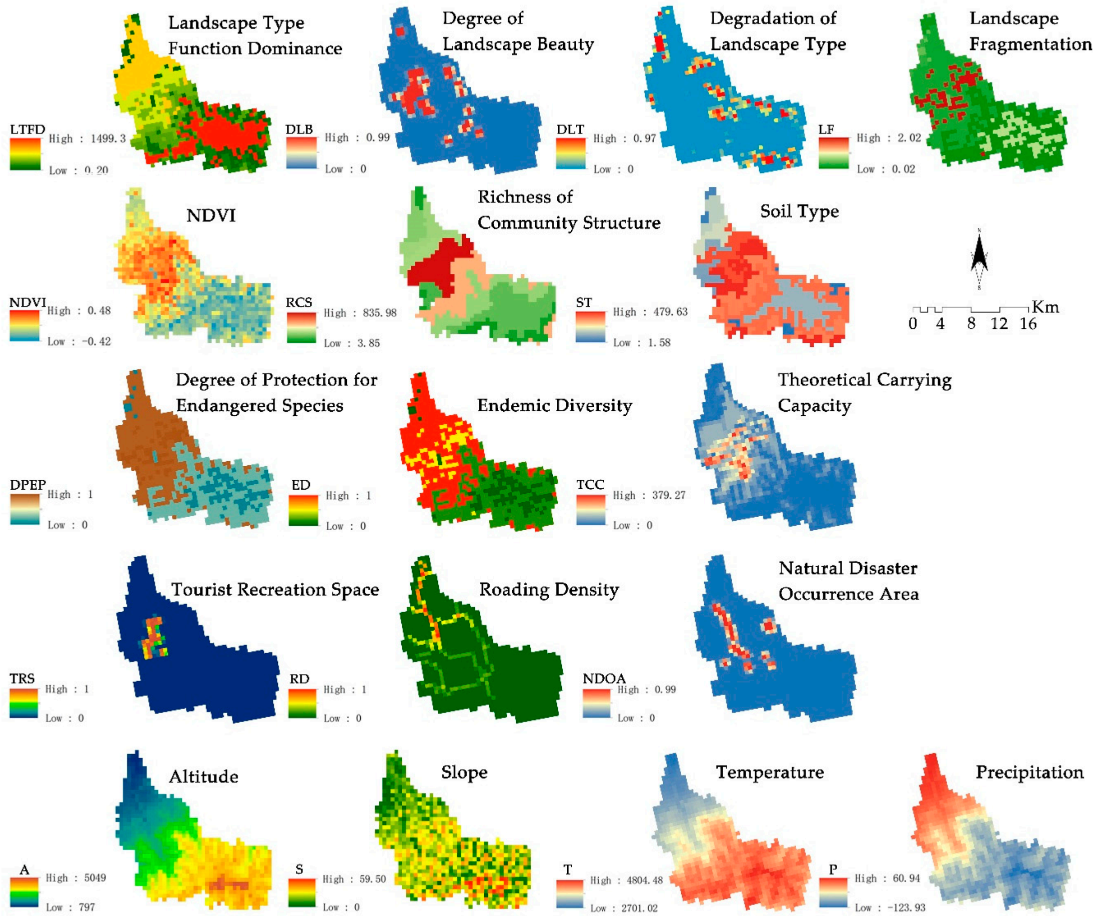

Figure 2. Indicators of OUV conservation indices.

2.3.2. Spatial Statistical Model

- Spatial autocorrelation analysis: Exploratory Spatial Data Analysis (ESDA) is a measure of the degree of spatial agglomeration. The ESDA is obtained by calculating the spatial autocorrelation coefficient, describing the spatial agglomeration and anomaly of the spatial distribution pattern of visual objects or phenomena and discovering the spatial interaction between research objects. ESDA has two types of analysis methods, namely, global statistics and local statistics [21,46,48]:
  1. Global Spatial Autocorrelation (Moran's I) is used to verify the spatial correlation of an element of the entire study area. The formula is:

$$\text{Moran's I} = \frac{N\sum_{i=1}\sum_{j=1}w_{ij}(x_i-\bar{x})\left(x_j-\bar{x}\right)}{\sum_{i=1}^{n}(x_i-\bar{x})^2\left(\sum_{i=1}^{n}\sum_{j=1}^{m}W_{ij}\right)}(i\neq j) \quad (7)$$

where, N is the total number of 1 km × 1 km raster data center points in the study area; x_i and x_j represent the observations of different feature attributes on x in the spatial unit; $\bar{x}$ is the mean value, w_{ij} is the spatial weight matrix. The same below.

  2. Local Indicators of Spatial Autocorrelation (LISA) reflect the degree of correlation between a geographical phenomenon or attribute of a unit of a small local area of the whole study area and the same phenomenon or property of an adjacent local small area unit. The formula is [72]:

$$I_i = \left(\frac{x_i-\bar{x}}{m}\right)\sum_{j=1}^{n}W_{ij}(x_i-\bar{x}) \quad (8)$$

$$m = (\sum_{j=1, j\neq i}^{n} x_j^2) \Big/ (n-1) - \bar{x}^2 \quad (9)$$

where, a positive I_i value represents a spatial agglomeration of similar values (high or low) around the area unit; and a negative I_i value represents the spatial agglomeration between non-similar values.

- Spatial econometric model: after determining the spatial correlation of the regional unit attributes, the spatial interaction between different areas should be introduced into the model as a variable to construct a spatial econometric model, which mainly includes two types: spatial lag model (SLM) and a spatial error model (SEM) [73].

1. The formula of SLM is:

$$y_{it} = \rho W y_{it} + \beta X_{it} + \varepsilon_{it} \quad (10)$$

where, y_{it} is the dependent variable matrix of region i at period t; X_{it} is the argument matrix of region i in period t; the parameter β reflects the influence of the independent variable on the dependent variable; W is a spatial weights matrix; ϱ is the spatial autoregressive coefficient, which reflects the influence of observation errors in neighboring areas; and ε represents the residual items.

2. SEM mainly considered whether the dependent variable is spread by the same behavior in its neighboring area. The formula of the SEM is:

$$y_{it} = \beta X_{it} + \mu_{it}\, \mu_{it} = \lambda W_{it} \mu_{it} + \varepsilon_{it} \quad (11)$$

where, μ_{it} and ε_{it} are error perturbation term vectors; and λ is the coefficient of autocorrelation for the SEM, which reflects the influence direction and degree of dependent variables in neighboring regions. The spatial dependence of the SEM is represented in the error term, which measures the influence of the error impact of the dependent variable on the observed values in the region.

- The choice of spatial econometric model requires Ordinary Least Squares (OLS) regression analysis first. If it is found in the spatial correlation test that the spatial lag model Lagrange multiplier test statistic LMLAG is statistically more significant than the spatial error LMERROR, then the SLM is selected. If LMERROR is statistically more significant than LMLAG, then the SEM is selected. If the both of LMLAG and LMERROR are not significant, then the results of the Ordinary Least Squares (OLS) regression were selected [74]. With ArcGIS 10.5 and the GeoDa software, we used above spatial regression analysis to analyze the relationship between the OUV conservation index and the plant community diversity characteristics of the study area.

2.3.3. Field Survey Method

From July 5, 2018 to July 22, 2019 (the season of vegetation growth), we conducted a vegetation survey on the study area. According to the distribution characteristics of the vegetation in the study area, vegetation survey plots were stratified in areas with similar conditions, such as altitude, topography, soil conditions and vegetation types. The plots, (10 m × 10 m), were sampled and the three groups were repeated to each plot to ensure the plant distribution and structure uniformity in the community. The herb sample size of each plot was set to 1 m × 1 m, with five replicates. Then, the following vegetation information was recorded: species' name, height, coverage, numbers and crown width in each sample. Community environmental and locational factors were recorded with the information, including the location name, latitude and longitude, elevation, slope direction, slope, soil type, interference factor and so forth [22,25,75].

Firstly, the field survey data were normalized. Then, the importance value, Simpson Index, Margalef Index and Pielou index were selected to measure the richness and evenness of community species in the study area. Among these measures, the Simpson Index comprehensively reflects the richness and evenness of the species in the community based on the number of species, the total number of individuals of all species and the diversity index of the number of individuals per species.

The Shannon-Wiener Index considers the number of species and the uniformity of individual distributions among species. The Margalef Index is positively correlated with the number of species. The formulas of the indices are [76]:

$$\text{Importance value (IV)} = (relative\ coverage + relative\ density + relative\ height)/3 \quad (12)$$

$$Simpson\ index: D = 1 - \sum P_i^2 \quad (13)$$

$$\text{Shannon} - \text{Wiener index: } H' = -\sum P_i ln P_i \quad (14)$$

$$\text{Margalef index: } Ma = (S-1)/lnN \quad (15)$$

$$\text{Pielou index: } J_{sw} = H'/lnS \quad (16)$$

where, relative coverage is the coverage of a certain plant in the sample plot, that is, the sum of the coverage of all plant species × 100; relative density is the number of individuals in a certain plant population, that is, the number of individuals in all plants × 100; and relative height is the sum of the heights of all plants of a certain height, that is, the sample of a certain plant population × 100. The importance value of any species in the community cannot exceed 100%. *S* is the total number of species in the plot. *N* is the total number of individuals in the plant community.

