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Evaluation for Appropriate Tillage of Sandy Land in Arid Sandy Area Based on Limitation Factor Exclusion Method

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Abstract: Investigating and evaluating the quantity and spatial distribution of arable sandy land in arid and semiarid sandy areas is of great significance for the sustainable development and utilization of sandy land resources and the maintenance of the stability of the structure and function of regional ecosystems. Based on the characteristics of sandy soil, being without structure and susceptible to wind erosion, this study used the limiting factor exclusion method to investigate and evaluate arable sandy land in arid and semiarid areas. All sandy soils were taken as the evaluation objects of arable sandy land (including visible sandy land and invisible sandy land). On the basis of following the principle of ecological protection, the evaluation indicators and limiting factor exclusion evaluation methods of arable sandy land were determined. The results of Hangjin Banner are as follows: the total area of the visible sandy land and the recessive sandy land was 1.2 × 106 hm^2; the visible sandy land accounted for 42.6%, and the invisible sandy land accounted for 57.5%. However, only 7.7% of the sandy land was suitable for farming, which is the current cultivated land of bare sand and sandy soil, extremely-low-coverage grassland, inland tidal flats, and other saline-alkali land. Even if these arable sandy lands are to be used sustainably after reclamation, reasonable ecological protection, irrigation engineering measures, and field protective farming measures must be taken. It is hoped that this study can provide a valuable reference for the sustainable development and utilization of arable sandy land and desertification control in arid and semiarid areas.

Keywords: appropriate tillage sand land; land survey; limiting factor; land evaluation

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1. Introduction

Desertification is a common type of land degradation in ecologically fragile areas [1,2]. It can threaten regional environmental security and is becoming an important barrier that hinders the global economy and the transition to a sustainable society [3]. In general, desertification refers to land degradation that is dominated by sand or gravel due to natural and human factors under various climatic conditions [4]. Sandy land refers to the land formed by the process of desertification, and the surface is mainly sand (or gravel) material. Research shows that desertification may be caused by natural or human factors, among which human factors play an important role in the process of land desertification [5,6]. In arid and semiarid areas, unreasonable land use will lead to the decline of vegetation coverage and the destruction of soil structure, which will lead to desertification [7,8]. Excessive reclamation is an important inducer of land desertification [9]. The growing coverage of sandy land is becoming an important issue and poses a serious threat to the sustainability of human habitation, especially in China [10]. Therefore, the protection and management of desertification land and the sustainable utilization of desertification land resources have attracted extensive attention from government departments and researchers [11,12].

There are two different views on the utilization of sandy land in the existing research. One is to protect the sandy land and abandon it completely, so that some sandy land that can be improved by engineering, is suitable for farming, and that can produce food has not exerted its production potential [13,14]. Second, there is a lack of supervision to include sandy land in the reserve resource pool of cultivated land. The disorderly and excessive development of sandy land destroys the balance of regional water resources and accelerates the speed of land wind erosion and desertification [15–17]. The existing studies on land desertification mainly focus on the process and causes of desertification [18,19], the desertification degree evaluation method and evaluation index system [20,21], desertification risk analysis [22,23], dynamic monitoring of land desertification [24,25], and sand control [26]. In addition, under the climate conditions of arid and semiarid areas, sandy soil flows in the wind because its sand particles are non-cohesive and single granular, resulting in rapid changes in land cover and landform [27,28]. As a result, the evaluation objects of existing studies on sandy land are mostly aeolian sandy soil or sandy land, which cannot cover all sandy soils [29,30]. Obviously, the evaluation and explanation of suitable sandy land in the existing research is insufficient, and it is necessary to carry out more detailed and targeted research to scientifically and rationally promote the protection and sustainable use of sandy land.

Therefore, this study defined suitable arable sandy land as sandy land suitable for crop growth, depending on natural conditions or with certain artificial measures. Based on the above characteristics of unstructured and wind-eroded sandy soils in arid and semiarid areas, the evaluation object of arable sandy soil was determined as all sandy soils without considering surface cover (land use type), and the study area is Hangjin Banner, Inner Mongolia, which is an arid and semiarid area with an obvious current land use structure. Then, the limitation factor exclusion method was used to carry out the investigation and evaluation of arable sandy soil in arid and semiarid areas, determine the quantity and distribution of arable sandy soil in the region, treat the development and protection of sandy soil from the perspective of ecological security, and put forward the direction and measures of arable sandy land development. We hope that the research results can provide a valuable reference for the sustainable development and utilization of arable sandy land and desertification control in arid and semiarid areas.

