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Spatial Variability and Ecological Effects of Anthropogenic Activities in a Nature Reserve: A Case Study in the Baijitan National Nature Reserve, China

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Abstract: Nature reserves play an essential role in protecting natural resources and maintaining an ecological balance. However, certain nature reserves are increasingly disturbed by human activities in the form of settlements, roads, farmland, etc. How to monitor the status of nature reserves by using remote sensing methods has been a focus of scholars for a long time. In this study, remote sensing satellite images from 2009 and 2014 were used to extract and analyze the distribution of anthropogenic activities, such as agriculture, industry, residency, traffic, and other human activities. On this basis, the Nature Reserve Human Interference (NRHI) and landscape indices (LI) were calculated to describe the intensity of anthropogenic disturbance; in addition, the slope and aspect were analyzed to describe the regularity in the distribution of anthropogenic activities. The results showed that more than 90% of the anthropogenic activity occurred in the experimental and buffer zones. Likewise, the NRHI increased from 0.0901 in 2009 to 0.1127 in 2014. The NRHI was proportional to the patch density (PD), landscape shape index (LSI), landscape division index (DIVISION), Shannon's diversity index (SHDI), and Shannon′s evenness index (SHEI), and it was inversely proportional to the contagion index (CONTAG). Moreover, 84.54% of the anthropogenic activity occurred in a range from 0 to 3.6 degrees, and 14.43% of the activity occurred in a range from 3.6 to 7.2 degrees. More than 60% of the anthropogenic activity occurred on sunny slopes because of the human adaptability to the environment and the possibility for humans to fulfill their physical needs (warmth and comfort). Thus, the monitoring of this nature reserve needs to be further strengthened and focused on the area with a range of 0–7.2 degrees and on the sunny slopes.

Keywords: anthropogenic activity; landscape indices (LI); Nature Reserve Human Interference (NRHI); slope; aspect

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1. Introduction

Increasing evidence has revealed that Earth ecosystems have been affected by anthropogenic activities [1–4]. Human activities and requirements are depleting the environmental resources. Meanwhile, humans need to sustain, preserve, and maintain the resources for future use. Indeed, there is little balance and harmony between anthropogenic activities and the preservation of nature in several parts of the world, and this outcome is attributed to an economic growth pattern [5]. Nature reserves, as the most efficient means for protecting natural ecological environments, are booming [6,7].

Sustaining nature reserves has contributed to improving the situation of ecological environments. However, because of the rapid development of the national economy and the increasing demands on natural resources, there are still certain nature reserves that are disturbed by anthropogenic activities to various degrees, such as expanding settlements, agricultural activities, road construction, and mining developments [8–10]. International Union for Conservation of Nature (IUCN) developed standardized guidelines for protected areas designation, based on six categories (Ia, Ib, II, III, IV, V, and VI) from most natural to least natural. Many ways to quantify naturalness involve the use of a proxy measure related to human disturbance [11,12]. Anthropogenic activities in nature reserves are the most direct indications that nature reserves are disturbed by humans. Therefore, a detailed monitoring of human activities in nature reserves is essential and constitutes an urgent task for the environmental protection of the country′s natural resources.

With the increase of anthropogenic activities in recent years, more studies have been conducted on the impacts of such activities on nature reserves [13,14]. Traditional nature reserve monitoring mainly depends on field investigations by reserve staff, which is difficult due to the vastness of the areas and the complicated natural and geographical conditions. The development of remote-sensing technologies offered a new way for solving these problems, supplying rich data sources with the characteristics of short period and low cost [15]. Remote sensing monitoring, which provides access to large amounts of information with a high observation scope, has become the main scheme of nature reserve monitoring and evaluation. Young et al. analyzed the land cover and land cover change in the Beaver Hills moraine and surrounding areas [16]. Zeng et al. studied the human disturbances to landscapes of the Wolong Nature Reserve and found that the main sources of human impacts were hydropower stations, settlements, and roads [17]. In previous years, medium-resolution satellite images, such as TM/ETM (15–30 m) or lower-resolution satellite images, such as MODIS data, were the primary data sources for investigating the present situation of nature reserves [18]. However, high-resolution remote sensing images are more suitable for the remote sensing monitoring of anthropogenic activities in nature reserves due to the usually small areas of anthropogenic activities. Conrad, Talita Nogueira Terra, and Duccio Rocchini obtained a highly accurate monitoring result using high-resolution remote sensing [19–21]. Thus, a highly accurate human activity disturbance index can be achieved using high-resolution remote sensing images. Landscape metrics can be used to describe human activity disturbances, such as the expansion of road networks or the construction of hydroelectric projects, among others [22–24]. The qualitative relationship between the landscape index and the intensity of human disturbances should also be well understood because human activities will ultimately lead to major landscape structural changes, which may cause habitat loss in nature reserves, then do harm to the ecological system and exert a serious threat to biological diversity of nature reserves [25]. The monitoring of anthropogenic activities is a large-scale effort that is not timely enough to account for discrete distributions. A study on the relationships between the spatial distribution of anthropogenic activities and relevant factors (such as slope and aspect) is necessary because it can help the authorities determine the major zone of monitoring.

