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Simulation of Human Activity Intensity and Its Influence on Mammal Diversity in Sanjiangyuan National Park, China

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Abstract: The rapid pace of development in western China has brought about inevitable concerns for environmental conditions and their management. The Sanjiangyuan National Park strives to address concerns for sustainable water resources management and biodiversity management, especially for the protection of endangered flora and fauna. In this study, a machine learning model (MaxEnt) was used to predict the human activity intensity and its effects on species in Sanjiangyuan protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The model used human settlements as input and datasets such as terrain factors, climate, and artificial structures as environmental factors. The results showed that human activity intensity was significantly different between the East and the West. The area with the highest human activity intensity was Yushu County in the south area, and Xinghai-Zeku County in the east. By comparing the mammal richness with human activity intensity, we found human–wildlife coexistence in Sanjiangyuan. A detailed analysis on the CITES protected species showed that many important species, such as snow leopards, red pandas, and small Indian civets, occupied areas with high human activity intensity. The national park protects 3/4 CITES species with 1/3 in the area of the Sanjiangyuan region, owing to the relatively low human activity intensity.

Keywords: biodiversity; human activity intensity; human–wildlife coexistence; MaxEnt; Sanjiangyuan National Park

1. Introduction

The extinction of mammals has become a global problem due to human activities [1,2]. Studies show that most areas of land and sea are affected by human activities [3,4]. With the rapid pace of development in western China, ecologists are becoming increasingly concerned with environmental conditions and their management. Now, the establishment of national park brings a sustainability focus to the Sanjiangyuan region.

Natural habitats have been increasingly affected due to human activity and other reasons. The distribution area of wild yak is shrinking to remote alpine regions from human settlements, in response to climate change and the intensifying of human activities on the Qinghai-Tibet Plateau [5]. The relationship between humans and wildlife is a complex issue involving many interacting and overlapping factors [6–8]. It is believed that artificial structures such as roads, fences, and agriculture lead to drastic changes in land cover and can destroy animal habitats [9–11]. Habitat modification, encroachment, and illegal harvesting also damages biodiversity and ecosystem stability [12,13].

Research has been conducted to comprehensively evaluate the influence of human activity [14–16]. Traditional methods are usually established from the perspective of land cover. With the development of Location Based Service (LBS), we are able to get accurate and integrated data of human settlements [17]. Human settlements have become the focus of numerous fields, including population geography, climatic change, and sustainability [18–20]. Because they are the most intensive area for daily human activities, they were used in evaluating the effects of human activities [21,22]. In this paper, we use settlements and the maximum entropy model (MaxEnt) to predict human activity intensity.

MaxEnt is a popular species distribution model; it specializes in delineating the spatial pattern of points. To investigate the human disturbance risk for wild fauna, and find the conflict points between human and wildlife, we simulated the human activity intensity in the Sanjiangyuan region, China, and analyzed the effect on the diversity of mammals. In this study, the MaxEnt model was firstly used to calculate the human activity intensity, with some typical environment factors such as terrain factors, climate conditions, and the road network.

2. Methods

2.1. Study Area

The Sanjiangyuan region is in the hinterland of the Qinghai-Tibet Plateau, and the origin of China's three major rivers: the Yangtze River, Yellow River, and Lancangjiang River (Figure 1). It has an area of 363,000 km^2, and the altitude range is ~2582–6815 m a.s.l. The annual temperature difference is small while the daily range is large. Due to the high altitude, Sanjiangyuan suffers a long sunshine time and strong radiation. The perennial average temperature is between −5.6 °C and 7.8 °C, and the cold season lasts for seven months. There is no absolute frost-free period, though the plant growth period is short. Annual average precipitation from northwest to southeast is 262.2–772.8 mm. The annual sunshine duration can be 2300–2900 h, and the annual solar radiation is between 5658–6469 MJ/m^2; the number of windy days of ≥8 gales is 3.9–110, and the oxygen content of the air is only equivalent to about 60%–70% of that of sea level. Snow disaster is the main meteorological disaster.

Figure 1 also shows the distribution of human settlements in Sanjiangyuan. It had a total population of 1.28 million people in 2012. The settlements, as well as the road networks, are concentrated in the south and northeast of Sanjiangyuan. Due to the degree of development, the density of roads is relatively low compared to the average across China. In the west part, only the Qinghai-Tibet highway/railway passes through, along with a few settlements.

Sanjiangyuan is a fragile ecological environment that has experienced drastic changes during the past several decades. The human population has increased more than sevenfold since 1950, and consequently, the demand for food, energy, housing, and public green space, inevitably puts excessive pressure on nature [23]. Moreover, human activities such as cultivation, overgrazing, and project construction damage the ecological environment. Therefore, the government has established a series of measures to protect the area. The Sanjiangyuan National Nature Reserve was established in 2003 to protect the environment. In 2010, the ecological resettlement project carried out ensured that about 100,000 people and 700,000 heads of livestock were moving out of Sanjiangyuan region. In 2015, a pilot project of China's first national park took place, and three sub-parks were established including the Yangze River headwater region, Yellow River headwater region, and Lancangjiang headwater region (Figure 1, I, II, III). Furthermore, the whole Sanjiangyuan region was brought in as a comprehensive pilot area [24].