2. Materials and Methods

2.1. Study Area

Hangjin Banner is located in southwestern Inner Mongolia, northwest Ordos city, with a total area of 1.89×104 km^2 (Figure 1). It is located in a mid-temperate monsoon continental climate with low annual rainfall and an uneven regional distribution of rainfall. The average annual rainfall is 281 mm, decreasing from southeast to northwest. The rainfall is concentrated from June to August, and the interannual variation is large. The annual evaporation is 2630 mm, which belongs to the arid and semiarid area. The topography of Hangjin Banner consists of alluvial plains of the Yellow River, sandy deserts, wavy high plains, and hills inlaid and arranged, with an obvious zonal distribution pattern (http://www.hjq.gov.cn/, 1 April 2022). The soil type is mainly aeolian sandy soil, which is distributed along the northern edge of the Kubuqi Desert and the Mu Us Sandy Land, accounting for 58.7% of the total area of Banner. Other soil types, such as fluvo-aquic soil, saline soil, brown calcium soil, chestnut soil, and grey desert soil, are sporadically distributed. Due to the large variability in annual precipitation and the loose sandy substances in sediments, Hangjin Banner will have a large risk of desertification with unreasonable development. In 2020, Hangjin Banner's Gross Domestic Product (GDP) was 12.8×10^9 Chinese Yuan (CNY), a 2.3% increase from 2019, and the per capita disposable income was 33,084 CNY, a 3.5% increase from 2019 (The Government of Hangjin Banner, 2021). In addition, because of the limitation of natural and socioeconomic conditions in Hangjin Banner, the current structure of land use is embodied in the high proportion of grassland and unused land (sand land), accounting for 50.0% and 28.8%, respectively, and the proportion of cultivated land and forestland is low, 3.5% and 9.2%, respectively (http://nmggky.cn/ 1 April 2022). Because Hangjin Banner has obvious regional differences in land use, with obvious differences between the planting areas along the Yellow River in the north and the high plains and sandy animal husbandry areas in the central and southern parts, it was selected as a typical case for empirical research.

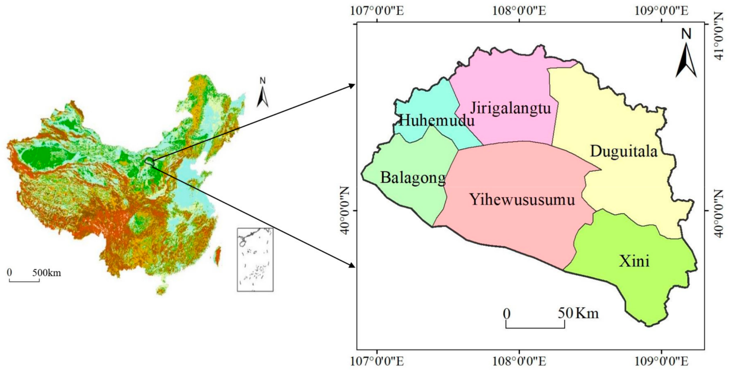

Figure 1. Location of the research area.

2.2. Data Source and Process

Hangjin Banner has a vast area and requires three remote sensing images to cover the entire administrative area. The strip numbers on the OLI-TIRS remote sensing images were 128/032, 129/032, and 128/033. Summer is the best time to extract information on sand, grassland, and other land types because vegetation grows luxuriantly. Therefore, the acquisition time of the Hangjin Banner Landsat 8 remote sensing images was from 1 August 2020 to 1 September 2020. At the same time, the cloud cover of the three remote sensing images was less than or equal to 4%. The pre-processing of remote sensing images includes radiometric correction, atmospheric correction, and image mosaicking and cropping. The data of soil, meteorological, socioeconomic, and land use came from the second soil census in Hangjin Banner, the daily value dataset of climate data in the past 30 years, "Hangjin Banner's National Economic Statistics (2004–2020)", and the land of Hangjin Banner in 2020 Utilize change investigation database (1:10,000), "Hangjinqi Salinization Grade Map" (1:250,000).