We selected the Baijitan National Nature Reserve as the study area and selected GF-1 remote sensing images as the main data source. The intensity and distribution rule are presented by analyzing the extracted human activities on high-resolution images. Likewise, a comparative landscape pattern analysis was performed using RS satellite images from 2009 and 2014, which were used to qualitatively analyze the landscape and the intensity of human disturbances.

2. Methodology

2.1. Study Area

The Baijitan National Nature Reserve was established in 1985 to preserve the desert ecosystem. It is located in the eastern desert zone of Ling Wu, in the Ningxia Hui Autonomous Region (longitude 106°23′–106°48′ and latitude 37°54′–8°22′) (Figure 1). It covers approximately 74,843 hectares, its climate is a typical continental monsoon, and the average elevation is 1250 m. In the Baijitan National Nature Reserve, most of the desert vegetation has been well preserved, and its natural desert shrub communities are the largest and the most centralized type in China.

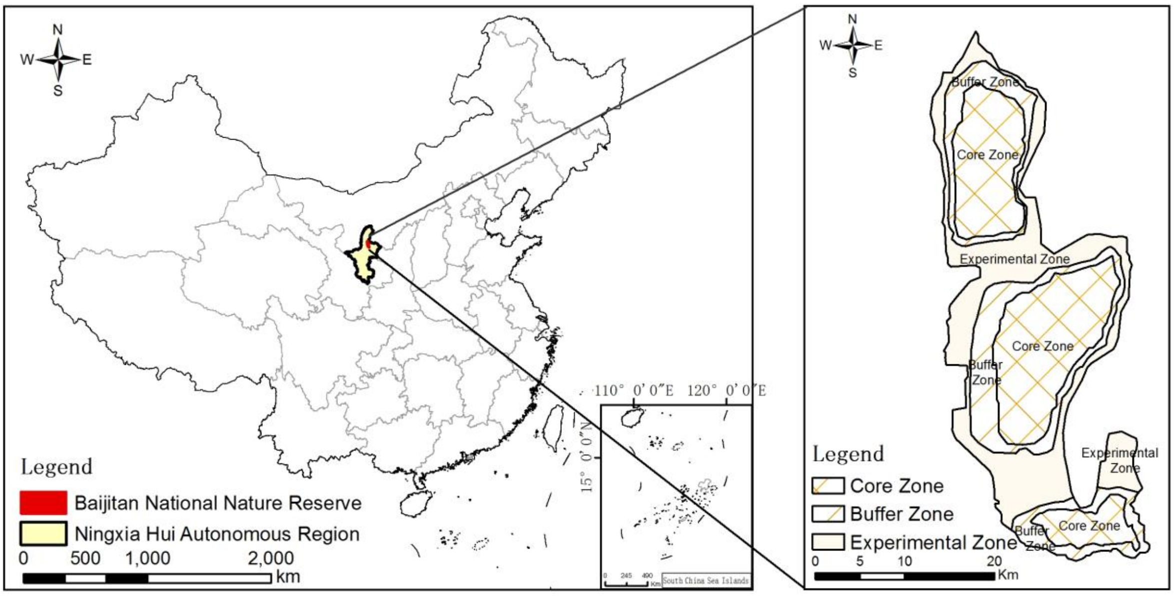

Figure 1. Location of the study area.

2.2. Data and Tools Used

The data used in this study include two GF-1 images, one Landsat (MSS/TM/ETM+) image and a Digital Elevation Model, DEM, with spatial resolution of 3 arc seconds (approximately 90 m ground resolution). The two GF-1 images were acquired on 19 May 2014 and were used for extracting the human activities after preprocessing it for radiant calibration, geometrical correction, mosaic, and clip. The GF-1 images have one panchromatic band (2 m) and four visible and VNIR multispectral bands (8 m). The spatial coverage is 800 km^2. Landsat (MSS/TM/ETM+) images, downloaded from the USUG (http://glovis.usgs.gov/) with a spatial resolution of 30 m, were used to obtain the land use cover in 2009. The false color RS images were geometrically corrected, synthesized, spliced, cropped, and enhanced under three optimal bands: TM5(R), TM4 (G), and TM3 (B). Digital Elevation Model (DEM) data were used for obtaining slope and aspect data.

We used FRAGSTATS spatial pattern analysis software in this study, developed by the Forest Science Department, Oregon State University, USA, to assess different metrics. FRAGSTATS can calculate more than 40 landscape metrics, such as areas, patch density, size and variability, edge, shape, core area, diversity, nearest neighbor, contagion, and interspersion. The detail of FRAGSTASTS can be found in the cited references [26,27].