3. Results

3.1. Analysis of the Spatial Pattern of OUV Conservation

3.1.1. Comprehensive Assessment of OUV Conservation Indices

According to the natural fracture method , the distribution values of the *HVPSI*, *HI*, *VI*, *SI*, *DI* and *EI* were divided into five grades: level 1 areas (0–0.3), level 2 areas (0.3–0.5), level 3 areas (0.5–0.6), level 4 areas (0.6–0.7) and level 5 areas (0.7–1) (Figure 3). The closer the distribution value is to 0 (Level 1), the lower the degree of protection; the closer the distribution value is to 1 (Level 5), the higher level of protection (Figure 3, Table 3).

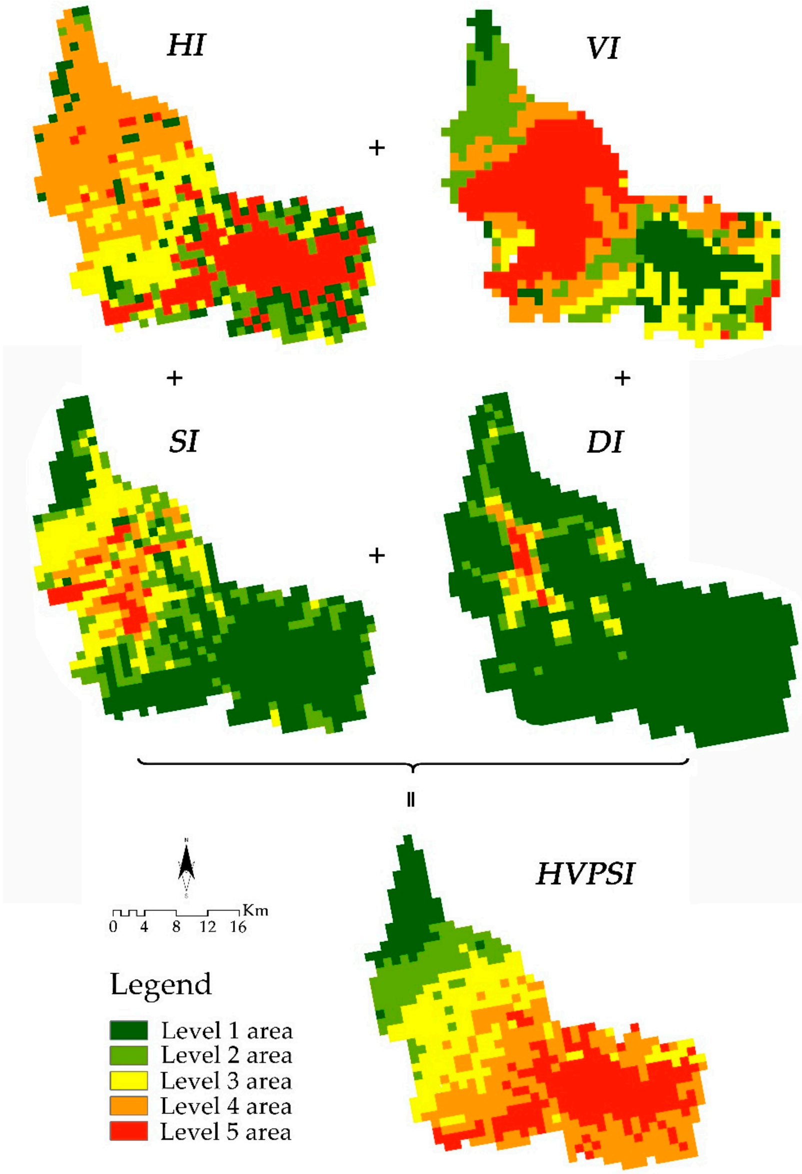

Figure 3. Spatial distribution areas of Bogda Outstanding Universal Value (OUV) conservation indices. Heritage Value Protection Significance Index (*HVSPI*), Integrity (*HI*), Vulnerability (*VI*), Sensitivity (*SI*), Degree of interference (*DI*). According to the distribution values of the *HVPSI*, *HI*, *VI*, *SI* and *DI*, level 1 areas (0–0.3) needs a little protection, level 2 areas (0.3–0.5) need light protection, level 3 areas (0.5–0.6) needs moderate protection, level 4 areas (0.6–0.7) need strong protection and level 5 areas (0.7–1) need very strong protection.

The spatial distribution of the *HVPSI* throughout the study area has obvious regional differences. *HVPSI* generally increases from north to south. The level 5 area of the *HVPSI* (red area), with an area of 182.51 km^2, accounts for 25% of the study area. It is concentrated in the Bogda Peak's ice snow zone (IZ) in the eastern part of the study area, with the exception of part of the alpine cushion vegetation zone (ACVZ). Other regional boundaries are consistent with the boundaries of the IZ. The Level 4 area of the *HVPSI* (orange area) is the largest distribution area of all, accounting for 32% of the study area; it is distributed in the periphery of the level 5 area as a buffer zone and spans five natural vertical zones: the montane conifer-forest zone (MCZ), the sub-alpine meadow zone (SMZ), the alpine meadow zone (AMZ), the ACVZ and the IZ. The level 3 area of the *HVPSI* (yellow area) has an area of 166.55 km^2 and is mainly distributed in the MCZ. This area has the widest range, spanning six natural vertical zones, including the mountain steppe zone (MSZ), the MCZ, the SMZ, the AMZ, the ACVZ and the IZ. The level 2 area of *HVPSI* (light green area) covers 88.76 km² and is concentrated in the MSZ and MCZ, in the northern parts of the study area. The level 1 area (green area) of *HVPSI* is distributed in the lower reaches of the Sangong River Basin, including the temperate desert zone (TDZ) and MSZ of Shirengou Village and Sangonghe Kazak Township.

Both level 5 areas of *HI* and *HVPSI* are spatially consistent and the distribution of the level 4 areas can be clearly seen in Figure 3. The range of the level 5 area for *HI* spans three vertical vegetation zones, namely, TDZ, MSZ and MCZ, with an area of 183.17 km² which accounts for 25% of the study area. The level 5 area of *VI* is concentrated in the MCZ and SMZ, with an area of 239.96 km² which accounts for 32% of the study area. The level 5 areas of the *SI* and *DI* are mainly distributed near Tianchi Lake. The level 4 and 3 area of *SI* are distributed in the periphery of the Level 5 area as a buffer zone. The level 1 area of the *SI* is the largest and is mainly distributed in the IZ and ACVZ. The level 5 area of *DI* is distributed in several areas, containing the area along the S101 provincial highway, the parking lot around the Tianchi Scenic Area, the infrastructure construction area and the debris flow-prone areas.

Table 3. Spatial distribution areas of Bogda OUV conservation indices.

	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
HVPSI	69.81	88.76	166.55	235.37	182.51
HI	103.32	77.96	154.99	223.56	183.17
VI	114.68	144.55	107.93	135.88	239.96
SI	374.78	137.73	149.91	46.85	33.73
DI	593.74	71.74	31.34	35.46	10.72

Notes: Heritage Value Protection Significance Index (*HVSPI*), Integrity (*HI*), Vulnerability (*VI*), Sensitivity (*SI*), Degree of interference (*DI*). Level 1 areas (0–0.3) needs a little protection, level 2 areas (0.3–0.5) need light protection, level 3 areas (0.5–0.6) needs moderate protection, level 4 areas (0.6–0.7) need strong protection and level 5 areas (0.7–1) need very strong protection.

3.1.2. Spatial Correlation Analysis of OUV Conservation Indices

The Moran's I of the OUV conservation indices were calculated using the GeoDa software. Combining this software with the LISA map of the scatter plot and the local spatial autocorrelation (z test $p = 0.01 < 0.05$), the spatial correlations of the conservation indices were analyzed (Table 4).

Table 4. Moran's I of Bogda OUV conservation indices.

	HVPSI	***HI***	***VI***	***SI***	***DI***
Moran's I	0.8940	0.4255	0.7967	0.6928	0.6521
Mean	0.0006	−0.0045	−0.0024	−0.0005	0.0012
sd	0.0286	0.0275	0.0217	0.0195	0.0188
z-value	31	15	36	35	34
p-value	0.01	0.01	0.01	0.01	0.01

Notes: Heritage Value Protection Significance Index (*HVSPI*), Integrity (*HI*), Vulnerability (*VI*), Sensitivity (*SI*), Degree of interference (*DI*).