2.3. Evaluation Method

2.3.1. Clarity of Evaluation Object

The "Land Use Status Classification" (GB/T 21010-2007) defines sandy land as land with a surface covered by sand and basically without vegetation. Low vegetation coverage and bare sandy soil on the surface can be perceived through the surface morphology of the land, which is an intuitive and realistic reflection of land degradation. This study defined the existing sandy land as visible sandy land and defines other land use types except the existing sandy land, and its soil texture is sandy soil as invisible sandy land (Figure 2).

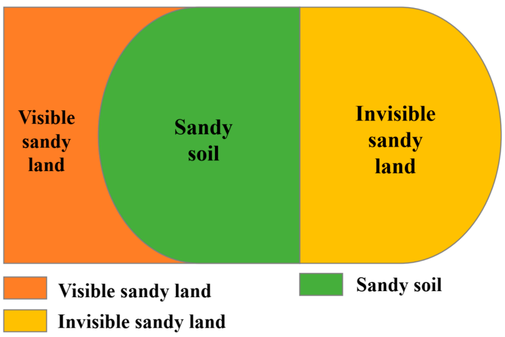

Figure 2. Relationship between sand land type and sandy soil.

All visible and invisible sandy land was considered as the object of investigation and evaluation of sandy land suitable for cultivation. According to the survey results of land use change in Hangjin Banner in 2013, the land use type of sandy land (land type code: 126) was extracted on the geographic information system (GIS) platform as the spatial range of dominant sandy land. The extraction process includes two aspects: one is the extraction of sandy soil. According to the analysis of soil types in Hangjin Banner, the sandy soil types in the soil map were extracted, including mobile aeolian soil, semifixed aeolian sand, fixed aeolian sand, sandy chestnut calcium soil, sandy fluvo-aquic soil, and sandy light brown calcium. There are 9 soil types in total: soil, sandy brown calcium soil, and sandy flood silt soil. The second is the extraction of invisible sandy land. With the help of the spatial superposition function of GIS, the superposition of the obtained sandy soil and the land use types outside the sandy land is the recessive sandy land. For the existing cultivated land, all are considered invisible sandy land (Figure 3).

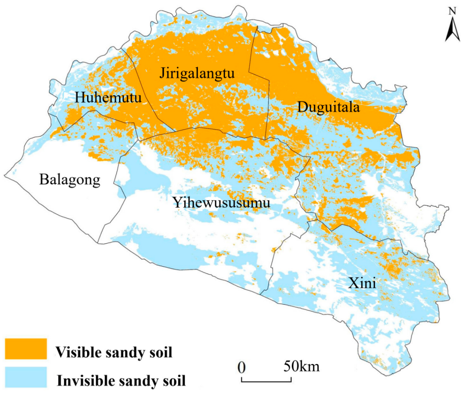

Figure 3. Type and spatial distribution of sandy land in Hangjin Banner.

2.3.2. Construction of the Evaluation Index System

Based on the natural and socioeconomic conditions of Hangjin Banner and combining existing research, this study constructed an evaluation index system for limiting factors of suitable arable sandy land in arid and semiarid regions. Evaluation indicators include land use type and vegetation coverage [31], irrigation conditions [32], ecological conditions [33], and soil properties [34,35] (Table 1).

Table 1. Limited evaluation index system of appropriate tillage sandy land.

Limited Evaluation Index	Inappropriate Tillage
Land use type	Other land use types except very-low-coverage grasslands (natural pastures and artificial pastures), other grasslands with very-low-coverage, saline-alkali land, inland tidal flats, semifixed dunes, and fixed dunes
Vegetation coverage	Degree of vegetation cover in land use type
Ecological conditions	In ecological reserves, or development may lead to land degradation
Irrigation conditions	The natural precipitation is less than or equal to 350 mm and there is no irrigation condition, which cannot meet the requirements of crop growth
Degree of salinization	The degree of soil salinization is more than severe

1. Land use types

The type of index of land use was based on the idea of protective development of sandy land suitable for cultivation and identifies the land use types suitable for cultivation in sandy land. For the purpose of ecological protection, forestland, grassland with high and medium coverage, swamp, and other lands should be regarded as ecological land and should not be reclaimed, while sandy land, saline-alkali land, tidal flats, and other grasslands with irrigation conditions and soil improvement conditions should be evaluated as suitable sandy land.