2.3. Landscape Indices (LI)

The landscape indices (LI) are a series of simple quantitative indices that can concentrate landscape information and reflect spatial composition and configuration characteristics from different points of view [23,28,29]. In this study, the patch density (PD), landscape shape index (LSI), landscape division index (DIVISION), contagion Index (CONTAG), Shannon's diversity index (SHDI), and Shannon's evenness index (SHEI) were calculated to perform a quantitative analysis to assess the landscape patterns. As shown in the following formulas [30–32]:

2.3.1. Patch density (PD)

PD is the basic index of landscape pattern analysis and represents patch number per unit area as the change of landscape scale. We calculated this index using following formula:

$$PD = \frac{N}{A} \times 10^6, \quad (1)$$

where N is the total number of landscapes, and A is the total area of the landscape;

2.3.2. Landscape shape index (LSI)

LSI is to determine the complexity of the landscape types by calculating the ratio of the perimeter of one particular landscape type patch and the perimeter of circular with the same area. The formula is as follows:

$$\mathrm{LSI} = \frac{0.25L}{\sqrt{A}}, \quad (2)$$

where A is the total area of the landscape, and L is the total length of all patch boundaries.

2.3.3. Landscape division index (DIVISION)

DIVISON quantifies fragmentation based on the distribution of cumulative patch area and reflects the probability that two randomly chosen places in the landscape under investigation are not situated in the same area. The index was calculated by the following formula:

$$\mathrm{DIVISION} = 1 - \sum_{i=1}^{m} \left(\frac{a_i}{A}\right)^2, \quad (3)$$

where A is the total area of the landscape, m is the number of landscape types, and a_i is the total area of the ith landscape.

2.3.4. Contagion Index (CONTAG)

CONTAG reflects non-randomized or aggregation degree of different patch types in the landscape. Because it considered the adjacent relation between patch types, it can reflect the characteristics of the space configuration of landscape components. The formula is as follows:

$$\mathrm{CONTAG} = \left\{ 1 + \sum_{i=1}^{m} \sum_{k=1}^{m} \left[\left(P_i \frac{g_{ik}}{\sum\limits_{k=1}^{m} g_{ik}} \right) \ln \left(P_i \frac{g_{ik}}{\sum\limits_{k=1}^{m} g_{ik}} \right) \right] / 2 \ln m \right\} \times 100, \quad (4)$$

where P_i is the ratio of the landscape, g_{ik} is the number of adjacencies between pixels of the ith landscape and the kth landscape, and m is the number of landscape types.

2.3.5. Shannon′s diversity index (SHDI)

SHDI reflects the landscape heterogeneity and it is more sensitive to unbalanced distribution of various patches. It also reflects the complexity and variability of each landscape patch type. It was calculated using the following formula:

$$\mathrm{SHDI} = -\sum_{i=1}^{m} (P_i \times \ln P_i), \quad (5)$$

where P_i is the ratio of the ith landscape, and m is the number of landscape types.

2.3.6. Shannon′s evenness index (SHEI)

SHEI reflects the distribution uniformity of different patch types. SHEI equals 0 when the landscape contains only one patch and approaches 0 as the distribution of area among the different patch types becomes increasingly uneven; SHEI equals 1 when distribution of area among patch types is perfectly even. The formula is as follows:

$$\mathrm{SHEI} = \frac{-\sum_{i=1}^{m} (P_i \times \ln P_i)}{\ln m}, \quad (6)$$

where P_i is the ratio of the ith landscape, and m is the number of landscape types.

2.4. Human Interference in the Nature Reserve

The intensity of human activities can be reflected through the Nature Reserve Human Interference (NRHI), which is based on the distribution of human activities. The NRHI was proposed by Ministry of Environmental Protection of the People's Republic of China [33]. It is calculated as follows:

$$\mathrm{NRHI} = (a_1 b_1 x_1 + a_2 b_2 x_2 + \cdots\cdots + a_i b_i x_i)/X \times 100, \quad (7)$$

where the NRHI is the impact index of human activities in a nature reserve; x_i is the area of the different types of human activities; X is the total area of the nature reserve; a_i is the weight of each functional zone (core, buffer and experimental zones); and b_i is the weight of type i human activity.

According to Technology Guides of Human Activities Remote Sensing Monitoring in Nature Reserve issued by Ministry of Environmental Protection of the People's Republic of China [33], the weights of the core, buffer, and experimental zones in Equation (7) were set to 0.6, 0.3, and 0.1, respectively. Table 1 provides the weights of certain types of human activities.

Table 1. Weights of the different activity types.

Types	Impact Degree	Weight
Industrial area	100	0.21
Traffic facilities	50	0.11
Other human activities	30	0.07
Farmland	10	0.02
Residential land	10	0.02

3. Results and Analysis

Base on the two GF-1 images and one Landsat (MSS/TM/ETM+) image, we extracted the human activities using the object-oriented classification method in 2009 and 2014 [34]. The results of the classification indicate that the extracted human activities (Figure 2) including agricultural land, industrial land, residential land, traffic land, and other human activities in the Baijitan National Nature Reserve. The slope and aspect were calculated based on DEM.

