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# Study on the Change of Eco-Environmental Quality in Jiufeng Mountain Area Based on InVEST Model

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## Abstract

Habitat is not only an important place for animals and plants to inhabit and reproduce, but also the basis of human survival and development. With the large-scale development of mineral resources, land use types have changed sharply, fragile habitats tend to collapse, and the future sustainable development has lost a stable carrier. Habitat quality is a comprehensive expression of the interaction of many factors such as land, biology and water resources for many years. Natural factors are the most direct factors affecting habitat quality, and human activities are the most intense factors. The habitat module of invest model was used to evaluate the changes and temporal and spatial characteristics of habitat quality in Jiufeng Mountain from 1990 to 2018. It is found that the habitat quality in Jiufeng Mountain area shows a downward trend, and the ecological environment is very fragile. The high value areas of eco-environmental quality are mainly distributed in mountainous and hilly areas with high vegetation coverage; The low value areas of eco-environmental quality are mainly distributed in industrial and mining land and gully areas. With the development of society and economy and the development of mining industry in Jiufengshan area, the area of construction land is also increasing.

## Keywords

Habitat Quality, Land Use Change, InVEST Model, Jiufengshan Area

## 1. Introduction

Human activities, especially large-scale mining of mineral resources, have destroyed the original landscape, surface soil, surface vegetation and biological community structure, forming a fragile ecological area sensitive to external environmental changes [1]. Such ecosystems are prone to succession in an unstable direction [2] [3] [4]. The risk assessment of habitat quality and evolution in mining area is the premise of correctly understanding the natural environment and artificial interference factors. The natural environment determines the stability of the ecological environment [5]. Human large-scale unreasonable utilization makes the fragile habitat more dangerous [6], and even collapse [7]. One of the main factors of land use and cover change is human development and utilization of natural resources. It is found that LULC is the main factor driving habitat quality [8] [9] [10]. Land use change explains the direction and trend of habitat quality change [11], and reveals the impact of human activities on habitat. The commonly used transfer matrix [12], landscape pattern [13], pollution assessment [14] [15] [16], ecological restoration [17] and other indicators and methods are evaluated to provide objective reference for human beings to better protect the mining environment [17] and take vegetation reconstruction [18] [19]. At the same time, in the mining process, we must do a good job in the environmental treatment, protection and planning of the mining area to reduce the damage to the environmental ecosystem caused by blind development. Based on the ecosystem service system evaluation model system [20], the change of ecosystem service value can be effectively evaluated [21]. Combined with natural, social and economic indicators, such as slope, altitude, soil conservation, carbon sink [22], population density, etc., evaluate local habitat quality and ecological value [23] [24], put forward ecosystem service and trade-off model [25], and make corresponding prediction [26], which can provide an implementation framework for future ecological protection and environmental governance [27].

Jiufeng Mountain in Baotou City, Inner Mongolia is located in a semi-arid climate area. The natural environment in mountainous areas is complex, the soil layer is barren, the land use mode in some areas changes sharply, and the mining activities in mountainous areas are frequent. The factors affecting the change of ecological environment quality are complex. At the same time, the habitat in Jiufeng Mountain area has obvious characteristics of nature, diversity, vulnerability and rarity. Therefore, this paper selects this area as the research object, which is representative. The changes of habitat quality and its relationship with risk factors in Jiufeng Mountain Ecological Reserve in recent years are analyzed by using GIS and investment model, which provides a reference basis for preventing the deterioration of habitat quality in Jiufeng Mountain Ecological Reserve. Remind stakeholders to pay attention to the protection and management of future habitats in Jiufengshan mining area.

## 2. Materials and Methods

### 2.1. Study Area

Jiufengshan mining area is located in Tumed Right Banner, Baotou City, Inner

Mongolia Autonomous Region. It is located in the middle of Yinshan Mountain range. Jiufengshan nature reserve covers a total area of 460 km$^2$, ranging from 40˚41'N - 40˚43'N and 110˚43'E - 110˚45'E (**Figure 1**). It is 60 km away from Baotou City and 80 km away from Hohhot city. It is adjacent to Beijing Baotou railway and National Highway 110 in the south. Jiufeng Mountain is the main peak of Daqing Mountain in Yinshan Mountain range, with an altitude of 2337.8 m. The natural vegetation such as forests and shrubs on the yinpo slope in the area is well preserved. Jiufeng Mountain system is mostly east-west, low in the South and high in the north. Jiufeng Mountain section belongs to the higher peak in the middle of Daqingshan National Nature Reserve, with Daqingshan Mountain as the boundary. The north of the mountain belongs to the Inner Mongolia axis of North China and the south of the mountain belongs to Ordos Zhongtai depression; The terrain here is open, slightly undulating, and there are scattered depressions. The surface is the impact of the Yellow River, and the underground layer is the lacustrine deposit.