The national park covers a 122,300 km^2 area, about 1/3 of the Sangjiangyuan region, and each part has its own position and orientation. The Yangtze River headwater region is positioned to protect alpine marshes, alpine meadows, and desert ecosystems; the Yellow River headwater region is positioned to protect the alpine wetland ecosystem; and the Lancangjiang headwater region is positioned to protect alpine valley landforms and the most abundant ecosystem types, including alpine meadow, alpine grassland, alpine shrub, and natural arbor forest. Thus, three sub-parks form a comprehensive protection area for the alpine ecosystem.

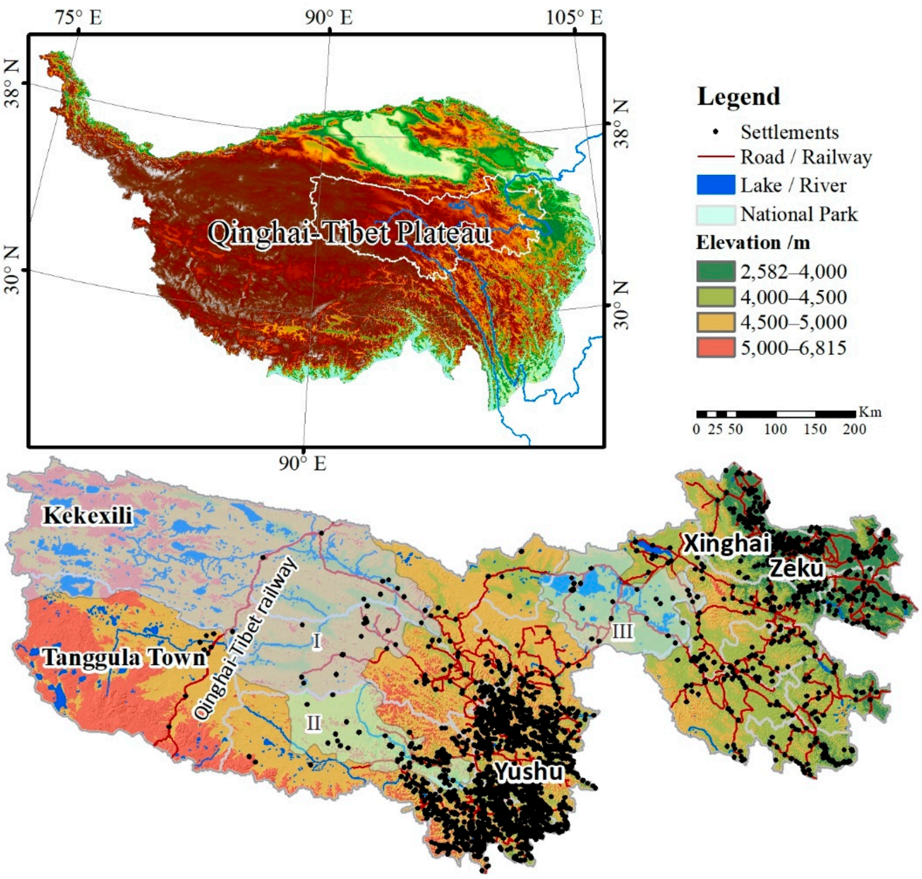
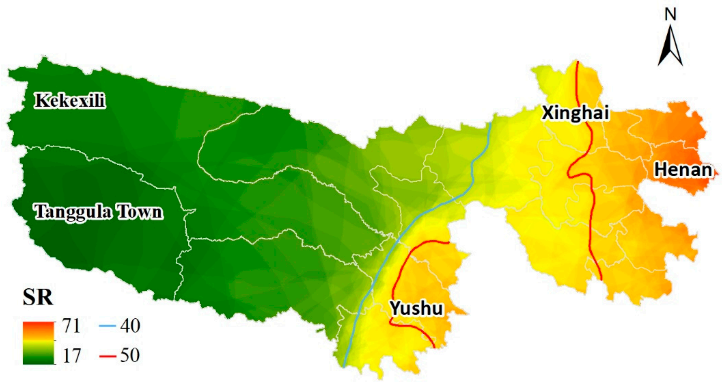


Figure 1. Overview of the Sanjiangyuan region. Sanjiangyuan is located in the central Qinghai–Tibet Plateau, which is a comprehensive pilot area of Sanjiangyuan National Park. Sanjiangyuan National Park consists of three main parts, (I) region of the Yangze River headwater, (II) region of the Lancangjiang River headwater, and (III) region of the Huang River headwater.