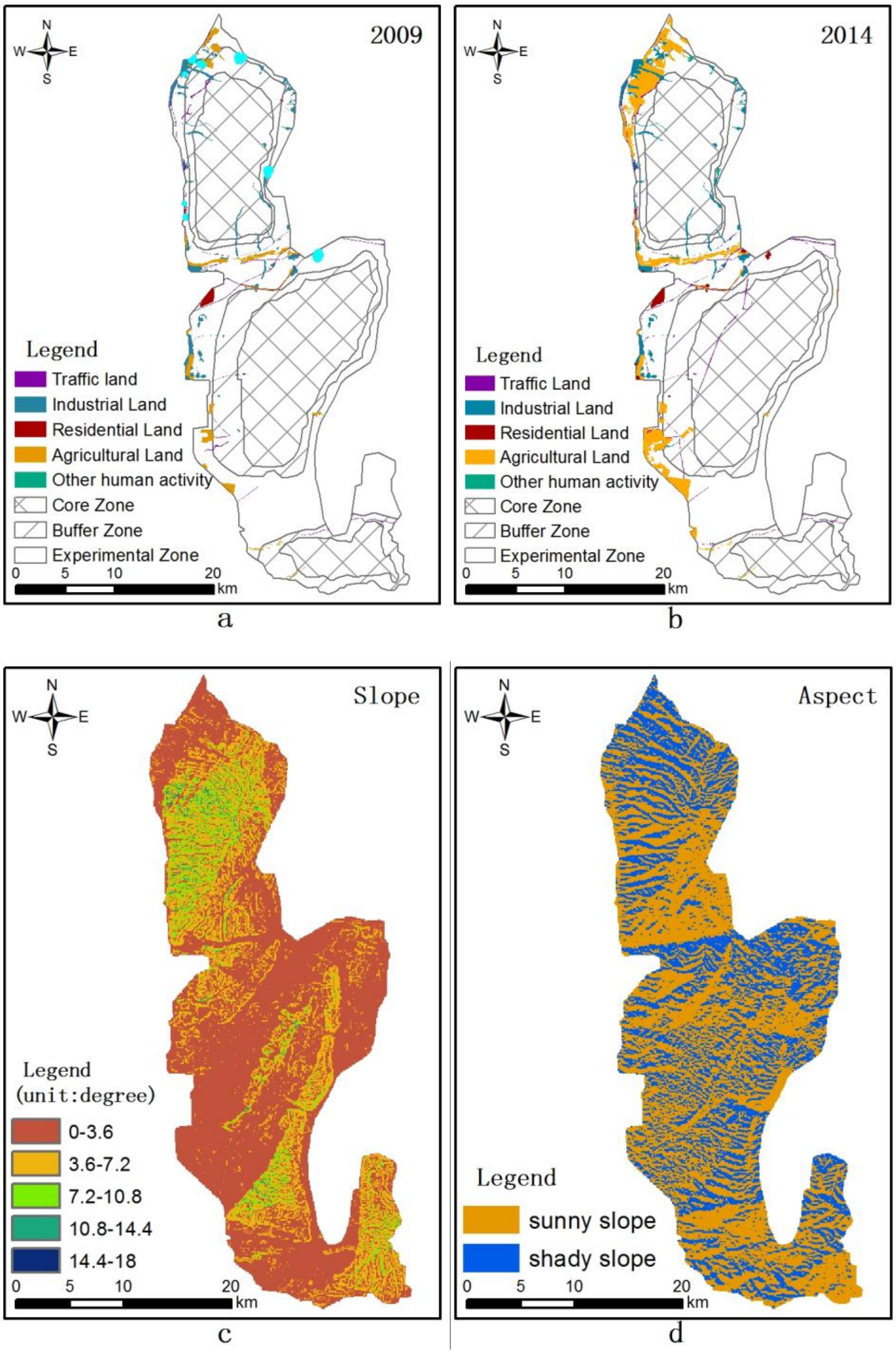

Figure 2. Distribution of human activities (**a**,**b**); slope (**c**); and aspect (**d**) in the Baijitan National Nature Reserve.

3.1. Distribution of Human Activities

Zonal statistical analyses were carried out on the distribution of human activities in 2009 and 2014 using the extraction of human land use activities. The results are shown in Table 2.

Table 2. Distribution of human activities between 2009 and 2014.