The Moran's I value of the OUV conservation indices are significantly positive ($p < 0.05$), indicating that the distribution of the OUV value elements are spatially related and that the areas with similar protection levels are spatially autocorrelated. Among the Moran's I values, the Moran's I value of *HVPSI* was largest (0.894) and the value of *HI* was smallest (0.4255). The order of indices in terms of their Moran's I value results are: *HVPSI* > *VI* > *SI* > *DI* > *HI*. This result indicates that there is a prominent positive spatial correlation of the *HVPSI* in the study area is prominent, showing a strong spatial autocorrelation; other related heritage value protection indices (*HVIs*) also have spatial correlation, such that the spatial measurement model is needed in the factor analysis.

The LISA map (Figure 4) was used to further analyze the spatial pattern characteristics of the *HVIs* in the study area. From this analysis, the following patterns were found. There is a positive spatial correlation pattern in which the value of the *HVPSI* has a high value area and a low value area. The high value area (H-H) of the *HVPSI* (red area) is located between the high value region itself and the adjacent area. The low value area (L-L) of the *HVPSI* (blue area) is located between the low value region itself and the adjacent area. The area of the H-H is 146 km^2, which accounts for 19.54% of the total area; the H-H is concentrated in the IZ. The area of the L-L is 137 km^2, which is concentrated in the TDZ and the MSZ in the northern part of the study area. The value of the *HI*'s spatial distribution shows a trend ranging from a cluster distribution pattern to a random distribution pattern. The H-H of the *HI* is similar to the H-H of *HVPSI*: it has a large area of 91 km^2. The L-L, low-high area (L-H) and high-low area (HL) are more dispersed and distributed in a dot shape around the H-H area. The H-H of the *VI* and *SI* are similarly distributed and have large areas of 139 km^2 and 104 km^2, respectively. The H-H of the *DI* is 59 km^2, which is concentrated in an area of intense human activity along the Tianchi Scenic Area and an area of debris flow.

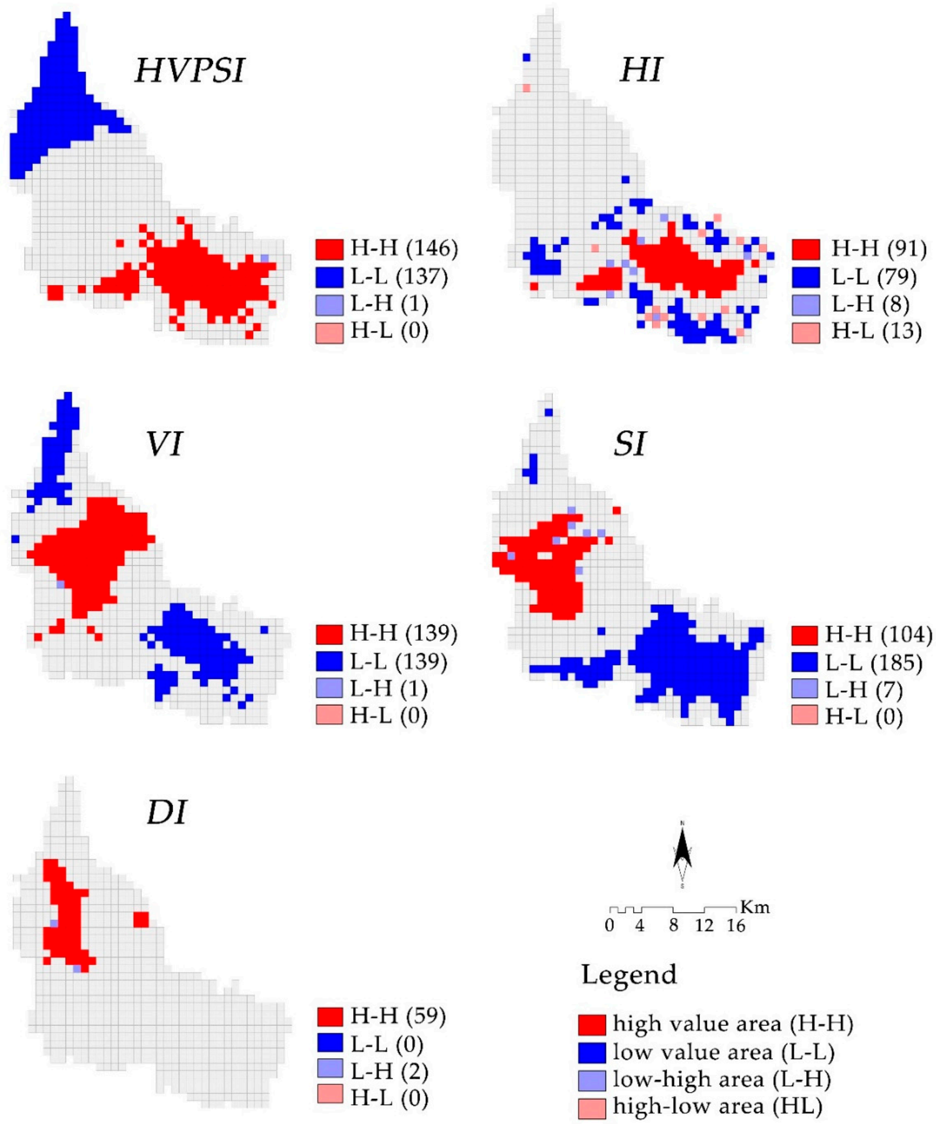

Figure 4. LISA cluster diagram of Bogda OUV conservation indices. Heritage Value Protection Significance Index (*HVSPI*), Integrity (*HI*), Vulnerability (*VI*), Sensitivity (*SI*), Degree of interference (*DI*).

3.2. Community Characteristics Under HVPSI Zones

3.2.1. Plant Community Composition

Fifty-one plots were surveyed in the study area from 2018–2019. There were 42 species of dominant species in each plot; these comprised 19 families, including Labiatae, Leguminosae and Gramineae.

Along with the spatial division of the *HVPSI*, the composition of plant communities and the importance value (IV) of the species were analyzed for each sub-area. It was found that the number of species in the levels 1, 2, 3, 4, 5 of the *HVPSI* areas were 6, 21, 16, 16 and 11 species, respectively. The species in the level 2 area of the *HVPSI* were the most abundant, with 21 dominant plants from 13 families. Among them, *Aegopodium alpestre*, *Carex caespitosa* and *Achillea millefolium* have higher importance values. The species in level 1 of the *HVPSI* area are the least dominant, with only six species. Among them, *Caragana soongorica*, *Ceratoides latens* and *Seriphidium borotalense* have higher importance value. The dominant species in the level 3 area of the *HVPSI* belong to 10 families, primarily Leguminosae and Gramineae plants. Among these, *Astragalus tibetanus* has the highest importance value, followed by *Polygonum viviparum*, *Poa annua* and *Carex caespitosa*, in the level 4 area of the *HVPSI*, having the highest importance values. The dominant species in the level 5 area of the *HVPSI* are concentrated in seven families, among which the importance values of Gramineae and Caryophyllaceae are higher (Table 5).

Table 5. Species composition and importance value of plant communities in different zones of the *HVPSI*.

Families	Species	Importance Value				
		Level 1	Level 2	Level 3	Level 4	Level 5
Labiatae	*Phlomis pratensis*		0.05 ± 0.01	0.19 ± 0.03		
Leguminosae	*Caragana soongorica*	0.49 ± 0.08				
	Trifolium repens		0.03 ± 0.01			
	Astragalus tibetanus		0.13 ± 0.02	0.85 ± 0.63		
	Oxytropis bogdoschanica		0.14 ± 0.01			0.09 ± 0.01
	Medicago lupulina			0.11 ± 0.01		
Gramineae	*Festuca pratensis*	0.27 ± 0.04			0.12 ± 0.01	0.18 ± 0.06
	Elymus nutans		0.09 ± 0.03	0.24 ± 0.03		
	Phleum alpinum		0.12 ± 0.01			
	Poa annua		0.18 ± 0.04	0.18 ± 0.02	0.3 ± 0.11	0.3 ± 0.09
	Alopecurus aequalis			0.31 ± 0.03		
	Bromus inermis			0.41 ± 0.24		
Saxifragaceae	*Saxifraga montana*					0.09 ± 0.02
Violaceae	*Viola tianschanica* Maxim.		0.03 ± 0.01			
Crassulaceae	*Rhodiola rosea*				0.07 ± 0.01	
Compositae	*Taraxacum mongolicum*		0.05 ± 0.01			0.1 ± 0.04
	Erigeron auranitiacus				0.19 ± 0.01	
	Saussurea involucrata				0.06 ± 0.01	
	Aster alpinus				0.08 ± 0	