2.2. Mammal Species Richness

The geography of the region includes diverse landscapes and different habitat types. Human settlements as well as animal populations are concentrated in the south and northeast area, where net primary productivity (NPP) is of a high level. Sanjiangyuan has the richest wildlife resources and biodiversity on the Qinghai-Tibet Plateau. Species richness is a common index for biodiversity status to estimate the number of species living within a certain space range [25]. This study is mainly based on the data reported in literatures of mammal species in China, including China's mammal diversity and geographical distribution [26], the Chinese animal database [27], and the Chinese red list of endangered animals [28].

The literature records circled the spatial range of each mammal species with multi-polygons. In this study, we selected all the mammal species distributed in Sanjiangyuan, and clipped the species range with the shape of Sanjiangyuan. Finally, we overlaid the multi-polygons of the clipped species range and got the species richness map (Figure 2). Statistical results show that a total of 111 mammal species are recorded in the Sanjiangyuan region, belonging to 9 orders including Primates, Rodentia, Carnivora, Artiodactyla, and Perissodactyla, 24 families including shrews and hedgehogs, and 67 genera.



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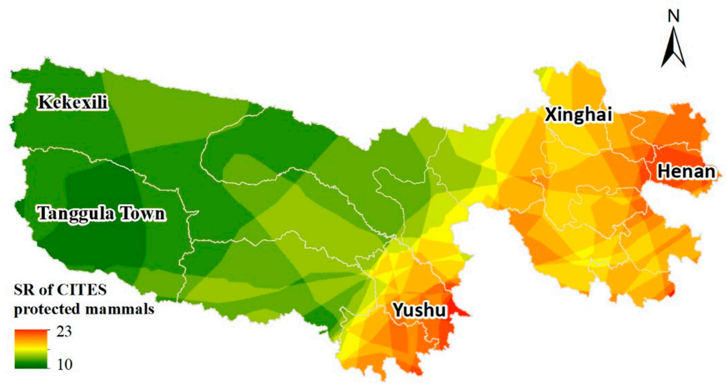


(**b**)

Figure 2. Mammal species richness and species richness of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)-listed mammals in the Sanjiangyuan region. Figure (**a**) shows the map of mammal richness in Sanjiangyuan. The lines represent the species richness isolines for 40 and 50. Figure (**b**) shows the map of CITES-listed mammal richness. Red color indicates high species richness while green indicates low species richness.

The mammal fauna feature of the Sanjiangyuan region is of high species diversity, with many endemic species, key protected species, and threatened species. According to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), there are 33 protected species in the area, and it is an important area for the protection of higher-value animals, especially large mammals. Many rare mammals live in Sanjiangyuan, such as the brown bear (*Ursus arctos*) and snow leopard (*Panthera uncia*). According to CITES, 12 of these species are listed in Appendix I, including all species at risk of extinction due to trade; 12 species are listed in Appendix II, including those that are currently endangered or that may become endangered if their trade is not strictly managed to prevent exploitation; nine species are listed in Appendix III, including species that are managed to prevent or limit exploitation and require international cooperation to control trading [29].

Similar to the distribution of landscape and settlements, Figure 2 shows a significant difference between east and west Sanjiangyuan. Mammal richness increases gradually from west to east. In the vast western area, species richness is lower than 40, especially in Tanggula Town and Kekexili where there are less than 25 species. Conversely, species richness is relatively high in the eastern area. There are two high-value regions, one is around Yushu County (>50 species), and the other is around Xinghai and Henan Counties (71 species).

Overall, 33 among 111 species recorded in the Sanjiangyuan region are listed in CITES (Figure 2b), accounting for about 30% of the total number, which shows a high value for biodiversity conservation. The CITES-listed mammal species richness, ranging from 10 to 23 in the study area, has the same trend as the whole mammal species richness. As is shown in Figure 2, owing to the wide and flat landscape and hypoxic conditions in the western area, species richness is relatively low. Most species belong to alpine ecological communities, such as the Tibetan antelope, wild yak, Tibetan argali, and other large cloven-hoofed animals. The south area existing of valleys and forests can provide sufficient nutrition; therefore, the number of species is large and includes leopards, impala, red panda, and Asian black bears. In general, Sanjiangyuan is rich in species and requires careful conservation.

2.3. The Maximum Entropy Model

The MaxEnt model is a widely used machine learning model [30]. The idea of MaxEnt is to estimate a target probability distribution by finding the probability distribution of maximum entropy [31]. MaxEnt takes a list of species locations and a set of environmental predictors across a user-defined landscape that is divided into grid cells. The result indicates the suitability probability for that individual being derived from each cell on the landscape. MaxEnt is particularly popular in conservation planning [32], for understanding environmental correlates of species occurrences [33], and for understanding species distribution change in response to climate change [34]. Furthermore, MaxEnt was also used for spatial analysis to determine the relationship between the distribution of village groves and various social factors [35].