Jiufeng Mountain is located in the mid temperate continental semi-arid monsoon climate area, with obvious boundaries in four seasons; Winter is long and cold, and summer is short and warm; The temperature difference between day and night is large, with the annual average temperature of 7˚C, the maximum temperature of 38.1˚C and the minimum temperature of −37˚C; The rainfall in summer is obvious, accounting for about 85% of the whole year; The frost free

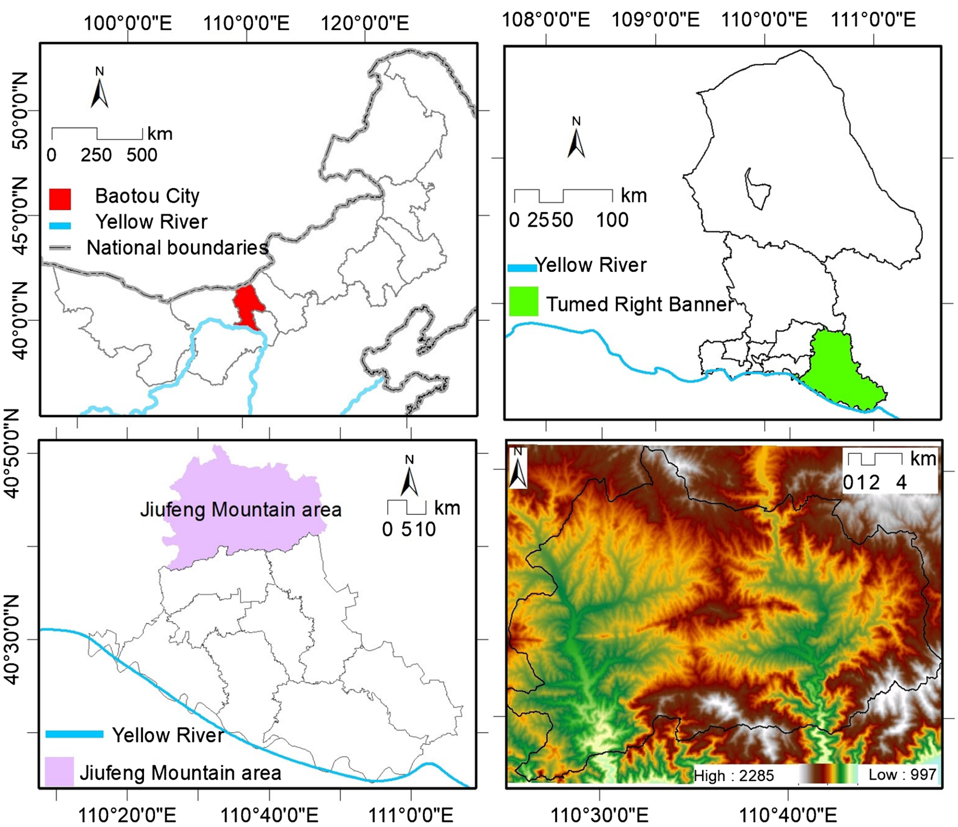


**Figure 1.** Location map of Jiufeng Mountain Area.

period is about 132 days, and the climate is suitable; The annual average evaporation is 2055 mm, and the maximum evaporation is from May to July, accounting for more than 50% of the annual evaporation. The soil type of Jiufeng Mountain belongs to gray cinnamon soil, which is divided into six types, namely gray cinnamon soil, chestnut soil, meadow soil, aeolian sand, saline soil and swamp soil. The soil is thin and thick with uneven layers, and there are exposed rocks in some places. The seasonal streams in Jiufeng Mountain area belong to meidaigou water system.