	Seriphidium borotalense	0.42 ± 0.06				
	Achillea millefolium		0.35 ± 0.01	0.19 ± 0.04		
Chenopodiaceae	*Ceratoides latens*	0.45 ± 0.19				
Polygonaceae	*Polygonum viviparum*			0.46 ± 0.01	0.2 ± 0.04	
Geraniaceae	*Geranium rectum*		0.13 ± 0.08	0.27 ± 0.05		
	Thalictrum alpinum		0.13 ± 0.07		0.16 ± 0.02	
Ranunculaceae	*Trollius lilacinus*				0.11 ± 0.01	0.1 ± 0.02
	Delphinium grandiflorum					0.16 ± 0.09
	Galium aparine		0.05 ± 0.01	0.25 ± 0.06		
	Galium verum			0.16 ± 0.01		
	Spiraea hypericifolia	0.18 ± 0.03	0.06 ± 0.01		0.19 ± 0.08	0.12 ± 0.06
Rubiaceae	*Fragaria vesca*		0.1 ± 0.09			
	Rosa platyacantha Schrenk		0.15 ± 0.1			
	Potentilla chrysantha		0.13 ± 0.02	0.09 ± 0.04	0.16 ± 0.03	0.17 ± 0.04
	Alchemilla tianschanica			0.36 ± 0.04	0.28 ± 0.01	
Caprifoliaceae	*Lonicera hispida*		0.11 ± 0.01			
Umbelliferae	*Aegopodium alpestre*		0.37 ± 0.19	0.23 ± 0.04		
	Aegopodium podagraria				0.14 ± 0.01	
Cyperaceae	*Carex caespitosa*	0.41 ± 0.04	0.33 ± 0.06	0.34 ± 0.01	0.28 ± 0.05	
Caryophyllaceae	*Arenaria serpyllifolia*				0.08 ± 0.01	0.16 ± 0.01
	Stellaria media					0.2 ± 0.1
Iridaceae	*Iris scariosa*		0.11 ± 0.01			
Boraginaceae	*Myosotis alpestris*				0.17 ± 0.01	

Notes: According to the distribution values of the *HVPSI*, level 1 areas (0–0.3) needs a little protection, level 2 areas (0.3–0.5) need light protection, level 3 areas (0.5–0.6) needs moderate protection, level 4 areas (0.6–0.7) need strong protection and level 5 areas (0.7–1) need very strong protection.

3.2.2. Plant Community Diversity

According to the spatial zoning characteristics of the *HVPSI*, the plant community diversity characteristics in each district are different. Regarding the distribution of plant community species diversity index values in different spatial regions, variation of the Simpson index and the Shannon-Wiener index is consistent. The largest value of both indices corresponds to the level 3 area of the *HVPSI* and the smallest value corresponds to the level 1 area of the *HVPSI*; the order of other partitions is slightly different. The order of the Simpson Index is $S_{\text{level 1}} > S_{\text{level 2}} > S_{\text{level 5}} > S_{\text{level 4}} > S_{\text{level 3}}$. The order of Shannon-Wiener Index is $SW_{\text{level 1}} > SW_{\text{level 2}} > SW_{\text{level 5}} = SW_{\text{level 4}} > SW_{\text{level 3}}$. The order of the Pielou Index is $P_{\text{level 1}} > P_{\text{level 5}} > P_{\text{level 2}} > P_{\text{level 3}} > P_{\text{level 4}}$. The Margalef Index has the smallest value in the level 1 area of the *HVPSI* and the largest value in the level 3 area of the *HVPSI*; the order is $M_{\text{level 3}} > M_{\text{level 4}} > M_{\text{level 5}} > M_{\text{level 2}} > M_{\text{level 1}}$ (Table 6).

Table 6. Species diversity of plant communities in different zones of the *HVPSI*.

Species Diversity	Level 1	Level 2	Level 3	Level 4	Level 5
Simpon index	0.31 ± 0.02	0.39 ± 0.12	0.68 ± 0.09	0.63 ± 0.15	0.58 ± 0.29
Shannon-Wiener index	0.2 ± 0.01	0.28 ± 0.07	0.54 ± 0.09	0.5 ± 0.12	0.5 ± 0.26
Pielou index	0.32 ± 0.07	0.48 ± 0.06	0.41 ± 0.09	0.34 ± 0.05	0.53 ± 0.26
Margalef index	0.48 ± 0.08	0.51 ± 0.2	0.75 ± 0.07	0.68 ± 0.11	0.56 ± 0.25

NDS	0.07 ± 0.05	0.27 ± 0.15	0.24 ± 0.06	0.24 ± 0.04	0.23 ± 0.15
NPDS	0.06 ± 0.05	0.08 ± 0.04	0.09 ± 0.03	0.25 ± 0.1	0.06 ± 0.01
AHDS	0.62 ± 0.19	0.27 ± 0.08	0.26 ± 0.04	0.05 ± 0.01	0.01 ± 0.01
TCDS	0.65 ± 0.02	0.75 ± 0.11	0.96 ± 0.02	0.65 ± 0.06	0.41 ± 0.3

Notes: According to the distribution values of the *HVPSI*, Level 1 areas (0–0.3) needs a little protection, level 2 areas (0.3–0.5) need light protection, level 3 areas (0.5–0.6) needs moderate protection, level 4 areas (0.6–0.7) need strong protection and level 5 areas (0.7–1) need very strong protection. Number of dominant species (NDS), number of plants of dominant species (NPDS), average height of dominant species (AHDS), total coverage of dominant species (TCDS).

There are also differences in the number of dominant species (NDS), number of plants of dominant species (NPDS), average height of dominant species (AHDS), total coverage of dominant species (TCDS) within each sub-region of the *HVPSI*. For the NPDS, the level 4 area of the *HVPSI* is significantly higher than in other areas and the number of plants in other areas is smaller, all less than 0.1. The AHDS differed greatly among the values in each zone of the *HVPSI*. The highest value of the AHDS is 0.62, which is distributed in the level 1 area of the *HVPSI*, followed by the level 2 area, with a value of 0.27. The AHDS of level 4 is 0.05 and of level 5 is 0.01. Comparing this to the other indices, the value of total coverage is the largest; the order of the levels is: level 3 > level 2 > level 4 = level 2 > level 5.

3.3. Relationship Between OUV Conservation Index and Plant Community Diversity

According to the results of Table 7, the value of the goodness-of-fit and the LogL are higher than the value of the OLS regression model, after considering the spatial dependence on the OUV conservation index. The SLM models were applied to *HVPSI*, *HI*, *VI* and *DI* to analyze the relationship between the OUV conservation index and the plant community, while the SEM model was applied to the *SI*. The regression coefficient also reflects the relationship between the diversity of community characteristics and the importance, integrity, vulnerability and the damage of heritage value protection.

For the regression results of the relationship between the *HVPSI* and plant community diversity, the significance value is smaller than 0.1 for the Simpson Index, Shannon-Wiener Index and Pielou Index. The values of all of them passed the significance test, showing that the above factors are the main driving factors for the importance of heritage value protection in the study area. Among these factors, the coefficients of the Shannon-Wiener Index and the Pielou Index are positive and the coefficients of the Simpson Index and the AHDS are negative. The positive coefficient signifies that an increase in the Shannon-Wiener Index or Pielou Index results in an increase in the value of the *HVPSI*. If either the Shannon-Wiener Index or the Pielou Index increases by 1%, the value of the *HVPSI* will increase by 1.50% or 0.35%, respectively.

For the regression of *HI* and plant community diversity, the value of the Simpson Index, the Shannon-Wiener Index, the Pielou Index, the NPDS and the AHDS pass the significance test. This explains that these factors have played important role in the integrity of the heritage value of the study area. For the *VI*, the value of the Pielou Index and TCDS pass the significance test, wherein the coefficient of TCDS is significantly positive. For the *SI*, the Margalef Index and the NPDS are the driving factors of heritage value sensitivity in the study area. For the *DI*, the coefficient of the Margalef Index is significantly positive, signifying that an increase of 1% in the Margalef Index results in an increase of 0.63% in the *DI*.

Table 7. Regression results of OUV conservation index and plant community diversity of Bogda [1].