2. Vegetation coverage

In the "Classification of Land Use Status" (GB/T21010-2007) issued by the Ministry of Land and Resources, the vegetation coverage of sandy land and other grasslands in land use types has not been clearly quantified. Through field investigation and the superposition of land use status and vegetation coverage in the internal industry, it was found that there is very-low-coverage vegetation, low-coverage vegetation, and medium–high-coverage vegetation in the grassland and sandy land in the land use status map. For vegetation with different coverage degrees in sandy land, according to the classification of desertification degree in "Technical Regulations for Monitoring Desertification Land" (GBT24255-2009), vegetation coverage $\leq$ 10% is extremely low vegetation coverage, belonging to mobile sand dunes, and 10% $\leq$ vegetation coverage $\leq$ 30% is low-coverage grassland, belonging to semifixed dunes.

3. Ecological conditions

Ecological land plays an important role in ecological security, was used directly or indirectly by humans or other organisms, and mainly plays the role of maintaining biodiversity and the regional environment. The nature reserves, parks, water sources, and tidal flats with an area of more than 100 hm^2 designated by governments are ecological land. Scenic spots, revolutionary sites, cultural heritage reserves, and scenic tourist areas are special human and ecological lands that also need to be protected. Therefore, suitable arable sandy land in these protected areas should not be developed.

4. Irrigation conditions

Water is a necessary condition for plants to synthesize carbohydrates for photosynthesis. During the growing season of crops, the soil must have a certain amount of water supply before it can mature. Soil moisture comes either from natural precipitation or from irrigation. The annual precipitation in Hangjin Banner was between 140 and 340 mm, and the interannual variation is large, so it was impossible to meet the basic requirements of agricultural water demand through natural rainfall. Therefore, taking irrigation conditions as a restrictive index for the development and utilization of sandy land in Hangjin Banner, sandy land without irrigation conditions is not suitable for reclamation.

5. Degree of salinization

Saline-alkaline soil is a general term for soils that contain a certain number of soluble salts and make crops unable to grow and are divided into saline soils and alkaline soils. Among them, saline soil contains a large amount of soluble neutral salt, and the PH value is not very high; alkaline soil contains a large amount of alkaline soluble salt, and the PH value is very high, greater than 9.0. Hangjin Banner has no alkaline soil, only salt, which can be improved by leaching the salt with fresh water. This fresh water could be from water irrigation and precipitation, especially in areas with better drainage systems. However, severe salinization leaching salt improvement consumes more water and costs too much, which is not suitable for arid and semiarid regions. Therefore, severe salinization is classified as unsuitable sandy land.

2.3.3. Evaluate Appropriate Tillage Sandy

We divided the research ideas of this article into the following three parts (Figure 4).

First, this study used ENVI 5.0 and ArcGIS 10.8 as research platforms to extract the vegetation coverage of Hangjin Banner in 2013 by using the band calculation and raster classification functions of ENVI 5.0 and obtained the final range of extremely-low-coverage grassland combined with the spatial intersection function of ArcGIS. Based on the strong linear relationship between Normalized Difference Vegetation Index (NDVI) values and vegetation coverage, we employed a pixel-by-pixel bipartite model to estimate vegetation coverage (VFC). In practical applications, the NDVI of Vegetation (NDVIV) and NDVI of Soil (NDVIS) were not fixed, which makes the estimation of vegetation coverage more difficult. Therefore, we used the maximum and minimum NDVI values during the plant growth season in August to approximately replace NDVIV and NDVIS.

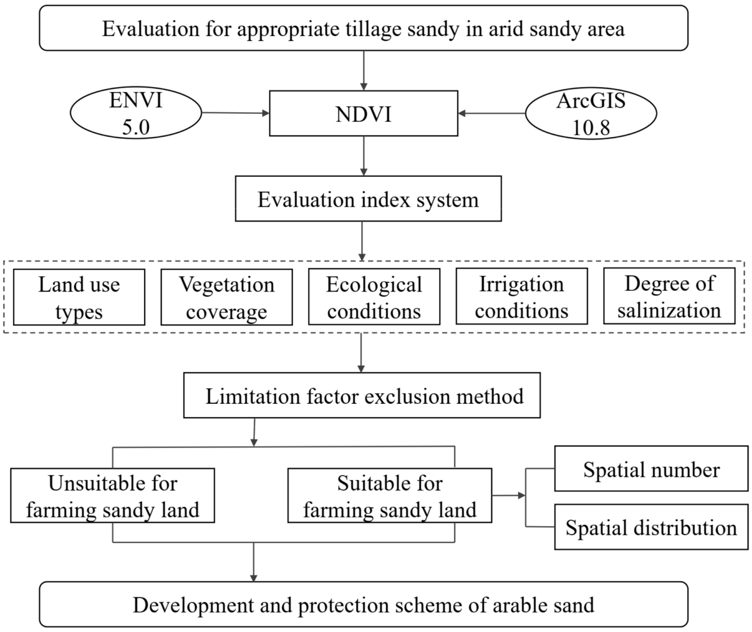

Figure 4. Research framework for the evaluation of appropriate tillage of sandy land in arid sandy area.