Function Zone	Area (km^2)											
	Residential Land		Agriculture Land		Industrial Land		Traffic Land		Other Human Activities		Total	
	2009	2014	2009	2014	2009	2014	2009	2014	2009	2014	2009	2014
Core Zone	0.00	0.00	0.04	0.13	1.71	1.71	0.15	1.12	0	0	1.9	2.96
Buffer Zone	0.00	0.09	1.79	10.19	1.76	1.94	1.3	1.59	0.27	0.27	5.12	14.08
Experimental Zone	1.51	2.50	9.79	26.06	10.49	10.45	3.29	3.68	0.58	0.29	25.66	42.98
Total	1.51	2.59	11.63	36.38	13.96	14.09	4.74	6.39	0.85	0.56	32.68	60.01

As the Table 2 shows, almost all the human activities (residential land, agricultural land, industrial land, traffic land, and other human activities) occurred in the experimental and buffer zones. In 2009, the area of residential land, agricultural land, industrial land, traffic land, and other human activities in the experimental zone represented up to 79% of the land affected by human activities. Moreover, 16% of the human activities occurred in the buffer zone, where most of them involved agricultural land, industrial land, or traffic land. Only three types of activities occurred in the core zone, i.e., the industrial land, and small percentages of agricultural land and traffic land (Table 2 and Figure 3).

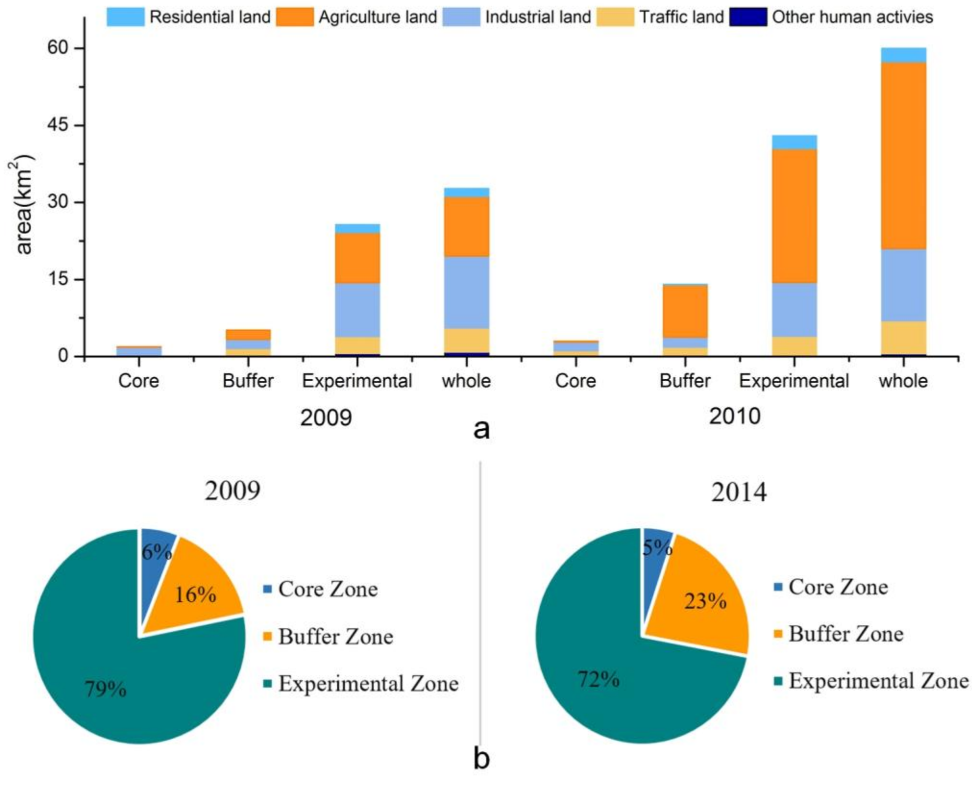

Figure 3. Distribution of the area (**a**) and ratio (**b**) of human activities in different zones.

Compared with 2009, there were more human activities in 2014, and the total area extended to 60.01 km^2. The residential, agricultural, industrial, and traffic lands had a different increase in their areas and the ratio of human activities in buffer zone increased clearly. For example, the agricultural land had the greatest change in its area, followed by the residential land and traffic lands. The agricultural land grew by 24.75 km^2 (0.09 km^2 in the core zone, 8.4 km^2 in the buffer zone and 16.27 km^2 in the experimental zone). The increase in residential and industrial lands occurred in the buffer zone. Only the traffic land increased in all three zones (Table 2 and Figure 3).

The area occupied by human activities suggests that the Baijitan National Nature Reserve was deeply disturbed by human reclamation activities. Comparing the areas of different zones from 2009 to 2014, we found that the proportion of human activities in the buffer zone increased; however, all the areas of human activity in the three zones increased to different degrees.

Combining the different human activity areas and the weights of the different types and different functional areas, this paper presents the results of the NRHI in the Baijitan National Nature Reserve using extracted human land use activities in 2009 and 2014. The calculations showed that the NRHI was 0.0901 in 2009 and 0.1127 in 2014. A comprehensive analysis of the human activities in 2009 and 2014 showed that the Baijitan National Nature Reserve was seriously disturbed by human activities with the development of human societies and the economy.

3.2. Landscape Indices (LI)

The strength of the human activities had a good correlation with the LI. The analysis of the landscape changes allowed us to understand that the ecosystem processes were influenced by the disturbances. The LI can be used to describe the spatial distribution of human activities. For the pattern analysis of the nature reserve, we used pattern analysis software to calculate the LI and related statistical analysis tools to evaluate the two-phase landscape pattern of the Baijitan National Nature Reserve in 2009 and 2014 (Table 3).