## 2.2. Data Sources

The land use data used in this paper comes from four 1:100,000 grid data sets in 1990, 2000, 2010 and 2018 provided by the resource and environmental science and data center of the Chinese Academy of Sciences (http://www.resdc.CN/default.ASPX). The land use data adopts a secondary classification system (**Table 1**), with a total of 6 primary classifications and 22 secondary classifications. DEM elevation data is downloaded from geospatial data cloud with a resolution of 30 m.

## 2.3. Methods

In this paper, the "habitat quality" module of the invest model is used to analyze the changes of habitat quality in Jiufeng Mountain from 1990 to 2018. The invest model is a comprehensive evaluation model that can be used for ecosystem services and trade-offs [28] which realizes the spatialization of the quantitative evaluation of the value of ecosystem services. The biggest advantage of this model is that its results are highly visible. It solves the problem that the previous ecosystem service function and habitat quality assessment are expressed abstractly but not intuitive [29]. The habitat quality module in the invest model is mainly used to evaluate the habitat quality. The grid land use data of the study year are reclassified according to the threat factor type. The coefficients corresponding to the selected threat factors can be queried in the land use remote

**Table 1.** Land use classification system.

| Primary land type | Secondary land type |
|---|---|
| Cultivated land | dry lands |
| woodland | woodland, shrub, open woodland, other woodland |
| grassland | high coverage grassland, medium coverage grassland, ground coverage grassland |
| waters | canals, lakes, reservoirs, ponds and beaches |
| Construction and industrial and mining land | urban land, rural residential areas, other construction land |
| Unused land | sandy land, saline alkali land, swamp land, bare land, bare rocky land |

sensing data of the national geographic information resource directory service system, and all layers are exported and loaded into the invest model, The habitat quality from 1990 to 2018 is calculated driven by threat factors and sensitivity coefficients. The calculation formula of habitat quality is:

$$Q_{xj} = H_j \left[ 1 - \frac{D_{xj}^z}{D_{xj}^z + k^z} \right] \tag{1}$$

In the formula: $Q_{xj}$ is the habitat quality index of grid $x$ in habitat type, $H_j$ is the habitat suitability of land use type $j$, $k$ is the semi saturation constant, $D_{xj}$ is the interference level of grid $x$ in land use type $j$, $z$ is the normalization constant, The default value of the model is 2.5.

The geographic detector is used to measure the driving factor. It is a spatial analysis method suitable for measuring the degree of spatial stratification heterogeneity. It is not based on linear hypothesis, but compares the spatial distribution of independent variables with the distribution of potential factors. The basic principle is that the total sample is divided into several sub samples, and the variance is used to judge the spatial heterogeneity and variable relationship; If the sum of variance of sub samples is less than the total variance of all samples, there is a spatial difference. If the spatial distribution of the two variables tends to be consistent, there is a statistical correlation between the two variables. The calculation formula is:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N \sigma^2} \tag{2}$$

where: $q$ is the explanatory power of an influencing factor on the temporal and spatial changes of habitat quality; $h$ is the number of classifications or partitions of factors; $l$ is the number of samples of influencing factors; $N_h$ and $N$ are the number of units of class $l$ and the whole region, respectively; The $q$ value is between 0 ~ 1, and the greater the $q$ value, the stronger the spatial heterogeneity of habitat quality.

Run the habitat quality model to input data such as threat factors and sensitivity of threat factors. In this paper, four land use types such as agricultural land, urban land, rural residential land and industrial and mining land are set as threat factors, and the data of threat factors are extracted (Table 2 and Table 3).

Table 2. Threat factors and threat degree.

| Threat factor | Maximum threat distance | Weight | Spatial decay type |
|---|---|---|---|
| Agricultural land | 8 | 0.7 | linear function |
| Urban land | 10 | 1.0 | exponential function |
| Rural residential land | 5 | 0.6 | exponential function |
| Industrial and mining land | 8 | 1.0 | exponential function |

Table 3. Sensitivity of land use types to habitat threat factors.