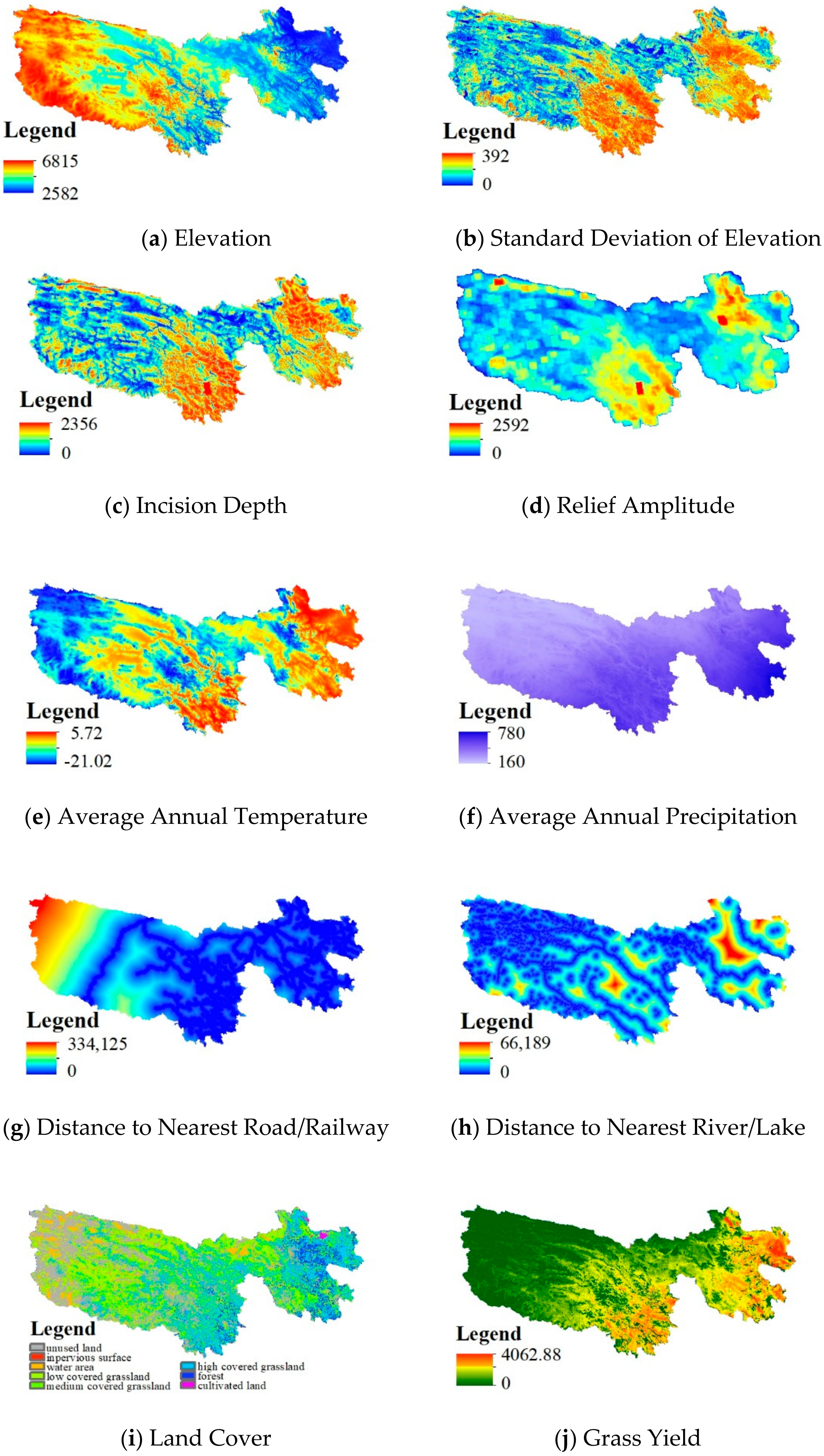
In this paper, MaxEnt was used to estimate human activity intensity. We use settlement locations and a set of environmental factors to make a prediction of the settlement areas as areas of high human presence. A logistic output, which ranges from 0 to 1, denotes the relative intensity. The larger the value, the higher the relative intensity would be.

Because the settlement records were highly spatially clustered, to remove the spatial bias before the modelling process, we subsampled the data, removing records within a buffer of 15 km. For the reduction of settlement records the number may cause occasionally, we took 10 independent experiments and selected the one that performed best. Area under the receiver operator curve (AUC) values were used to judge the performance.

2.4. Data and Environmental Factors

Selecting the appropriate environmental factors ensures the accuracy of the predictions. Climate (e.g., precipitation, temperature) can have an effect on species richness and human population density [36,37]. It is generally assumed that the principal factors that influence human activity are landscape and roads [38–40]. We also used land cover and grass yield datasets as correlative variables, which were retrieved from the National Earth System Science Data Center, National Science & Technology Infrastructure of China [41].The chosen environmental factors according to previous research are shown in Table 1. Albers projection was used in the calculation and visualization, and all the raster dataset was resampled to 30 m × 30 m resolution. Terrain factors were computed from digital elevation model (DEM) data from ASTER Global Digital Elevation Model Version 2 (ASTER GDEM2) [42]. ASTER GDEM2 was released in GeoTIFF format with a resolution of 1" (~30 m). Terrain factors are common indicators for landscape types, and they were calculated from ASTER GDEM2 and divided into two types based on the calculation scope. One represents micro factors of a 90 m scope; the other represents macro factors of a 21 km scope. Together, they can delineate the landscape of the Sanjiangyuan region.