Table 3. Comparison of landscape indices between 2009 and 2014.

Year	NRHI	PD	LSI	CONTAG	DIVISIO	SHDI	SHEI
2009	0.0901	0.34	8.60	92.87	0.53	0.25	0.13
2014	0.1127	0.48	11.00	89.16	0.59	0.39	0.20

From the point of view of the landscape patch density (PD), the density was 0.48 in 2014, which is higher than that in 2009. The increase of the landscape patch density indicated that the number of patches increased but that their areas became smaller. This increase also indicated that the degree of connection in each area was enhanced and that the fragmentation of the landscape was reduced.

The landscape shape index (LSI) can be used to reflect the influence of human activities on the landscape [35]. In the Baijitan National Nature Reserve, the landscape shape index increased from 8.6 in 2009 to 11 in 2014. The obvious increase shows that the shapes of the patches and the landscape structure were more complex and more irregular in the study area, which was fragmented by human activities.

Contrary to the LSI, the contagion index (CONTAG) describes the aggregation and extending trend of different patch types [36], which ranged from 0 to 100. A value close to 100 indicates that there are dominant patches with high connectivity. In the nature reserve, the high overlay of natural desert shrub communities is dominating. The negative trend of the CONTAG index (from 92.87 in 2009 to 89.16 in 2014) suggests a high landscape fragmentation and reduced landscape connectivity in the nature reserve.

The landscape division index (Division) is based on the cumulative patch area distribution. Higher Division values indicate increased fragmentation. The division index in 2014 was larger than that in 2009, which showed that the patch distribution became more dispersed because of the increase in human activities [37].

The positive trend of Shannon′s diversity index (SHDI) indicates an increase in the diversity of landscape types. The index can also reflect landscape heterogeneity, especially an unbalanced distribution of patches [14]. Therefore, the increase in SHDI shows that the Baijitan National Nature Reserve moved toward a diverse land status that leads to instability, which presumably resulted from the increase in human disturbances.

Like SHDI, Shannon′s evenness index (SHEI) is also a powerful method for comparing the landscape diversity in different periods, and a value close to 0 indicates that the landscape is dominated by one or a few types [38]. SHEI of the Baijitan National Nature Reserve increased from 0.13 in 2009 to 0.20 in 2014. This result shows the decrease in the domination of the natural desert shrub communities.

3.3. Distribution Regularity of Human Activities

3.3.1. Slope

Humans always tend to reconstruct the sloped land to flat land for the needs of agriculture or construction. The ground slope is an important factor for affecting the use of land [39]. For analyzing the distribution regularity of human activities, the slope was calculated from the DEM obtained in this paper. The slope in the Baijitan National Nature Reserve ranged from 0° to 17.8° and was evenly divided into five grades: gradient 1 (0°–3.6°), gradient 2 (3.6°–7.2°), gradient 3 (7.2°–10.8°), gradient 4 (10.8°–14.4°), and gradient 5 (14.4°–18°) [40].

The distribution of human activities in different slope zones can be seen in Table 4 and Figure 4, and it was significantly different in different slopes. Comparing and analyzing the two years, the human activities had the same distribution with little differences in different grades, although the area of human activities significantly increased (Table 2, Figure 3). In total, more than 80% of human activities occurred in the range of 0 to 3.6 degrees, approximately 15% of human activities occurred in the range of 3.6 to 7.2 degrees, approximately 1% of human activities occurred in the range of 7.2 to 10.8 degrees, and the human activities in the range of 10.8 to 18 degrees were negligible. From 2009 to 2010, the ratios of the residential and traffic lands in the range of 0–3.6 degrees increased, whereas the ratios of the agricultural land, industrial land, and other human activities slightly decreased. In the range of 3.6–7.2 degrees, the ratio of the residential lands decreased significantly (from 23.68% to 13.81%) and the ratio of the traffic lands decreased slightly, whereas other types increased slightly. In 7.2–10.8 degrees and in 10.8–14.4 degrees, the changes of the ratios of all human activities were not obvious.

The distribution of human activities in the two years indicates that the most suitable area for human production and life is the area most frequently used for human activities, i.e., the region of 0–0.36 degrees of the Baijitan National Nature Reserve. Almost all the human land uses occurred in the range of less than 10.8 degrees. Thus, it is clear that the distribution of human activities is obviously affected by slope. Hence, when monitoring human activities in nature reserves, we can focus on the area of less than 10.8 degrees to reduce the difficulty and save labor, money, and time. The 0–3.6 degrees area is particularly the area that requires more exhaustive monitoring.

Table 4. Distribution of human activities in different gradients.