| Serial number | Land use type | Habitat suitability | Agricultural land | Urban land | Industrial and mining land | Rural residential land |
|---|---|---|---|---|---|---|
| 11 | Paddy field | 0.3 | 0.3 | 0.5 | 0.5 | 0.7 |
| 12 | Dry land | 0.3 | 0.3 | 0.5 | 0.5 | 0.7 |
| 21 | Woodland | 1 | 0.7 | 0.5 | 0.55 | 0.85 |
| 22 | Shrubwood | 0.9 | 0.6 | 0.8 | 0.6 | 0.45 |
| 23 | Open woodland | 0.7 | 0.6 | 1.0 | 0.75 | 0.9 |
| 24 | Other woodlands | 0.5 | 0.8 | 1.0 | 0.65 | 0.95 |
| 31 | High coverage grassland | 0.8 | 0.5 | 0.6 | 0.3 | 0.45 |
| 32 | Medium coverage grassland | 0.75 | 0.55 | 0.65 | 0.4 | 0.5 |
| 33 | Low coverage grassland | 0.7 | 0.5 | 0.7 | 0.5 | 0.55 |
| 41 | Canal | 0.8 | 0.65 | 0.85 | 0.9 | 0.7 |
| 42 | Lake | 1 | 0.7 | 0.9 | 0.8 | 0.75 |
| 43 | Reservoir | 0.7 | 0.7 | 0.9 | 0.8 | 0.75 |
| 46 | Beach land | 0.5 | 0.75 | 0.95 | 0.8 | 0.8 |
| 51 | Urban land | 0 | 0 | 0 | 0 | 0 |
| 52 | Residential area | 0 | 0 | 0 | 0 | 0 |
| 53 | Other construction land | 0 | 0 | 0.7 | 0 | 0 |
| 61 | Sand | 0.01 | 0.1 | 0.1 | 0 | 0.1 |
| 63 | Saline alkali land | 0.01 | 0.1 | 0.1 | 0 | 0.1 |
| 64 | Swamp | 0.9 | 0.7 | 0.7 | 0.7 | 0.7 |
| 65 | Bare land | 0.01 | 0.1 | 0.1 | 0 | 0.1 |
| 66 | Bare rock | 0.7 | 0 | 0 | 0 | 0 |

# 3. Result

## 3.1. Analysis of Temporal and Spatial Variation of Habitat Quality

The habitat quality of each grid in Jiufengshan mining area in 1990, 2000, 2010 and 2018 is obtained by using the invest model. In ArcGIS, the habitat quality of Jiufengshan is divided into five levels by using the natural breakpoint method: low level, lower level, medium level, high level and higher level (Figure 2). The value of habitat quality index is 0 - 1. The larger the value, the better the habitat quality in this area, the model evaluation results show that the habitat quality in the southeast corner of the study area is the best, and the habitat quality in the West and south is low. Jiufengshan mining area is located in the northeast of Tumed Right Banner and in the area with high habitat quality. It can be seen that the area with high habitat quality can account for about 80% of the total area of the study area, but the habitat quality around Jiufengshan mining area will decline from high to low in 2018. The habitat quality around the southwest