Average annual temperature and precipitation were retrieved from WorldClim [43], which is freely provided for global researchers. We measured the distance to roads/rail lines and rivers/lakes with corresponding vector data from OpenStreetMap [44]. The relative environmental factors are shown in Figure 3.



(**a**) Elevation (**b**) Standard Deviation of Elevation

(**c**) Incision Depth (**d**) Relief Amplitude

(**e**) Average Annual Temperature (**f**) Average Annual Precipitation

(**g**) Distance to Nearest Road/Railway (**h**) Distance to Nearest River/Lake

(**i**) Land Cover (**j**) Grass Yield

Figure 3. Map of environment factors influencing the human activity intensity in Sanjiangyuan region.

Table 1. Environmental factors that can influence the intensity of human activities in Sanjiangyuan.

Factor Type	Factor Name	Descriptions	Window Size
Terrain Factors	Elevation	The average vertical distance from the Earth's surface.	90 m
	Standard Deviation of Elevation	The standard deviation of the grid's elevations	90 m
	Incision Depth	Elevation difference between local elevation and the minimum value at the center of the current cell	21 km
	Relief Amplitude	Elevation difference between the maximum and minimum values, at the center of the current cell	21 km
Climate	Average Annual Temperature	Average annual temperature 1970–2000	1000 m
	Average Annual Precipitation	Average annual precipitation 1970–2000	1000 m
Others	Distance to Nearest Road/Railway	The nearest Euclidean distance to roads or railway in all levels	30 m
	Distance to Nearest River/Lake	The nearest Euclidean distance to rivers or lakes.	30 m
	Land Cover	Contains 8 types of land cover: cultivated land, forest, high/medium/low covered grassland, water area, impervious surface, and unused land	30 m
	Grass Yield	Average quantity of grass yield in August from 1989–2012	30 m

3. Results

3.1. Human Activity Intensity in Sanjiangyuan

The most parsimonious MaxEnt model relating the occurrence of settlements to explanatory variables showed a good fit (AUC-train = 0.995; AUC-test = 0.871). The human activity intensity is shown in Figure 4. High intensity of human activity was mainly distributed in the south and east regions (around Yushu County and Xinghai-Zeku County). Furthermore, the overall human activity intensity of the three sub-parks of the national park is relatively low.

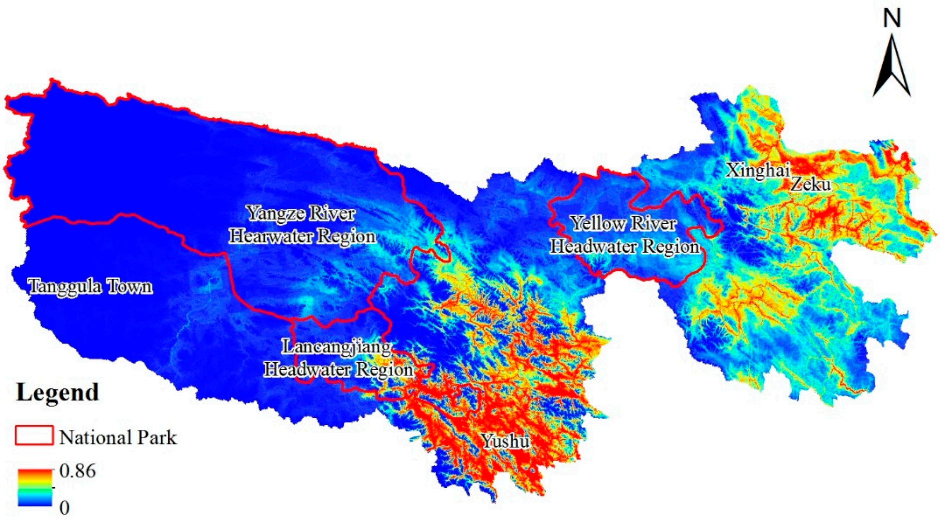


Figure 4. Map showing the intensity of human activities in Sanjiangyuan. Red color indicates high intensity of human activities, and blue color indicates low intensity of human activities. The boundary of the national park is shown in red line.

The area with the minimum intensity is Tanggula Town and Kekexili (to the south of the Yangze River headwater region), where the human population is small. However, the presence of the Qinghai-Tibet railway/highway leads to a relatively high human activity intensity in a belt area across the western Sanjiangyuan.