	HVPSI			*HI*			*VI*			*SI*			*DI*		
	CLM	**SLM**	**SEM**	**CLM**	**SLM**	**SEM**	**CLM**	**SLM**	**SEM**	**CLM**	**SLM**	**SEM**	**CLM**	**SLM**	**SEM**
Constant	0.495 ***	0.137 **	0.548 ***	0.993 ***	0.778 ***	0.929 ***	0.304	−0.032	0.566	0.140	0.067	0.255 *	0.138	-0.118	−0.098
Simpon index	−1.584	−1.428 ***	−1.276 ***	−6.635 **	−6.697 ***	−5.813 ***	3.652	1.534	0.502	0.178	−0.080	−0.786	0.979	0.500	−0.273
Shannon-Wiener index	1.773	1.499 ***	−5.102 ***	6.186 **	6.353 ***	5.505 ***	−2.927	−0.974	−0.120	−0.686	−0.458	0.185	−1.549	−1.346	−0.772
Pielou index	0.513	0.346 **	0.317 **	1.526	1.473 **	1.164 **	−1.597	−0.769 *	−0.336	0.036	0.173	0.372	−0.063	0.519	1.150 **
Margalef index	−0.347	−0.027	0.039	−0.075	−0.080	0.124	0.569	0.248	0.036	0.704 **	0.636 ***	0.609 ***	0.986	0.627 *	0.249
NDS	0.345	−0.173	−0.216 *	−0.731	−0.779	−0.893 *	−0.345	−0.384	−0.144	−0.288	−0.249	−0.333	−0.925	−0.259	0.298
NPDS	−0.020	0.007	0.022	−0.470	−0.471 *	−0.422 *	−0.073	−0.181	−0.159	0.063	0.063	0.026	0.185	0.239	0.366 *
AHDS	−0.146	−0.095*	−0.076	−0.394	−0.445 **	−0.498 ***	−0.294	−0.116	−0.040	−0.254	−0.230 *	−0.196 *	−0.299	−0.236	−0.061
TCDS	−0.118	−0.035	−0.024	−0.167	−0.087	−0.019	0.689	0.310 ***	0.127	0.109	0.024	−0.059	0.153	−0.022	−0.161
ϱ/λ	-	0.804	0.892	-	0.444	0.518	-	0.838	0.865	-	0.492	0.612	-	0.651	0.769
LogL	20.423	37.78	34.930	6.776	9.107	9.214	−1.831	15.6459	13.402	17.130	20.071	20.803	1.437	6.459	8.908
R^2	0.626	0.939	0.934	0.464	0.589	0.603	0.267	0.888	0.870	0.363	0.544	0.595	0.222	0.572	0.688
LMLAG	17.899 ***	-	-	5.071 ***	-	-	24.8916 ***	-	-	6.275 **	-	-	8.994 ***	-	-
R-LMLAG	18.772 ***	-	-	1.295	-	-	18.4914 ***	-	-	2.561	-	-	3.749 *	-	-
LMERR	2.983 **	-	-	3.810 *	-	-	12.1336 ***	-	-	4.095 **	-	-	6.452	-	-
R-LMERR	3.855 **	-	-	0.033	-	-	5.7334 **	-	-	0.381	-	-	1.207	-	-

[1] Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Classical Linear Regression Model (CLM), Spatial lag model (SLM), Spatial error model (SEM), ϱ/λ is the Spatial lag parameter, LogL is the Log likelihood, R^2 is goodness-of-fit, Lagrange multiplier test of spatial lag model (LMLAG), Robust Lagrange multiplier test of spatial lag model (R-LMLAG), Lagrange multiplier test of spatial error model (LMERR), Robust Lagrange multiplier test of spatial error model (R-LMERR). Heritage Value Protection Significance Index

(*HVSPI*), Integrity (*HI*), Vulnerability (*VI*), Sensitivity (*SI*), Degree of interference (*DI*). Number of dominant species (NDS), number of plants of dominant species (NPDS), average height of dominant species (AHDS), total coverage of dominant species (TCDS).

4. Discussion

4.1. Indicators of the OUV Conservation Index

The use of the proposed model provides objective results in the process of determining a heritage site's value and the level of protection it needs [46,77]. To determine the index weight, the entropy weight method is selected. This method is not affected by subjective factors and is well organized, which can deeply reflect the utility value of the index information entropy value [46]. In addition to allowing for high credibility and precision, the weights obtained by the entropy weight method are in good agreement with the actual situation in the study area. Therefore, the magnitude of the weight of each indicator reflects the importance of the protection of the heritage sits' value [14,48,55].

4.2. Space Zoning Verification of HVPSI and Screening of Characterisation Elements in the Zone

In view of the protection objectives of the OUV elements, this study focused on the calculation of the *HVPSI* to assess heritage value and perform a spatial division according to the value of the *HVPSI*. Existing research has asserted that the spatial zoning of heritage sites is an important measure towards achieving conservation management; such spatial zoning can reflect the heterogeneity of landscapes at different temporal and spatial scales, achieve multi-level zoning of protection functions and provide scientific evidence for decision makers to conduct comprehensive management of WNHS [12,26,44].

Here, the resulting OUV conservation indices show differences across their spatial divisions. These are outlined in the following five points:

1. The level 5 areas of *HVPSI* and *HI* are uniformly distributed in space. There is a positively correlated spatial agglomeration in the H-H, which is mainly distributed in the southern IZ. The area is dominated by glaciers, which completely preserves the Quaternary glacial and moraine landform type [14]. It has been thought that the mountain glaciers were the material basis and characteristic cultural foundation for the ecological environment and sustainable socio-economic development of the arid regions, which has unique and irreplaceable ecological service functions [78]. The assessment results of this sub-area are consistent with previous research on the importance of glacier values, as well as with the results of the IUCN experts' assessment of the value of the region's heritage. Therefore, in view of the above-mentioned zoning and determination of value elements, the glaciers in the study area should be strictly protected; for the subsequent heritage protection processes, glaciers should be maintained in their original natural state such that the original ecological environment is not disturbed by humans [79].
2. The level 4 area of the *HVPSI* is dominated by alpine mat vegetation, which is distributed in the buffer zone around the H-H. The region includes a climbing base camp area, ice dammed lake and the area that the glacial snow has degraded into areas of alpine meadows, alpine grasslands, bare land and sparse grassland in the period between 1990 and 2015. In the field survey, many plant species were found in the area, contained in the families of Compositae, Ranunculaceae and Rosaceae. The region is rich in species diversity (the values of the Simpson Index and Margalef Index are high). Many rare, endangered and endemic species of animals and plants are distributed in this area, such as *Myosotis alpestris* (Near Threatened, NT), the *snow leopard (Panthera uncia)* (Endangered, EN) and the *ibex (Capra ibex)* (Least Concern, LC) on the IUCN Red List of Threatened Species, *Saussurea involucrata* on the Xinjiang Uygur Autonomous Region key protected wild plants list and *Oxytropis bogdoschanica* on the list of endemic plants in Bogda. The species diversity and distribution of rare, endangered and endemic species of animals and plants embody the ecological value of WNHSs. The field survey of plant species verified that the division of the area was more reasonable; from these results, key areas needing protection were identified. Therefore, it is necessary to demarcate the partition and screen the important key species within the partition. This study is the basis for research work on the number of important

key species, habitats, migration routes and the impact of human activities in the vertical natural zone [24,27,79].

3. The level 3 area is the area spanning the largest geographical space among the five partitions of the *HVPSI*. This area intersects with the level 5 area of the *VI*, *SI* and *DI*, spanning six natural vertical zones. The main natural vertical zone in the area is the MSZ, mainly comprised of *Picea schrenkiana*, Tianchi Lake and nearby resource points. In the field research, many plant species were found in the area, including 16 species and 10 families. The region is rich in species diversity (the values of the Simpson index and Margalef index are high). Additionally, rare and endangered endemic species are more distributed in this region than in the others, including *Betula tianschanica* (EN), *Larix sibirica* (LC), *Juniperus pseudosabina* (LC), *Picea schrenkiana* (LC) and so forth. Of the flora and fauna listed in the IUCN Protection List, CITES List and National Key Protected Areas list, 92.7% are located in this area. At the same time, the Tianchi Sigong River Basin in this region is an area prone to landslides and debris flow during natural disasters and the Tianchi Scenic Area is a concentrated area of tourism activities [55,80,81]. Thus, natural and human activities strongly impact on this area; therefore, protection is important for the conservation of *Picea schrenkiana*, *Capreolus* and *Cervus elaphus tianshanicus*. During the tourist and fire-prone seasons, high-frequency patrols of spruce forests should be conducted to control the scope of tourist visits and to thus minimize human and natural interference within the area. Additionally, to prevent forest fires, real-time monitoring and video surveillance of the tourist area and surrounding district should be undertaken [80]. Even when activities such as eco-tourism and popular science education are conducted in some of these areas, measures must be taken to ensure that the originality and integrity of the site must be maintained [48].
4. The level 2 area of the *HVPSI* is distributed in the MSZ and the MCZ in the northern parts of the study area. In this area, the landscape type of temperate grassland has degraded into dry land in the period between 1990 and 2015. Also, this region contains temperate cluster grasses typical grassland, dwarf semi-shrub desert grasslands and areas with endangered and endemic species. In the field survey, the greatest number of plant species were found here, including 21 species from 14 families; these mainly involved Leguminosae, Gramineae and Rosaceae, which are rich in species diversity (the values of the Pielou Index and Margalef Index are high). In the process of protecting heritage, rare and endangered endemic species in the area should be targeted protection. The entry of invasive alien species should be prevented and the native ecological environment of the protected area should be conserved to maintain the originality of the OUV.
5. The level 1 area of the *HVPSI* is concentrated in the areas where the herdsmen live in the north of the study area (including Shirengou Village and Sangonghe Kazak Township). The distribution of this area shows spatial agglomeration, where the temperate grassland has degraded into a mining area and a dry land and a sparse grassland has degraded into a dryland in the period between 1990 and 2015. The region is mainly distributed in the TDZ and the MSZ, with low vegetation coverage, low community structure and poor soil. In the field survey, the number of species in this area is less than other areas; the species are dominated by the TDZ's *Caragana soongorica*, *Seriphidium borotalense*, *Ceratoides latens* and so forth [47]. The ecological environment is relatively fragile as there is some human disturbance in this area. Additionally, the original residents of the heritage site live here. Therefore, a reasonable protection of original residents should be allowed and the necessary tourist service facilities and protection facilities should be installed. However, in the process of conducting targeted heritage protection, such installations must not interfere with the ecological environment of the WNHS [82].