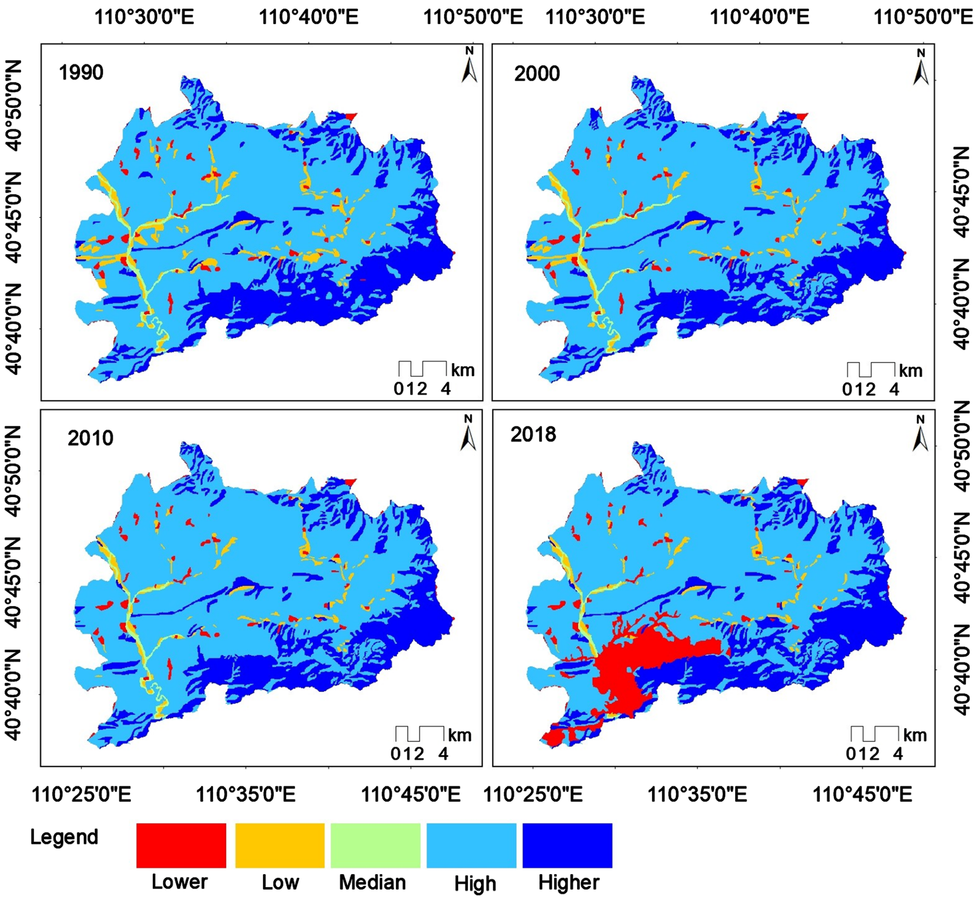


Figure 2. changes in habitat quality of Jiufeng Mountain from 1990 to 2018.

boundary line increased, and the habitat quality in the central region decreased. The habitat quality in the study area decreased slightly from 1990 to 2000, remained stable from 2000 to 2010, and showed a downward trend from 2010 to 2018. The quality of higher habitat decreased the most from 1990 to 2000, while the quality of higher habitat decreased the most from 2000 to 2018; In 2000, the lower habitat quality increased by 0.05 compared with 1990, and then remained stable; From 1990 to 2018, the area proportion of low-grade habitat quality fluctuated (**Figure 3**).

In terms of spatial distribution pattern, the high-value areas of habitat quality are mainly distributed in the southeast and north of Jiufeng Mountain area, and are scattered in the valley areas within the region. However, from the habitat quality in 2018, it can be seen that the habitat quality near Jiufeng Mountain area has decreased seriously, directly from higher level to lower level, and the area of low-level habitat quality has increased significantly. On the whole, the decline of habitat quality in Jiufengshan mining area is obviously related to the change of land use types. The total land area of Jiufengshan mining area is 501.54 $km^2$, By analyzing the area proportion occupied by different levels of habitat quality every year (**Table 4**), it can be found that the area occupied by low-level habitat quality has increased, from 2.46% in 1990 to 10.19% in 2018, while the area