Year	Slope	Ratio					
		Residential Land	**Agriculture Land**	**Industrial Land**	**Traffic Land**	**Other Human Activities**	**Total**
2009	0°–3.6°	75.24%	92.73%	82.13%	76.50%	86.23%	82.57%
	3.6°–7.2°	23.68%	6.86%	15.75%	21.58%	12.93%	16.16%
	7.2°–10.8°	1.08%	0.41%	1.67%	1.81%	0.84%	1.16%
	10.8°–14.4°	0	0	0.44%	0.11%	0	0.11%
	14.4°–18°	0	0	0.01%	0	0	0
2014	0°–3.6°	85.07%	91.42%	80.57%	79.94%	85.71%	84.54%
	3.6°–7.2°	13.81%	7.71%	17.16%	19.16%	14.29%	14.43%
	7.2°–10.8°	1.12%	0.88%	1.72%	0.90%	0	0.92%
	10.8°–14.4°	0	0	0.48%	0	0	0.10%
	14.4°–18°	0	0	0.07%	0	0	0.01%

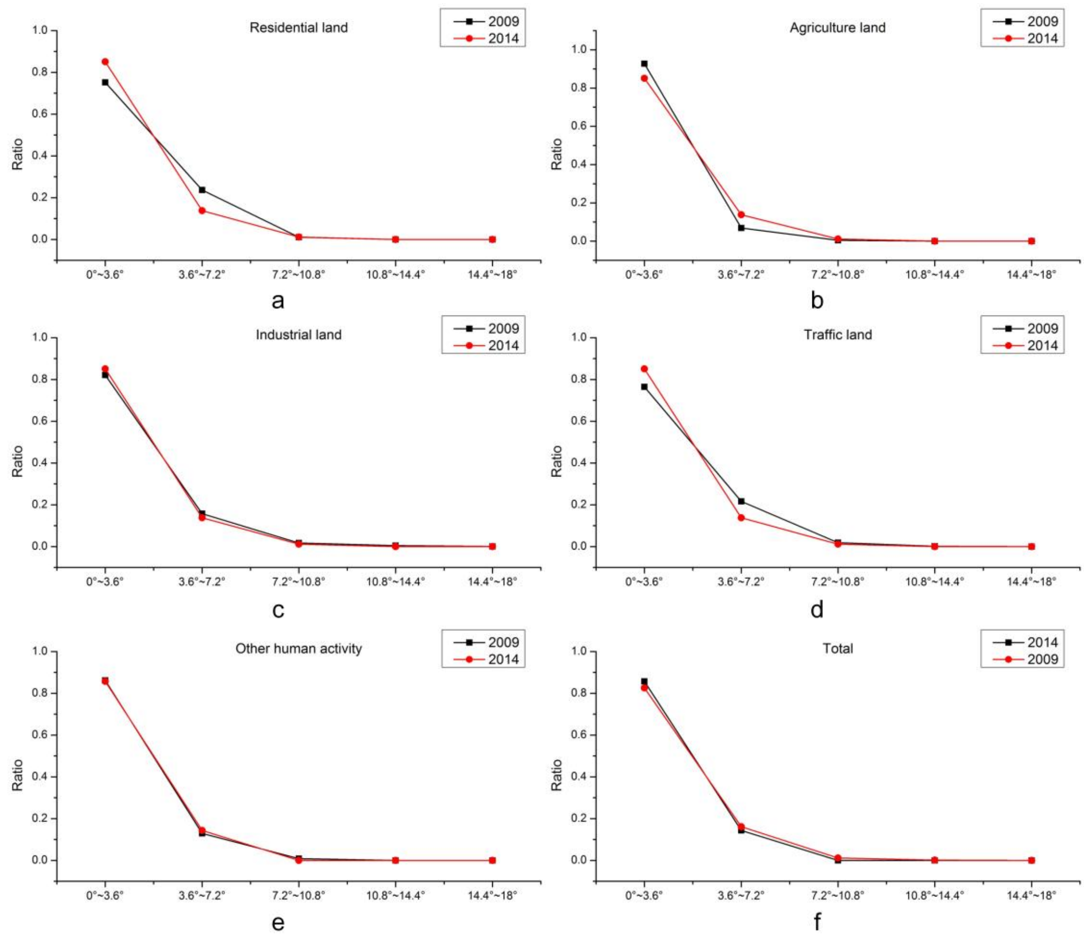

Figure 4. Ratio of human activities in different slope zones: (**a**) Residential land; (**b**) Agriculture land; (**c**) Insdustrial land; (**d**) Traffic land; (**e**) Other human activity; (**f**) Total.

3.3.2. Aspect

We were also interested in the relationship between land use and aspect. Aspect is one of the most import factors that influence the amount of sunshine received on the ground surface and the redistribution of solar radiation. Aspect has an important effect on light, heat, and moisture, and it influences on spatial pattern of land use in a certain extent [41]. We used DEM and slope to extract the aspect factor. The aspect factor can be classified into two types: shady slope and sunny slope. We defined the 90°–270° range as the sunny slope and the remainder of the range as the shady slope, clockwise where the north was set as 0°. Table 5 shows the statistical area of the different land uses in different aspects.