4.3. Limitations and Prospects of This Study

This study verifies the rationality of spatial zoning through the research results of the field survey and combines them to identify the important protective elements of the OUV. The data from the field survey directly reflects the characteristics of plant species in the area and indirectly reflects the characteristics of animal distribution in the area and the characteristics of the natural vertical zones in the area[22,75]. Because of the relative inaccessibility of the study area, 51 sample plots were surveyed. The sample size is relatively small compared to the size of the study area, such that the characteristics of the area may not be sufficiently reflected. Therefore, to address this shortcoming, the authors will continue to conduct in-depth research on the specific value elements of the heritage site, the temporal and spatial evolution characteristics of the natural vertical zones and the important species diversity within the zone.

5. Conclusions

This study considered the Bogda heritage site as the research object with the aim of evaluating and the aesthetic and bioecological value elements. From the five aspects of integrity, vulnerability, sensitivity, degree of interference and environmental factors, 17 indicators were selected to build the *HVPSI* and the related *HVIs*. We applied the spatial autocorrelation analysis method to the protection indices to comprehensively measure the spatial pattern characteristics of the OUV conservation index and to divide the spatial space of the *HVPSI*. Through the result of the community composition and diversity characteristics in the field survey, the rationality of the spatial division of the heritage site is verified. To identify the elements of OUV, we explored the relationship between the OUV conservation index and community characteristics with the spatial econometric model.

The order of weighting (W) for the OUV conservation indices is: $W_{\text{Tourist Recreation Space}} > W_{\text{Natural Disaster Occurrence Area}} > W_{\text{Road Density}} > W_{\text{Degree of Landscape Beauty}} > W_{\text{Degradation of Landscape Type}} > W_{\text{Landscape Fragmentation}} > W_{\text{Theoretical Carrying Capacity}} > W_{\text{Endemic Diversity}} > W_{\text{Landscape Type Function Dominance}} > W_{\text{Degree of Protection for Endangered Species}} > W_{\text{Richness of Community Structure}} > W_{\text{Altitude}} > W_{\text{Temperature}} > W_{\text{Slope}} > W_{\text{Soil Type}} > W_{\text{Precipitation}} > W_{\text{NDVI}}$. The order of the value of the related *HVI* is $W_{DI} > W_{HI} > W_{SI} > W_{VI} > W_{EI}$. The spatial distribution of the *HVPSI* generally increased from north to south. The area of level 4 is the largest. The distribution space of integrity is consistent with *HVPSI*, the level 4 area of vulnerability is the largest and the level 5 area of sensitivity and interference are the largest. Among the Moran's I values, the Moran's I value of *HVPSI* is the largest (0.894) and the order of the indices: *HVPSI* > *VI* > *SI* > *DI* > *HI*. Moreover, there is a positive spatial correlation model that the values of indices are clustered in the high value area and the low value area. Along with the spatial division of the *HVPSI*, there were differences in the composition of plant communities and the importance values of species in different protected zones. The number of dominant species in the level 2 area was the largest, followed by the level 3 and level 4 areas and then the level 1 had the lowest number of dominant species. Variations of the Simpson Index and the Shannon-Wiener Index are consistent in the different protected zones. The largest value of both indices corresponds to the level 3 area of the *HVPSI* and the smallest value to the level 1 area of the *HVPSI*.

In the process of research on the value protection of WNHSs, scholars have conducted related research on the aspects of integrity, originality and influencing factors; however, the definition of the conservation of OUV for WNHSs is yet to be formed as a recognized standard. Thus, based on the available data, this study comprehensively considers the characteristics of the natural heritage value elements by selecting 17 indicators; to a certain extent, this satisfies the requirements of constructing an *HVI* on a regional scale. This study has a good reference value in line with local and actual conditions. Therefore, this research has a certain objectivity and scientific authenticity. The results of this study can be applied to the protection and management of the heritage sites, as well as to the identification of important value elements of OUV; this can be used in the protection, patrol and monitoring of forestry. This study provides a scientific basis for management decision makers to develop future protection and management measures.

Author Contributions: writing—original draft, H.S.; investigation, T.S.; designer of research frame and data acquisition, F.H.; methodology, Q.L.; software, Z.H.; writing—review & editing, H.Z.;

Funding: This research was funded by the Provincial Natural Science Foundation of Xinjiang Uyghur autonomous region (No. 2019D01A96), National Natural Science Foundation of China (No. 41661039) and National Natural Science Foundation of China (No. 41971192).

Acknowledgments: The authors wish to express gratitude to Yayan Lu and Jianwei Qi. They provided great help in the process of data collection in the field survey.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. All of the acronyms used in this paper are listed in the table.

Acronyms	Full Name
OUV	Outstanding Universal Value
WNHS	World Natural Heritage Site
UNESCO	United Nations Educational, Scientific and Cultural Organization
HVPSI	Heritage Value Protection Significance Index
HVI	Heritage Value Protection Index
IUCN/SSC	International Union for the Conservation of Nature Species Survival Commission
TDZ	Temperate Desert Zone
MSZ	Mountain Steppe Zone
MCZ	Montane Conifer-forest Zone
SMZ	Sub-alpine Meadow Zone
AMZ	Alpine Meadow Zone
ACVZ	Alpine Cushion Vegetation Zone
IZ	Ice-snow Zone
DEM	Digital Evaluation Model
NDVI	Normalized Difference Vegetation Index
HI	Index of Integrity
VI	Index of Vulnerability
SI	Index of Sensitivity
DI	Index of Degree of interference
EI	Index of Environmental Factor
SBE	Scenic Beauty Estimation method
DLT	Degree of Degradation of Landscape Type
ESDA	Exploratory Spatial Data Analysis
Moran's I	Global Spatial Autocorrelation Index
LISA	Local Indicators of Spatial Autocorrelation
SLM	Spatial Lag Model
SEM	Spatial Error Model
OLS	Ordinary Least Squares
IV	Importance Value

References

1. WHC. *World Heritage and Sustainable Development. Decision 20 ga 13 of the 20th Session of the General Assembly of States Parties to the Convention Concerning the Protection of the World Cultural and Natural Heritage*; UNESCO: Paris, France, 2015.
2. UNESCO. *Convention Concerning the Protection of the World Cultural and Natural Heritage. Adopted by the General Conference at Its Seventeenth Session in Paris, 16th November 1972*; UNESCO: Paris, France, 1972.
3. UNESCO. *Operational Guidelines for the Implementation of the World Heritage Convention*; UNESCO: Paris, France, 2015.