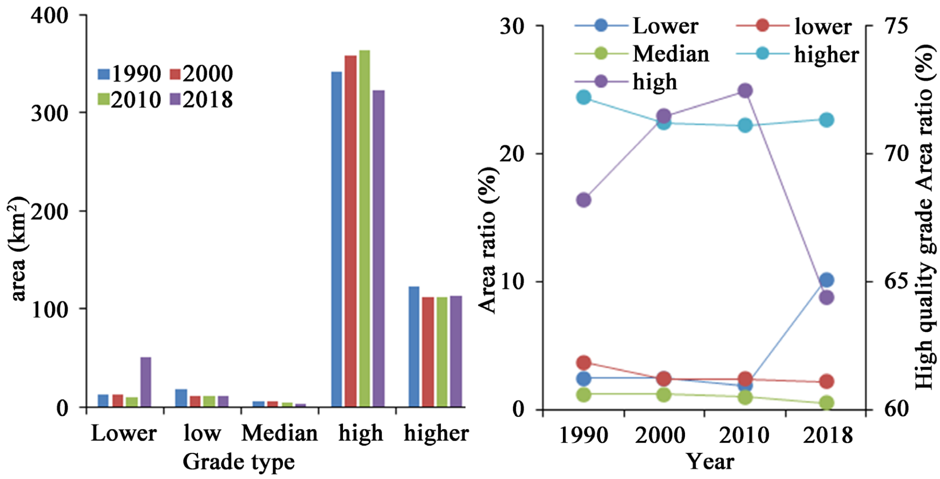


**Figure 3.** Percentage of habitat quality area from 1990 to 2018.

**Table 4.** Habitat quality statistics of Jiufeng Mountain from 1990 to 2018

| Serial number | Land use type | Habitat suitability | Agricultural land | Urban land | Industrial and mining land | Rural residential land |
|---|---|---|---|---|---|---|
| 1990 | $km^2$ | 12.32 | 18.66 | 6.05 | 342.02 | 122.49 |
| | % | 2.46 | 3.72 | 1.21 | 68.19 | 24.42 |
| 2000 | $km^2$ | 12.31 | 12.13 | 6.05 | 358.52 | 112.54 |
| | % | 2.45 | 2.42 | 1.21 | 71.48 | 22.44 |
| 2010 | $km^2$ | 9.53 | 12.14 | 4.90 | 363.44 | 111.53 |
| | % | 1.90 | 2.42 | 0.98 | 72.46 | 22.24 |
| 2018 | $km^2$ | 51.11 | 11.10 | 2.83 | 322.93 | 113.57 |
| | % | 10.19 | 2.21 | 0.56 | 64.39 | 22.67 |
| 1990-2000 | (%) | −0.08 | −34.99 | 0.00 | 4.82 | −8.12 |
| 1990-2000 | (%) | −22.58 | 0.08 | −19.01 | 1.37 | −0.90 |
| 1990-2000 | (%) | 43.60 | −8.57 | −42.20 | −11.15 | 1.83 |

proportion occupied by lower level, intermediate level, high-level and higher-level has decreased, from 3.72%, 1.21%, 68.19% and 24.42% to 2.21%, 0.56% respectively 64.39% and 22.67%. On the whole, the habitat quality in the study area is developing in a good direction, but the rate is relatively slow. The area of low and lower habitat quality in the study area can be as high as more than 50%, which shows that the study area is vulnerable to natural and human factors, and the area of ecologically fragile area is relatively large.

## 3.2. Analysis of Land Use Change

From the area proportion of each land use type (**Figure 4**), cultivated land, grassland and forest land are the main land use types in Jiufengshan mining area, of which grassland accounts for the largest proportion, accounting for