The MaxEnt result accurately reflects the current situation of human activities in the Sanjiangyuan region. It is important to mention that, since we use settlements to define the human activity intensity in this paper, the model (Figure 4) just represents people's daily activities. Many daily activities occur in the surroundings, such as farming, herding, and infrastructure construction. Some human activities cannot be reflected by this model, such as mining, forest harvesting, and even illegal hunting.

Human activity is a handicap for environment protection and biodiversity conservation. Thus, we calculated the human activity intensity for the three sub-parks of the national park (Table 2). The Yangzi River headwater region and the Yellow River headwater region are low human activity intensity areas, with the value of 0.02 and 0.06; while part of the Lancangjiang headwater region is close to Yushu County, and the sub-park has a higher value (0.13) than the whole Sanjiangyuan region (0.12). Overall, the result reflects accurately the human activity intensity of the national park.

Table 2. A statistical result of human activity intensity in each part of national park.

Parts	Area (km^2)	Mean	Max	Range	STD
Yellow River Headwater Region	18,300	0.06	0.38	0.38	0.04
Yangzi River Headwater Region	90,300	0.02	0.39	0.39	0.04
Lancangjiang Headwater Region	13,700	0.13	0.76	0.77	0.17
Remain Area	236,700	0.16	0.86	0.86	0.18
Sanjiangyuan Total	360,000	0.12	0.86	0.86	0.16

3.2. Contribution of Environmental Factors

The contribution of each factor to the MaxEnt model is shown in Table 3. The average temperature contributes the most proportionally, with 46.1%. The alpine continental climate is characterized by cold temperatures (average annual temperature −5.6 °C to 3.8 °C). Research has shown that hypoxic conditions not only affect human behavior but are also disadvantages for agriculture [45]. It prevented people from living on the Qinghai-Tibet Plateau until 5000 years ago, when humans learned to raise livestock and grow crops [46]. Thus people strive to find warmer places to live.

Table 3. Data description of each factor and their contribution to the model.

Factors	Mean	Min	Max	Percent Contribution
Average annual temperature (°C)	−5.04	−21.02	5.72	46.1
Distance to nearest road/railway (km)	41.775	0	334.125	18.5
Relief amplitude (m)	742	0	2592	11.7
Elevation (m)	4589	2582	6815	10.8
Average annual precipitation (mm)	427	160	780	8.3
Incision depth (m)	337	0	2356	1.8
Land Cover	-	-	-	1.8
Grass Yield (kg/hm^2)	662.24	0	4062.88	0.8
Nearest distance to river/lake (km)	13.168	0	66.189	0.2
Standard deviation of elevation (m)	42.14	0	392	0.2

The second most important factor is the nearest distance to road/railway, accounting for 18.5%. Road networks play a key role in promoting regional development by decreasing journey time and increasing accessibility [47]. The road networks, which highly correlate with human population density, are extremely unbalanced in Sanjiangyuan (Figure 3g). The distance to roads varies greatly; the longest distance is 334 km, and the average distance is 41 km. Thus, the human activity intensity in the eastern area is much larger than in the western area. It is noteworthy that the Qinghai-Tibet road/railway raised the intensity in the western area (Figure 4). Human influences in the western part are mainly concentrated near this road/railway. Research suggests that the construction of the Qinghai-Tibet railway has greatly accelerated the urbanization of the Qinghai-Tibet Plateau; the northern section of the Qinghai-Tibet railway is a central axis for urbanization and will be a major residential area for herders [48]. Therefore, the road network is not only an indicator of the human activity intensity but also an important driving force to human activity.

Climate and landscape factors each play an important role in the model. Average annual precipitation and relief amplitude contribute 10.8% and 8.3% respectively. Other correlative variables have a modest effect on human activities. Sanjiangyuan is the source region of three rivers; therefore, water is abundant and provides sufficient water for the whole region. Therefore, the percentage contribution of average annual precipitation is not as great as expected. The relief amplitude describes the relative location in a large area, such as in a valley or on a summit. This study coincides with previous research, which found that ancient human settlement cultures in the northeast of the Qinghai-Tibet Plateau had the tradition of living in valleys [49]. The small contribution of the land cover and grass yield dataset does not mean human activities are not limited; lower classification accuracy problems in remote sensing can lead to this situation.

4. Discussion

4.1. Human–Wildlife Coexistence

The relationship between human disturbance and biodiversity has been a long-term topic for researchers [50]. Previous study has found positive correlations between human populations and species richness of different animal groups [36]. To investigate the regulation of animal groups in the Qinghai-Tibet Plateau, we made a zonal statistic for mammal richness and human activity intensity. We divided the study area into five equal-area regions according to the prediction of the human activity intensity. Each region represented one of the five levels of human activity intensity: very low, low, normal, intensive, and highly intensive. Then, we investigated the relationship between mammal richness and the intensity of human activities through a spatial statistical analysis. Results show the constitution of the intensity of human activities (Figure 5). Since the cell number of mammal richness, between 17–20 and 70–71, was small and with no statistical significance, we combined them with adjacent groups.