4. Mitchell, N.; Leitão, L.; Migon, P.; Denyer, S. *Study on the Application of Criterion VII: Considering Superlative Natural Phenomena and Exceptional Natural Beauty within the World Heritage Convention*; IUCN: Gland, Switzerland, 2013; pp. 113–115.
5. Su, Y.; Lin, H. Analysis of international tourist arrivals worldwide: The role of world heritage sites. *Tour. Manag.* **2014**, *40*, 46–58.
6. Zhang, Z.; Xiong, K.; Xiao, S.; Ying, B. Study on temporal-spatial distribution and inscription criteria of global World Heritage. *World Reg. Stud.* **2017**, *26*, 152–168.
7. Huo, S.; Fan, W.; Sun, K. Study on the value and sustainable development of World Natural Heritage. *J. Anhui Agric. Sci.* **2011**, *39*, 17995–17998.
8. Wu, L. Authenticity, integrity, and the protection of Taishan World Heritage resources. *Soc. Sci.* **2009**,*144*, 100–103.
9. Yuan, Z. Discussion on the Countermeasures to maintain the authenticity and completeness of World Natural Heritage: A case study of wulingyuan. *CPA Chin. Public Adm.* **2006**, *249*, 73–75.
10. Zhang, Y.; Min, Q.; Jian,W.; Liu, M. Values and conservation of honghe hani rice terraces system as a GIAHS site. *J. Resour. Ecol.* **2016**, *7*, 197–204.
11. Chen, P.; Xiong, K.; Xiao, S. Global comparative analysis on the world natural heritage values of Libo cone karst in China. *Geogr. Res.* **2013**, *32*, 1517–1527.
12. Hazen, H. Of outstanding universal value: The challenge of scale in applying the World Heritage Convention at national parks in the US. *Geoforum* **2008**, *39*, 252–264.
13. Nian, S.; Zhang, H.; Mao, L.; Zhao, W.; Zhang, H.; Lu, Y.; Zhang, Y.; Xu, Y. How outstanding universal value, service quality and place attachment influences tourist intention towards world heritage conservation: A case study of Mount Sanqingshan National Park, China. *Sustainability* **2019,** *11*, 3321.
14. Xu, X.; Yang, Z. Saiken, A.; Shao, R.; Liu, X. Natural heritage value of Xinjiang Tianshan and global comparative analysis. *J. Mt. Sci.* **2012**, *9*, 262–273.
15. Ha, S.; Yang, Z. Evaluation for landscape aesthetic value of the Natural World Heritage Site. *Environ. Monit. Assess.* **2019**, *191*, 483-502.
16. Zhong, Y.; Xiong, K.; Du, F. Landscape aesthetic value of Nominaten Huanjiang Karst World Heritage and its comparative analysis based on World Heritage Criteria (vii). *J. Kunming Univ. Sci. Technol. (Nat. Sci. Edution)* **2014**, *39*, 25–32.
17. Han, X.; Liu, C.; Hu, J.; Wang, X.; Luo, L.; Zhao, Y.; Li, L.; Ji, X.; Yan, H.; Wang, Y. Dynamic evolution of landscape pattern and ecological health assessment of Tianshan Natural Heritage Site in Xinjiang. *Arid Land Geogr.* **2019**, *42*, 195–205.
18. Li, W.; Xiong, K.; Zhou, W. Aesthetic characters and world heritage value of Shibing karst landscape in Southeast Guizhou. *J. Guizhou Norm. Univ. (Nat. Sci.)* **2010**, *28*, 19–22.
19. Zhou, Q.; Fang, H.; Su, W. Evaluation of ecotourism suitability for the Western Sichuan Plateau based on GIS and the artificial neural network. *Resour. Sci.* **2010**, *32*, 2384–2390.
20. Bi, X.; Han, F. Overview of identification and evaluation of aesthetic values of World Natural Heritage. *Landsc. Archit.* **2018**, *25*, 115–119.
21. Liu, Q.; Yang, Z.; Shi, H.; Wang, Z. Ecological risk assessment of geohazards in Natural World Heritage Sites: An empirical analysis of Bogda, Tianshan. *Open Geosci.* **2019**, *11*, 327–340.
22. Yao, X.; Du, Y.; Hao, G.; Ping, X.; Hu, J.; Hao, J. Outstanding universal value of plant diversity and conservation in Emeishan World Heritage Site. *Guihaia* **2018**, *38*, 1605–1613.
23. Alves, R.J.V.; Weksler, M.; Oliveira, J.A.; Buckup, P.A.; Pombal, J.P.; Jr.; Santana, H.R.G.; Peracchi, A.L.; Kellner, A.W.A.; Aleixo, A.; Bonino, A.R.L.; et al. Brazilian legislation on genetic heritage harms Biodiversity Convention goals and threatens basic biology research and education. *An. Da Acad. Bras. De Cienc.* **2018**, *90*, 1279–1284.
24. Xie, Z.; Shen, G.; Zhou, Y.; Fan, D.; Xu, W.; Gao, X.; Du, Y.; Xiong, G.; Zhao, C.; Zhu, Y.; et al. The outstanding universal value and conservation of the Shennongjia World Natural Heritage Site. *Biodivers. Sci.* **2017**, *25*, 490–497.
25. Ma, M.; Shen, G.; Xiong, G.; Zhao, C.; Xu, W.; Zhou, Y.; Xie, Z. Characteristic and representativeness of the vertical vegetation zonation along the altitudinal gradient in Shennongjia Natural Heritage. *Chin. J. Plant Ecol.* **2017**, *41*, 1127–1139.
26. Ding, C. Comparative research on the proportion and combination sorts of adopted criterions of World Heritage between the globe and China. *Acta Sci. Nat. Univ. Pekin.* **2006**, *42*, 231–237.

27. Wang, Y.; Yao, S.; Deng, Y. Spatio-temporal pattern evolution and influencing factors of governance efficiency of soil and water loss in theWeihe River Catchment. *Sci. Geogr. Sin.* **2019,** *39*, 836–846.
28. Dong, S.; Wu, Y.; Liu, S.; Su, X.; Zhao, H.; Zhang, Y. Evaluation on grassland eco-security of the Altun Mountain National Nature Reserve. *Acta Agrestia Sin.* **2016,** *24*, 906–909.
29. Shi, H.; Shi, T.; Yang, Z.; Wang, Z.; Han, F.; Wang, C. Effect of roads on ecological corridors used for Wildlife movement in a natural heritage Site. *Sustainability* **2018,** *10*, 2725.
30. Nicu, I.C.; Romanescu, G. Effect of natural risk factors upon the evolution of Chalcolithic human settlements in Northeastern Romania (Valea Oii watershed). From ancient times dynamics to present days degradation. *Z. Fur Geomorphol.* **2016,** *60*, 1–9.
31. Allan, J.R.; Venter, O.; Maxwell, S.; Bertzky, B.; Jones, K.; Shi, Y.; Watson, J.E.M. Recent increases in human pressure and forest loss threaten many Natural World Heritage Sites. *Biol. Conserv.* **2017,** *206*, 47–55.
32. Bailey, K.M.; McCleery, R.A.; Binford, M.W.; Zweig, C. Land-cover change within and around protected areas in a biodiversity hotspot. *J. Land Use Sci.* **2016,** *11*, 154–176.
33. Heino, M.; Kummu, M.; Makkonen, M.; Mulligan, M.; Verburg, P.H.; Jalava, M.; Rasanen, T.A. Forest loss in protected areas and intact forest landscapes: A Global Analysis. *PLoS ONE* **2015,** *10*, e0138918.
34. Hu, X.; Hu, K.; Zhang, X.; Wei, L.; Tang, J. Quantitative assessment of the impact of earthquake-induced geohazards on natural landscapes in Jiuzhaigou Valley. *J. Mt. Sci.* **2019,** *16*, 441–452.
35. Zhang, X. Research on outstanding universal value and the analysis method of heritage assessment: The Grand Canal as an example. *Sci. Conserv. Archaeol.* **2009,** *21*, 1–8.
36. Li, Z.; Liu, L.; Sun, Y.; Cui, J. Assessment method of regional ecological security based on Pressure-State-Response model. *Acta Ecol. Sin.* **2010,** *30*, 6495–6503.
37. Chen, Z.; Guo, L.; Xue, D. GIS-based ecological sensitivity analysis in Xin County. *Ecol. Sci.* **2015,** *34*, 97–102.
38. Zhu, Q.; Zhou, W.M.; Jia, X.; Zhou, L.; Yu, D.P.; Dai, L.M. Ecological vulnerability assessment on Changbai Mountain National Nature Reserve and its surrounding areas, Northeast China. *Ying Yong Sheng Tai Xue Bao* **2019,** *30*, 1633–1641.
39. Xu, W.; Yang, Y.; Zhang, L.; Xiao, Y.; Wang, X.; Ouyang, Z. Evaluation methods and case study of regional ecological carrying capacity for early-warning. *Prog. Geogr.* **2017,** *36*, 306–312.
40. Pan, J.; Liu, X. Landscape ecological risk assessment and landscape security pattern optimization in Shule River Basin. *Chin. J. Ecol.* **2016,** *35*, 791–799.
41. You, W.-B.; He, D.-J.; Qin, D.-H.; Ji, Z.-R.; Wu, L.-Y.; Yu, J.-A.; Chen, B.-R.; Tan, Y. System construction of early warning for ecological security at cultural and natural heritage mixed sites and its application: A case study of Wuyishan Scenery District. *Ying Yong Sheng Tai Xue Bao* **2014**, *25*, 1455–1467.
42. Ma, X.; Lu, Z.; Lin, T. Ecological risk assessment of Yancheng Coastal Wetland. *Mar. Environ. Sci.* **2010,** *29*, 599–602.
43. Wu, Y.; Deng, N. Resource-based urban ecological security early warning based on RBF Neural Network Model: A case study of Yulin city. *Ecol. Econ.* **2019,** *35*, 111–118.
44. Wang, Z.; Du, X. Monitoring Natural World Heritage Sites: Optimization of the monitoring system in Bogda with GIS-based multi-criteria decision analysis. *Environ. Monit. Assess.* **2016,** *188*, 384-401.
45. Ai, Y.; Zhu, H.; Tan, X. Evaluation and prediction of urban ecological security of Changsha based on ＲS /GIS and GM (1, 1) Model. *Acta Agric. Jiangxi* **2019,** *31*, 131–137.
46. Pang, Y.; Wang, L. A review of regional ecological security evaluation. *China Popul. Resour. Environ.* **2014,** *24*, 340–344.
47. Lv, Y.; Xiong, K.; Rong, L.; Chen, H.; Gao, Y.; Ying, B. Comparative analysis of world heritage values on biological and ecological evolution in Fanjingshan Mountain. *World Reg. Stud.* **2016,** *25*, 131-141.
48. Shi, H.; Yang, Z.; Han, F.; Shi, T.; Luan, F. Characteristics of temporal-spatial differences in landscape ecological security and the driving mechanism in Tianchi scenic zone of Xinjiang. *Prog. Geogr.* **2013**, *32*, 475–485.
49. Gulijiang, H.; Liang, Y. Countermeasures for forest fire prevention and control in Bogda Peak Nature Reserve, Tianchi, Xinjiang. Available online: https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFQ&dbname=CJFDLAST2019&filename=SLFH201902004&v=MTgwMTFNclk5RllJUjhlWDFMdXhZUzdEaDFUM3FUcldNMUZyQ1VSTE9lWitScUZ5N25VTHpKTmlITlpyRzRIOWo= (accessed on 25 October 2019).