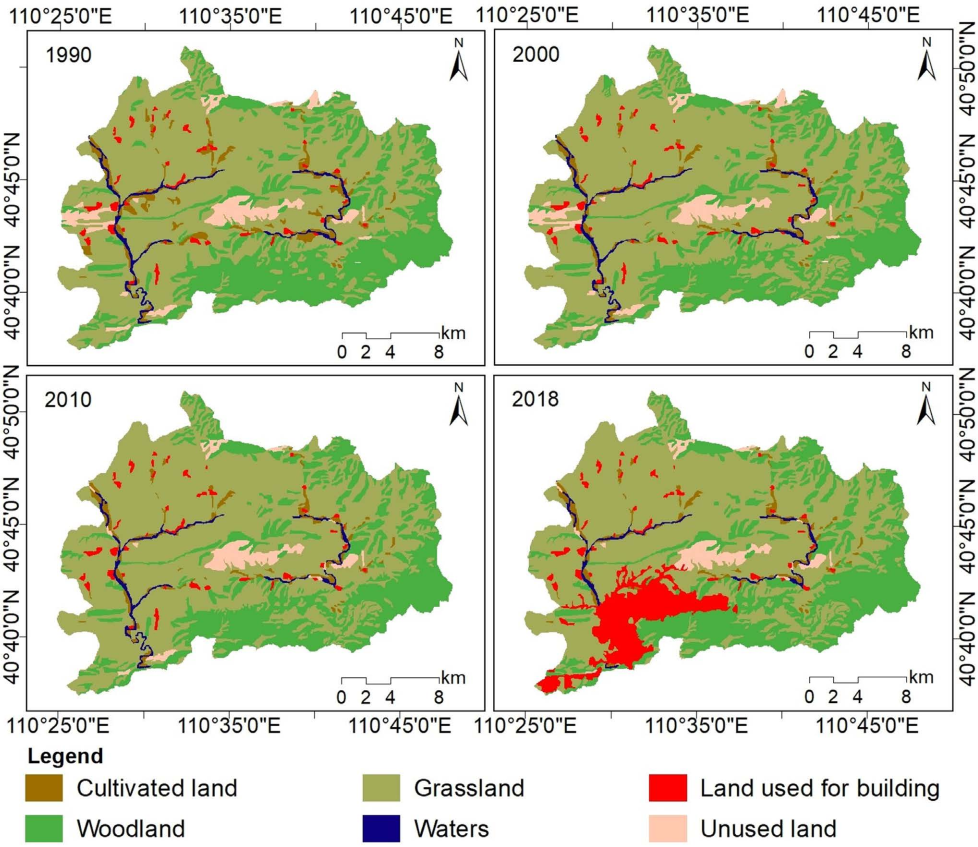


**Figure 4.** Statistics of land use change in Jiufengshan area from 1990 to 2018.

about 75% of the total land area. From 1990 to 2018, grassland and forest land constituted the main land use type of Jiufeng Mountain, with a total area of more than 70%. From 1990 to 2000, the area of grassland increased significantly and the area of cultivated land and forest land decreased; From 2000 to 2010, the area of grassland continued to increase, and the area of forest land and water area decreased, but the reduction range was small; From 2010 to 2018, the area of construction land increased greatly, which can be clearly seen from the figure.

The area of construction land in Jiufengshan mining area has continued to increase in the past 28 years, but the change is most obvious from 2010 to 2018. Grassland increases first and then decreases, while the area of forest land decreases first and then increases. There are many cultivated land and forest land transferred to grassland and construction land, and there are many grasslands trans-formations, indicating that grassland is an important source of the increase of construction land area in recent years, and some grassland is transformed to cultivated land. Generally speaking, the overall characteristics of land use in Jiufengshan mining area from 1990 to 2018 are forest land, the conversion between cultivated land, grassland and construction land (Table 5). From 1990 to 2000, the largest land use type transferred from Jiufeng Mountain was grassland, of which the main sources of grassland were cultivated land and forest land, with a transfer area of 6.53 $km^2$ respectively And 9.08 $km^2$, The main sources

**Table 5.** Habitat quality statistics of Jiufeng Mountain from 1990 to 2018.

| Year | Cultivated Land | Woodland | Grassland | Waters | Construction and industrial and mining land | Unused Land |
|---|---|---|---|---|---|---|
| 1990 | 18.66 | 142.61 | 301.95 | 8.89 | 7.27 | 20.46 |
| 2000 | 12.13 | 133.52 | 317.58 | 8.89 | 7.26 | 20.45 |
| 2010 | 12.14 | 133.29 | 324.09 | 8.15 | 7.31 | 14.93 |
| 2018 | 11.11 | 133.37 | 286.91 | 6.11 | 48.89 | 13.52 |

of construction land transfer are forest land and water area, and the habitat quality shows an upward trend; From 2000 to 2010, the area of cultivated land increased by 0.05 km$^2$, The area of forest land and water area decreased by 0.33 km$^2$ respectively And 0.73 km$^2$, Habitat quality remained basically unchanged; From 2010 to 2018, the grassland around Jiufeng Mountain was trans-formed into construction land, with a transfer area of 37.18 km$^2$, Compared with 2000-2010, the transferred area increased slightly, the area occupied by low-level habitat quality increased relatively, and the overall habitat quality showed a down-ward trend.

### 3.3. Habitat Quality Driving Force Analysis

The driving forces of different factors are different. It can be seen from **Table 6** that the decisive force is land use efficiency > altitude > temperature > population density > GDP > rainfall > slope. Each factor explains the spatial distribution of habitat quality to varying degrees. The determinant of land use coverage is higher than other factors, with a value of 0.587, which has become the dominant factor affecting regional habitat quality and the core factor affecting the spatial distribution of habitat quality, followed by temperature, with a determinant of 0.4294. According to the land use change in the study area, the expansion of construction land has become the biggest threat factor to the habitat quality of Jiufengshan mining area and the main reason for the decline of habitat quality. The increase of forest land, cultivated land and other land use areas is the main reason for the rise of habitat quality in the study area, and the change of land use rate is the core factor affecting the spatial distribution characteristics of habitat quality. With the development of economy, mining economic activities and corresponding production and construction activities lead to the increase of industrial and mining construction land and change the type of surface coverage, so the habitat quality will be reduced. Rainfall is also one of the factors leading to the decline of habitat quality, but its decisive power is not very strong. Other factors will also affect the spatial distribution pattern of habitat quality. Excessive rainfall will lead to natural disasters, cause great losses to human production and life, and weaken the service function of ecosystem, which will affect the climate regulation function of the system and worsen the habitat quality, At the same time, measures such as returning farmland to forest and grassland have