Second, this study used the restriction factor method to screen sandy land suitable for cultivation. We digitized the collected indicator (including land use type, vegetation cover, irrigation conditions, ecological conditions, and soil properties) data into various evaluation index factors, which were used as limiting factors to obtain the relevant evaluation index information of the evaluation object by using the spatial analysis function of GIS. In addition, we used the single factor restriction and exclusion method to evaluate the evaluation units. Among the evaluation indicators of the evaluation unit, if any index item is unsuitable for farming, it was classified as unsuitable for farming, and the rest were suitable for farming sandy land.

Finally, this study used the spatial analysis function of GIS to obtain the evaluation objects of suitable arable sandy land in the process of dividing the evaluation objects of suitable arable sandy land. Based on the analysis of the survey and evaluation results of suitable arable sandy land, we counted the number of different types of suitable arable sandy lands and analysed the spatial distribution of different types of suitable arable sandy lands.

3. Results

3.1. Analysis of the Results of Suitable Arable Sandy Land from an Overall Perspective

The area of sandy land of suitable arable sandy land in this survey was 1,274,935.9 hm^2, accounting for 67.5% of the total area of Hangjin Banner. After the screening of four limiting factors of land use or cover, ecological conditions, irrigation degree, and salinization, the sandy land area suitable for reclamation was 97,550.1 hm^2, accounting for only 7.7% of the sandy land area, and 92.3% of evaluation unit is not suitable for farming. According to the different types of sandy land, the suitable ploughing sandy land in Hangjin Banner can be divided into explicit suitable visible sandy land and suitable invisible sandy land. The dominant land type suitable for arable sandy land was sandy land, and the land use types of invisible sandy land are cultivated land, inland tidal flats, saline-alkali land, natural and artificial grasslands with very low coverage, and other grasslands with low coverage (Table 2).

Table 2. Result of survey evaluation for appropriate tillage sandy land.

Type of Sandy Land	Source of Land Type	Appropriate Sandy Land		Evaluation Object		Decrease Range (%)
		Area (hm^2)	Proportion (%)	Area (hm^2)	Proportion (%)	
Recessive suitable ploughing sandy land	Cultivated land	65,020.87	66.65	65,020.87	5.63	0.00
	Inland tidal flats	2010.90	2.06	3492.98	0.29	42.43
	Other grasslands	1291.96	1.32	31,087.27	2.55	95.84
	Saline-alkali land	214.03	0.22	314.54	0.03	31.95
	Natural grassland and artificial grassland	5668.12	5.81	513,457.85	42.05	98.90
Explicit suitable ploughing sandy land	Sandy land	23,344.2	23.93	542,514.34	44.42	95.70
Total		97,550.08	100.00	1,155,887.9	100.00	91.56

The area of visible sandy land suitable for cultivation was the largest at 23,344.2 hm^2, accounting for 23.9% of all sandy land suitable for cultivation. The invisible sandy land suitable for cultivation was 74,205.9 hm^2, accounting for 76.1% of the sandy land suitable for cultivation. Among the land use types of the invisible sandy land suitable for cultivation, the main land use types are the extremely-slow-coverage natural grassland and artificial grassland, accounting for 5668.1 hm^2, accounting for 5.8% of the sandy land suitable for cultivation. However, the decrease was also the largest. First, less than 3% of natural pastures and artificial pastures were reserved as sandy land suitable for cultivation. Second, the area of inland tidal flats suitable for cultivation was 2010.9 hm^2, accounting for 2.1% of all sandy land suitable for cultivation, and 57.6% of the inland tidal flats were suitable for development and utilization. Third, the area of other grassland suitable for cultivation was 1292.0 hm^2, accounting for 1.3% of the suitable arable sandy land. The decrease was very large, and only 4.2% of other grassland was suitable for development and utilization. Finally, although the suitable arable saline-alkali land only accounted for 0.2% of the suitable arable sandy land, the decrease was the smallest, and 68.1% of the saline-alkali land was suitable for development and utilization (Table 2).