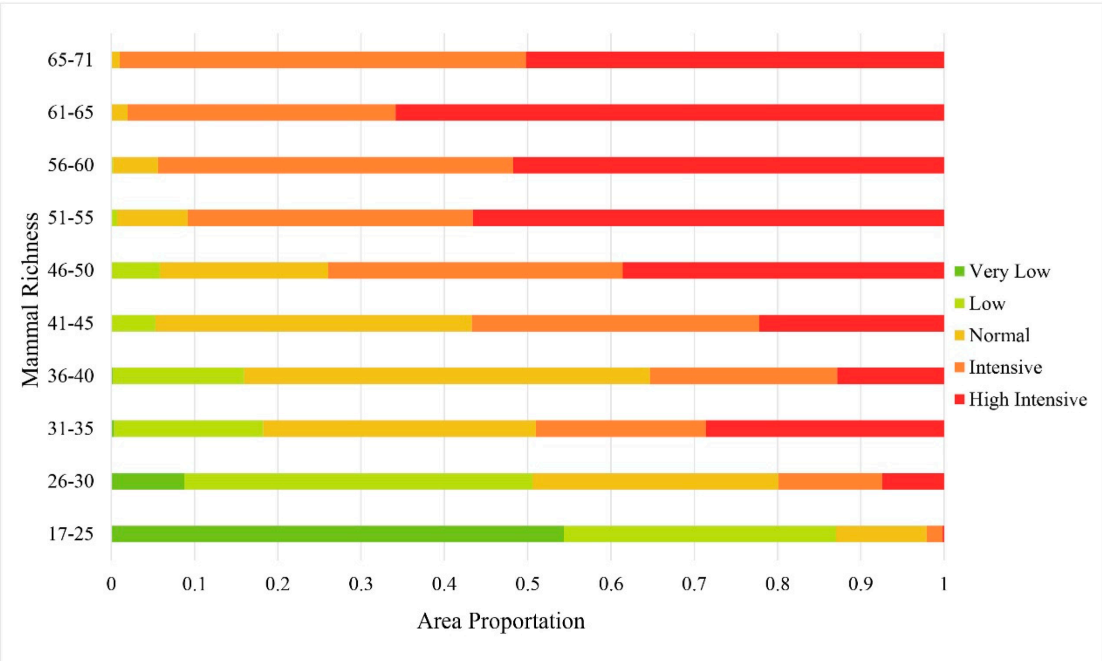


Figure 5. Intensity of human activities at different levels of mammal species richness. Sanjiangyuan was divided into five equal-area regions with different levels of human activity intensity. Mammal species richness was divided into 10 groups. The vertical axis represents mammal richness, and the horizontal axis represents the proportion of the five levels of intensity for human activities.

As is shown in Figure 5, a large proportion, accounting for ~55%, fall in the very low level of human activity intensity for the group 17–25. Furthermore, a small proportion, accounting for ~33%, fall in the low level. The area of high intensity increases when the mammal richness increases. Vice versa, the area of low intensity declines when mammal richness declines. The group 61–65 bears a high intensity of human activities (68% highly intensive; 31% intensive). For the group 66–71, the intensity of human activities remained high, and the proportion of highly intensive and intensive levels accounted for >99%. It shows that the more mammals there are, the higher the intensity of human activities they bear, which is the human–wildlife coexistence phenomenon.

Human–wildlife coexistence leads to human–wildlife conflict [51]. With the development of modern technologies, humans are capable of modifying the natural environment to suit their needs. Human activities not only lead to habitat loss, but also change animal behavior [52,53]. Research shows that biodiversity in Southeast Asia is closely related to population density, and species diversity increases initially and then decreases as population density increases [7]. The larger the human population is, the faster the human population grows, and then the faster the loss of biodiversity will be [54].

To maintain the human–wildlife coexistence, developing nature reserves are the most effective measure [55]. As a new national park, Sanjiangyuan should take measures to govern the area with high intensity of human activities, and protect the area with low intensity of human activities.

4.2. CITES Species in the National Park

With rapid economic growth and changes in production, China has a high conservation responsibility to protect mammals [56]. There are 33 species in CITES Appendix I, II, and III in the Sanjiangyuan region, which is one of the reasons to establish the Sanjiangyuan National Park. We carried out a statistical analysis with the geographic range and human activity intensity for each species to examine the impact of human disturbance to each species and investigate the effect of the national park (Table 4).

Human daily activities usually impact on the areas around settlements, manifested as urban construction, pollution, and agriculture, which leads to serious problems regarding habitat fragmentation [57,58]. Besides, illegal poaching of the protected animals may cause a population crash, which has happened in history [59,60]. Studies have shown that the number of Tibetan antelopes in the northwest of the Qinghai-Tibet Plateau decreased from nearly 1,000,000 at the beginning of the 20th century to about 75,000 in the 1990s. In addition, the Qinghai-Tibet railway/highway was completed in 2006, bringing many more travelers to the region that also threaten the local wildlife.