**Table 6.** Driving intensity of influencing factors of spatial distribution of habitat quality.

| Influence factor | Population density | GDP | rainfall | slope | altitude | air temperature | Land utilization rate |
|---|---|---|---|---|---|---|---|
| Driving effect | 0.2357 | 0.210 | 0.2066 | 0.1537 | 0.433 | 0.4294 | 0.587 |

played a key role in the restoration of ecosystem, increasing the area of grassland and forest land in the study area, which can effectively resist natural disasters. Therefore, efforts to restore biodiversity should be strengthened. At the same time, the mining volume of the mining area also affects the habitat quality. Excessive mining volume leads to the reduction of vegetation coverage in the area, the reduction of underground resources, and the destruction of aboveground and underground resources. Therefore, the habitat quality will be reduced and develop towards a lower level. In the future, we should strengthen the protection of the natural environment, implement ecological restoration and restore biodiversity, which can ensure the ecological security of the study area to a certain extent.

## 4. Discussion

Habitat quality is closely related to human survival and development [24]. The research on habitat quality in Jiufengshan mining area shows that the vulnerability of mountain habitat and human activities are important factors affecting habitat quality [30]. In recent years, with the expansion of construction land, the damage to forest land, cultivated land, grassland and other natural landscapes has become increasingly serious [31], so it is necessary to establish a reasonable expansion range of construction land. While doing a good job in rational land use management [32], we should also actively promote the project of returning farmland to forest and grassland in the mining area, increase the construction of ecological governance projects in the mining area [33], improve the habitat quality and reduce the intensity of habitat degradation. In terms of policy, we should strengthen financial support for habitat quality transformation in mining areas, formulate more stringent ecological protection system [34], and pay attention to the accuracy and consistency of policies. Especially in fragile mountain ecological areas driven by natural conditions such as climate, terrain and precipitation, whether the implementation of habitat protection policies is strict, whether the scope of institutional measures includes strict restrictions on unreasonable methods [35]. The change of land use type is the main reason for the decline of habitat quality in the study area [36]. LULC is consistent with the change of habitat quality in ecologically fragile areas; The direction and intensity of human development and utilization of land resources have directly led to changes in ecological landscape and habitat quality. Of course, only economic interests are considered without considering the development of ecological environment, resulting in new land use modes with low habitat quality [37] [38].

## 5. Conclusions

Taking Jiufengshan mining area in Baotou as an example, based on the grid LULC data of four periods in 1990, 2000, 2010 and 2018, and using the data results of invest model, this paper mainly discusses the change factors affecting habitat quality from the change of land use type, and divides the change of habitat quality into three stages: 1990-2000, 2000-2010 and 2010-2018, and draws the following conclusions: 1) From 1990 to 2000, the habitat quality of Jiufengshan mining area remained balanced, which was in the high-level and higher-level range as a whole, with strong ecosystem stability and strong resistance to interference from nature and human activities. 2) From 2000 to 2010, on the whole, the habitat quality of the study area changed to high-level and higher-level areas, which were scattered around the boundary line, but had little impact on the assessment of the change of habitat quality in the study area. During the study period, the area of forest land and grassland decreased and the area of cultivated land increased. This change was mainly distributed around Jiufeng Mountain. 3) From 2010 to 2018, the habitat quality showed a downward trend, and the habitat quality around Jiufeng Mountain area directly decreased from high to low. The main reason for the decrease is that a large area of grassland and cultivated land around Jiufeng Mountain has been transformed. The habitat quality in the north is greater than that in the south, but the habitat degradation intensity in the north is less than that in the south, but the overall development is still in a better direction.

In recent years, the area of industrial and mining land has expanded, and Jiufeng Mountain area is a concentrated area of industrial land, which will lead to the decline of regional habitat quality. In addition, the habitat quality in other areas has increased to varying degrees, which is mainly due to the important measures of returning farmland to forest in Jiufeng Mountain area. The area with low habitat quality is the Southwest River Valley. With the abandonment of cultivated land and the expansion of industrial and mining land, it is also the main reason for the decline of habitat quality in this area. With the strengthening of ecological environment protection and reconstruction in the country and autonomous region, it is necessary to strengthen vegetation reconstruction and ecological restoration in areas with drastic changes in habitat quality and serious vegetation damage, break through the restrictions of difficult site conditions, increase the ecological environment in mining areas, and curb the rate of habitat degradation through government, enterprises and overall coordination. Promote the overall improvement of habitat quality in the whole region from point to area.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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