50. Tumur, A.; Mamut, R.; Abbas, A. Community structure characteristics of saxicolous lichens in the Bogda Mountains of Xinjiang, China. *Acta Ecol. Sin.* **2018,** *38*, 1053–1064.
51. Ji, X.; Luo, L.; Wang, X.; Li, L.; Wan, H. Identification and change analysis of Mountain Altitudinal Zone in Tianshan Bogda Natural Heritage Site based on DEM-NDVI-land cover classification. *J. Geo Inf. Sci.* **2018,** *20*, 1350–1360.
52. Wang, P.; Li, Z.; Li, H.; Wu, L.; Jin, S.; Zhou, P. Changes of ice-thickness and volume for representative glaciers in Tianshan Mountains in the past 50 years. *Acta Geogr. Sin.* **2012**, *67*, 929–940.
53. Yu, Y.; He, B.; Estimation of the non- tratable value of Xinjang Tianchi wetland ecosystem service function bassced on the CVM. *J. Arid Land Resour. Environ.* **2012**, *26*, 53–58.
54. Zheng, Y.; Sun, W.; Guo, X.; Liang, T.; Gao, J.; Zhou, R. Structural characteristic and orogenic mechanism of Bogeda Tectonic Belt, Xinjiang. *J. East. China Univ. Technol. (Nat. Sci.)* **2014**, *37*, 199–206.
55. Li, D.; You, Y.; Luan, F.; Chen, X. A research of tourism landscape resources evaluation and protection for Bogda World Natural Heritage Site. *World Reg. Stud.* **2015**, *24*, 159–167.
56. Wang, X.; Yu, S.; Tang, D. The heritage value of mountain vertical zonation in Temperate Desert Region of China. *Arid Zone Res.* **2009**, *26*, 694–701.
57. Ji, X. Fine Extraction and Change Analysis of Mountain Altitudinal Zone on the Northern Slope of Tianshan Bogda. Master's Thesis, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing, China, 2018.
58. Geldmann, J.; Joppa, L.N.; Burgess, N.D. Mapping change in human pressure globally on land and within protected AREAS. *Conserv. Biol.* **2014,** *28*, 1604–1616.
59. Han, F.; Yang, Z.; Liu, X.; Di, F. Impact assessment and protection of outstanding landscape integrity in a Natural Heritage Site: Fairy Valley, Kanas Nature Reserve, Xinjiang, China. *J. Mt. Sci.* **2011,** *8*, 46–52.
60. Han, F.; Yang, Z.; Shi, H.; Liu, Q.; Wall, G. How to promote sustainable relationships between heritage conservation and community, based on a Survey. *Sustainability* **2016,** *8*, 886.
61. Zhang, L.; Wu, B.; Yin, K.; Li, X.; Kia, K.; Zhu, L. Impacts of human activities on the evolution of estuarine wetland in the Yangtze Delta from 2000 to 2010. *Environ. Earth Sci.* **2015,** *73*, 435–447.
62. Mohamed, S.A.; El-Raey, M.E. Land cover classification and change detection analysis of Qaroun and Wadi El-Rayyan lakes using multi-temporal remotely sensed imagery. *Environ. Monit. Assess.* **2019,** *191*, 229.
63. Xu, W.; Tian, Y.; Liu, Y.; Zhao, B.; Liu, Y.; Zhang, X. Understanding the spatial-temporal patterns and influential factors on air quality Index: The case of North China. *Int. J. Environ. Res. Public Health* **2019,** *16*, 2820.
64. DeFries, R.; Hansen, A.; Newton, A.C.; Hansen, M.C. Increasing isolation of protected areas in tropical forests over the past twenty years. *Ecol. Appl.* **2005,** *15*, 19–26.
65. Shi, H.; Yang, Z.; Han, F.; Luan, F.; Shi, T.; Assessment and analysis of eco-environment vulnerability in Tomur region of natural heritage site. *Arid Land Geogr.* **2013,** *36*, 318–328.
66. Xiao-Long, S.; Xiao-Wen, L.I.; Jun-Hong, B.A.I.; Cong, L.I.; Yu, Z.; Song-Song, J. The ecological sensitivity evaluation in Yellow River Delta National Natural Reserve. *Acta Ecol. Sin.* **2009**, *29*, 4836–4846.
67. Shi, H.; Yang, Z.; Han, F.; Shi, T.; Wang, Z. Analysis of ecological risk temporal-spatial change in Arid Alpine Wetland—A case study of Bayanbulak World Natural Heritage Site. *Arid Zone Res.* **2015,** *32*, 614–621.
68. Liao, S.; Qin, Y. A spatialization method for survey data of theoretical stock-carrying capacity of grassland in China and its application. *Geogr. Res.* **2014**, *33*, 179–190.
69. Xu, M.; He, J. A review of grassland carrying capacity: Definition, theoretical consideration and model. *Acta Prataculturae Sin.* **2014**, *23*, 313–324.
70. Mellino, S.; Buonocore, E.; Ulgiati, S. The worth of land use: A GIS-emergy evaluation of natural and human-made capital. *Sci. Total Environ.* **2015,** *506*, 137–148.
71. Li, H.; Wang, S.; Wang, W.; Duan, Q.; Li, G. Three parallel rivers world natural heritage hongshan district ecological security assessment. In *Progress in Environmental Science and Engineering, Pts 1–4*; Xu, Q.J., Ju, Y.H., Ge, H.H., Eds.; Trans Tech Publications: Shanghai, China, 2013; Volume 610–613, pp 673.
72. Zhou, K.; Fan, J. Regional disparity of environmental pollution source and its socio-economic influencing factors: Based on the cross-section data of 339 cities at prefecture level or above in China. *Acta Geogr. Sin.* **2016,** *71*, 1911–1925.

73. Li, L.G.; Zhang, P.Y.; Liu, W.X.; Li, J.; Wang, L.F. Spatial-temporal evolution characteristics and influencing factors of county-scale environmental pollution in Jilin Province, Northeast China. *Ying Yong Sheng Tai Xue Bao J. Appl. Ecol.* **2019,** *30*, 2361–2370.
74. Anselin, L.; Bongiovanni; Lowenberg, D. A spatial econometric approach to the economics of site-specific nitrogen management in corn production. *Am. J. Agric. Econ.* **2005,** *87*, 261–261.
75. Yang, Y.; Jia, L.; Qiao, J.; Li, M.; Zhang, F.; Chen, D.; Zhang, H.; Zhao, M. Effect of mowing patterns on community characteristics and plant diversity in Stipa grandis Steppe. *Chin. J. Grassl.* **2019,** *41*, 38–44.
76. Sun, L.; Shi, C.; Zhao, T.; Li, D.; Lai, W.; Ding, W. Vegetation recovery in the landslide-tackling area of Wenchuan earthquake. *Sci. Soil Water Conserv.* **2015,** *13*, 86–92.
77. Guo, Y.; Yu, H. Application analysis of ecological sensitivity evaluation index system in urban plnning. *Environ. Sci. Manag.* **2016,** *41*, 23–27.
78. Zhang, Z.; He, X.; Liu, L.; Li, Z.; Wang, P. Ecological service functions and value estimation of glaciers in the Tianshan Mountains, China. *Acta Geogr. Sin.* **2018,** *73*, 856–867.
79. Conradin, K.; Hammer, T. Making the most of world natural heritage-linking conservation and sustainable regional development? *Sustainability* **2016,** *8*, 323.
80. Niu, S.; Liang, Y.; Zhang, S. Countermeasures for prevention and control of forest fires in Xinjiang Tianchi Nature Reserve after ban on grazing. Available online: https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFQ&dbname=CJFDLAST2015&filename=SLFH201501010&v=MjIyODdTN0RoMVQzcVRyV00xRnJDVVJMT2VaK1JxRnk3Z1U3N01OaUhOWnJHNEg5VE1ybzlFWklSOGVYMUx1eFk= (accessed on 25 October 2019).
81. Tang, X. Based on tourist satisfaction research in Xinjiang Tianchi Scenic Spot. Available online: http://www.wanfangdata.com.cn/details/detail.do?_type=perio&id=xjjyxyxb-skb200904028 (accessed on 25 October 2019).
82. Cetin, M.; Zeren, I.; Sevik, H.; Cakir, C.; Akpinar, H. A study on the determination of the natural park's sustainable tourism potential. *Environ. Monit. Assess.* **2018**, *190*, 167-190.