There are 23 protected species (in CITES) distributed in the Sangijangyuan National Park, and there remains nine protected species not in this region. As is shown in Table 4, three sub-parks share the same goal to protect the endemic species in the Qinghai-Tibet Plateau, such as the snow leopard, the Tibetan argali, and the chiru. Meanwhile they have different responsibilities to some other species living in separate ecological systems, such as the small Indian civet and astatic black bear which live in the Lancangjiang headwater region, the Chinese serow and wild cat which live in the Yellow River headwater region, and the wild yak which lives in Yangze River headwater region. Not all species lie within protected areas, but the options are limited for building on the present network to generate a more comprehensive one, which protects all species and significantly reduces the conflict with human activities by designating new reserves in areas with lower human populations [61]. The sub-parks scientifically function as a comprehensive system.

Table 4. The human activity intensity on the inhabiting area of CITES-listed species. HAI represents the mean value of human activity intensity in geographic range of species.

NAME	SPECIES	CITIES	ORDER *	HAI	P1 **	P2	P3
Leopard	*Panthera pardus*	I	CAR	0.376			
Red Panda	*Ailurus fulgens*	I	CAR	0.363			√ ***
Small Indian Civet	*Viverricula indica*	III	CAR	0.353			
Asiatic Black Bear	*Ursus thibetanus*	I	CAR	0.347			√
Assam Macaque	*Macaca assamensis*	II	PRI	0.314			
Leopard Cat	*Prionailurus bengalensis*	I	CAR	0.299			
Tibetan Macaque	*Macaca thibetana*	II	PRI	0.298			
Chinese Serow	*Capricornis milneedwardsii*	I	ART	0.278		√	
Yellow-throated Marten	*Martes flavigula*	III	CAR	0.263			
Rhesus Monkey	*Macaca mulatta*	II	PRI	0.249		√	√
Siberian Weasel	*Mustela sibirica*	III	CAR	0.243		√	√
Altai Weasel	*Mustela altaica*	III	CAR	0.227		√	√
Forest Musk Deer	*Moschus berezovskii*	II	ART	0.218			
Chinese Mountain Cat	*Felis bieti*	II	CAR	0.215			
Wild Cat	*Felis silvestris*	II	CAR	0.209		√	
Eurasian Otter	*Lutra lutra*	I	CAR	0.205	√	√	√
Large Indian Civet	*Viverra zibetha*	III	CAR	0.182			
Dhole	*Cuon alpinus*	II	CAR	0.171	√	√	√
Jungle Cat	*Felis chaus*	II	CAR	0.161		√	
Chinese Goral	*Naemorhedus griseus*	I	ART	0.148			
Pallas's Cat	*Otocolobus manul*	II	CAR	0.139	√	√	√
Himalayan Marmot	*Marmota himalayana*	III	ROD	0.117	√	√	√
Bharal	*Pseudois nayaur*	III	ART	0.117	√	√	√
Eurasian Lynx	*Lynx lynx*	II	CAR	0.117	√	√	√
Gray Wolf	*Canis lupus*	II	CAR	0.117	√	√	√
Red Fox	*Vulpes vulpes*	III	CAR	0.117	√	√	√
Brown Bear	*Ursus arctos*	I	CAR	0.117	√	√	√
Stone Marten	*Martes foina*	III	CAR	0.117	√	√	√
Snow Leopard	*Panthera uncia*	I	CAR	0.117	√	√	√
Tibetan Argali	*Ovis hodgsoni*	I	ART	0.117	√	√	√
Kiang	*Equus kiang*	II	PER	0.092	√	√	√
Chiru	*Pantholops hodgsonii*	I	ART	0.048	√	√	√
Wild Yak	*Bos mutus*	I	ART	0.002	√		

*. CAR: carnivore; PRI: primates; ART: artiodactyl; ROD: rodent; PER: perissodactyl **. P1: Yellow River headwater region; P2: Yangzi River headwater region; P3: Lancangjiang headwater region ***. √: recorded in this area.

5. Conclusions

In this paper, we successfully estimated the human activity intensity in the Sanjiangyuan region with the MaxEnt model. Settlements were used as key factors for human activity, and a fine set of environment factors were selected as correlated variables. Precipitation, distance to road, and relief amplitude contribute a great deal for the model. Climate, infrastructure, and landscape each displays an important role in human activity. The results show that the overall intensity is relatively low, but the south and northeast part has a high level of intensity.

Sanjiangyuan has high species richness and an abundance of endemic species, and it is one of the most important centers of biodiversity in the world. Analysis of habitat conditions with human activity intensity presents a human–wildlife co-existence phenomenon. However, most of the endemic species bear low human activity intensity, due to the remote alpine habitat.

The results also show that the national park is well planned. The three sub-parks keep away from the high human activity intensity area in the Sanjiangyuan region. They can shelter 3/4 of the protected species listed in CITES, within only 1/3 of the area of the region. Sanjiangyuan National Park can shoulder the historical mission for ecological conservation, the protection of endangered fauna, and sustainability.

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