3.2. Analysis of the Results of Suitable Arable Sandy Land from a Local Perspective

The cultivated land suitable for cultivation was mainly distributed in Jirigalangtu town (33.1%), Duguitala town (32.2%) and Huhemudu town (15.3%). There was a small amount of distribution in Balagong town and Yihewusumu, while there was no cultivated land distribution in Xini town. From the spatial distribution, the arable land is mainly concentrated along the Yellow River in the north, where the irrigation conditions are relatively favourable (Table 3; Figure 5).

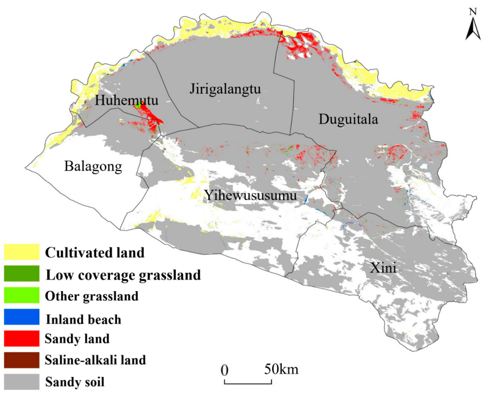

Figure 5. Type and spatial distribution of appropriate tillage sandy land.

Table 3. Statistics on spatial distribution of sandy soil suitable for ploughing in Hangjin Banner.

Source of Land Type		Balagong	Duguitala	Huhemudu	Jirigalangtu	Xini	Yihewususumu	Total
Cultivated land	Area (hm^2)	5035.82	20,924.19	9918.49	21,500.25	0.00	7642.12	65,020.87
	Proportion (%)	7.74	32.18	15.25	33.07	0.00	11.75	100.00
Low coverage grassland	Area (hm^2)	591.50	1612.45	536.39	11.85	625.6	2290.3	5668.12
	Proportion (%)	10.41	28.49	9.47	0.20	11.06	40.34	100.00
Inland beach	Area (hm^2)	97.65	871.08	177.96	37.15	350.42	476.62	2010.9
	Proportion (%)	4.85	43.31	8.84	1.84	17.42	23.7	100.00
Other grassland	Area (hm^2)	125.88	282.56	739.71	85.24	47.33	11.22	1291.96
	Proportion (%)	9.74	21.87	57.25	6.59	3.66	0.86	100.00
Sandy land	Area (hm^2)	2203.13	12,034.83	3305.64	2795.02	238.31	2767.24	23,344.20
	Proportion (%)	9.43	51.55	14.16	11.97	1.02	11.85	100.00
Saline-alkali land	Area (hm^2)	7.05	3.34	139.41	64.21	0.00	0.00	214.03
	Proportion (%)	3.29	1.56	65.13	30.00	0.00	0.00	100.00
Total	Area (hm^2)	8061.03	35,728.45	14,817.60	24,493.72	1261.66	13,187.50	97,550.08
	Proportion (%)	8.26	36.63	15.19	25.11	1.29	13.52	100.00

Natural grasslands and artificial grasslands suitable for cultivation were mainly distributed in Yihewususumu (40.3%) and Duguitala Town (28.5%). Except for Jirigalangtu town, where the distribution was only 11.06 hm^2, the distribution in other towns was between 590 and 2286 hm^2. From the spatial perspective, extremely-low-coverage grassland suitable for cultivating sandy land was intertwined with the dominant sandy land suitable for ploughing and sporadic inlaid in the dominant sandy land suitable for ploughing (Table 3; Figure 5).

The inland tidal flats suitable for farming are mainly distributed in Yihewususumu (23.7%), Xini town (17.4%), and Duguitala town (43.3%). In terms of spatial distribution, there was only a small area of Bayin Wendur Gacha in the Huhemudu Township in the northern Yellow Irrigation District. However, in the Liangwai District, it was distributed in strips along the inland rivers near Arishan Gacha and Baiyinbugacha (Table 3; Figure 5).

Other grasslands suitable for cultivation were mainly distributed in Huhemudu town (57.3%) and Duguitala town (21.9%), and the distribution in the other four towns was not large, ranging from 0.9% to 9.0%. This sandy land was mainly divided into two parts in space: one part was concentrated in Chagannur Gacha in Huhemudu town, and the other part was relatively concentrated in Sharizhao Gacha in Duguitala town. In general, other grassland pattern areas suitable for cultivation were small and fragmented (Table 3; Figure 5).