Table 5 and Figure 5 show the area ratios of human activities on sunny slopes in 2009 and 2014, which were higher than 60% and significantly higher than those in the shady slopes. In 2009, 69.87% of residential land, 55.97% of agricultural land, 62.24% of industrial land, 61.90% of traffic land, and 73.91% of other human activities occurred in the sunny slopes. In 2014, 61.57% of residential land, 60.09% of agricultural land, 61.41% of industrial land, 63.77% of traffic land, and 80.36% of other human activities occurred on the sunny slopes. Thus, sunny slopes are advantageous for human activities. The south-facing slopes can provide more sunshine; therefore, they are more conducive to human life than the north-facing slopes, where people generally choose to live.

Table 5. Distribution of human activities in different aspects.

Year	Aspect	Area (km^2)					
		Residential Lands	Agriculture Lands	Industrial Lands	Traffic Lands	Other Human Activities	Total
2009	sunny slope	1.04	6.45	8.50	2.93	0.65	19.57
	shady slope	0.45	5.07	5.16	1.81	0.23	12.71
2014	sunny slope	1.58	21.60	8.51	4.07	0.43	36.18
	shady slope	0.98	14.35	5.35	2.31	0.11	23.10

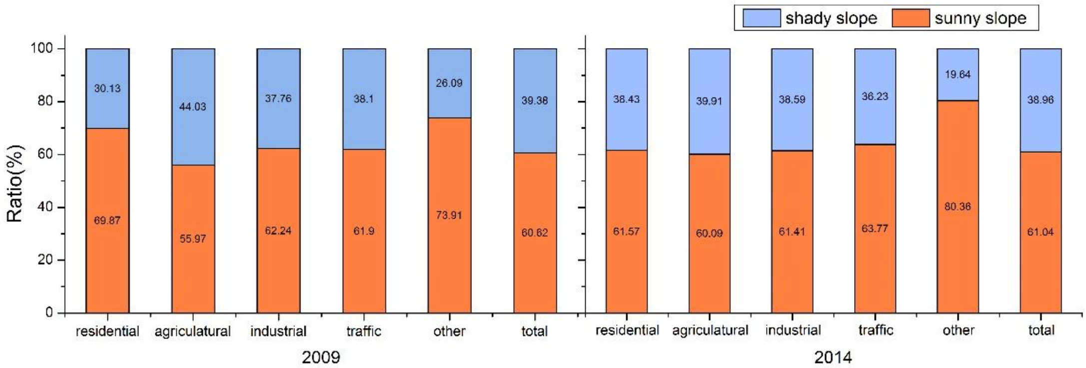

Figure 5. Ratio of human activities in different aspects.

A comparative analysis revealed that the area ratios of all the human land uses on sunny slopes in 2014 were nearly the same as those in 2009. Among of them, the areas of the industrial and traffic lands had no obvious change. Instead, the agricultural area and areas affected by other human activities slightly increased. The area ratios of the residential land decreased from 69.87% to 61.57%. These results indicate that the expansion of human activities occurred due to human adaptability to the environment and the possibility for humans to fulfill their physical needs: warmth and comfort.

4. Conclusions

Here, we analyzed the spatial distribution of anthropogenic activities in the Baijitan National Nature Reserve using remote sensing satellite images from 2009 and 2014. Our results indicate that the Baijitan National Nature Reserve was seriously disturbed by human activities. The area of anthropogenic activities in 2014 increased from 32.68 km^2 to 60.01 km^2; more than 70% of them occurred in the experimental zone and more than 20% occurred in the buffer zone. The increase of the NRHI (from 0.0901 in 2009 to 0.1127 in 2014) shows that the anthropogenic interference in the Baijitan National Nature Reserve was enhanced. Through a comprehensive analysis of the NRHI and the landscape indices, the PD (from 0.34 to 0.48), LSI (from 8.6 to 11), DIVISION (from 0.53 to 0.59), SHDI (from 0.25 to 0.39), and SHEI (from 0.13 to 0.2) were proportional to the NRHI, and the CONTAG (from 92.87 to 89.16) was inversely proportional to the NRHI. The analysis of the distribution of anthropogenic activities shows that up to 99% of the anthropogenic activities occurred in the range of 0 to 7.2 degrees. Among them, 84.54% of the anthropogenic activities occurred in the range of 0 to 3.6 degrees and 14.43% in the range of 3.6 to 7.2 degrees. In addition, more than 60% of the anthropogenic activities occurred on the sunny slopes. Therefore, we can conclude that human activities in nature reserves are the result of human adaptability to the environment and the possibility for humans to fulfill their physical needs: warmth and comfort. Thus, nature reserve monitoring needs to be further strengthened and focused on the area that ranges from 0–7.2 degrees and on the sunny slopes.

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Author Contributions: Yaohuan Huang and Dong Jiang conceived and designed the experiments; Xiaoyang Song performed the experiments; Jingying Fu analyzed the data; Guangjin Tian contributed materials; Xiaoyang Song wrote the paper. All authors read and approved the manuscript.

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