The saline-alkali land suitable for cultivation was distributed in the other four towns except Xini town and Yihe Wususumu town, and the most distributed was in Huhemudu town and Jirigalangtu town, accounting for 65.1% and 30% of the saline-alkali land suitable for cultivating sandy land, respectively. The sandy land suitable for cultivation in saline-alkali land was concentrated in Chagannur in Huhemudu town and along the river in Bayinwenduer in Jirigalangtu town, with an area of approximately 180.8 hm^2 (Table 3; Figure 5).

The visible sandy land suitable for cultivation was mainly distributed in Huhemudu town (14.2%) and Duguitala town (51.6%), and the distribution in other towns was relatively small. Among them, the dominant sandy land in Huhemudu town was relatively concentrated and contiguous, and mainly concentrated in Chagannur Gacha in Huhemudu town; the dominant sandy land in Jirigalangtu town and Duguitala town was in the shape of a concentrated and continuous strip in space, and the span extends from Gegenzhao Gacha in Jirigalangtu town to Huhemudu Shari Zhao Gacha; the visible sandy land in the other four towns was relatively small in number and small in size, but it was relatively concentrated in space (Table 3; Figure 5).

4. Discussion

In this paper, Hangjin Banner was taken as the research area, and the evaluation object of sandy land research was expanded from the traditional soil type of aeolian sandy soil or the land type of sandy land to all sandy land [36]. According to the different types of land use, specifically vegetation coverage, the sandy land with low vegetation coverage in the current land use survey was regarded as the visible sandy land, and other land types with sandy soil but land use types classified as cultivated land, forestland, grassland, garden land, swamp, water surface, etc., were regarded as invisible sandy land. Although these land types have various types of cover, they have the risk of desertification, and even desertification due to the characteristics of sandy soil, so they need to be taken as the evaluation object [37]. In another method, limiting factors such as land use type, irrigation conditions, and salinization degree are screened and eliminated one by one, and an evaluation system of limiting factors suitable for cultivated sandy land is constructed [38]. This method abandons the conventional comprehensive evaluation method of index factor scoring, avoids the superposition of factors, and ignores the influence of dominant control factors [39]. Our result also shows that 95.7% of the land units were screened by this method (compared with the sandy land units before screening), which means our research method is more effective.

Vegetation coverage can quantitatively characterize the degree of land desertification, but there are large differences in the thresholds of vegetation coverage set by different researchers for the degree of desertification [40,41]. According to the classification of vegetation coverage on desertification degree in "Technical Regulations for Monitoring Desertification" (GB/T 24255-2009), in the investigation and evaluation of arable sandy land in Hangjin Banner, vegetation coverage $\leq$ 10% is regarded as extremely-low-coverage vegetation, and the corresponding degree of desertification is extremely severe desertification. In addition, taking 10% $\leq$ vegetation coverage $\leq$ 30% as low-coverage vegetation, the corresponding degree of desertification is severe desertification; taking vegetation coverage $\geq$ 30% as medium–high vegetation, the corresponding degree of desertification is moderate–slight desertification [42]. This division is based on the idea of protective development and with reference to the overall situation of local land desertification, and other sandy areas can be selected for threshold selection and related research based on this method [43].

The current situation of land use is an important indicator for the investigation and evaluation of arable sandy land. In the investigation and evaluation of arable sandy land in Hangjin Banner, the vegetation coverage calculated by remote sensing is superimposed with the current situation of land use. Among the sandy land types, extremely severe sandy land (vegetation coverage $\leq$ 10%) and severe sandy land (10% $\leq$ vegetation coverage $\leq$ 30%) account for 96% of the total area of sandy land. In the grassland category, 1% of the grassland had extremely-low-coverage vegetation (vegetation coverage $\leq$ 10%), and 31% of the other grasslands had medium and high coverage (vegetation coverage $\geq$ 30%). Overall, the accuracy of sandy land surveying and mapping is relatively high [44,45]. However, for the purpose of research, we should further divide the land types in the current land use situation to meet the accuracy needs of the research. Therefore, on the basis of the current situation of land use, sandy land with vegetation coverage $\geq$ 10% in sandy land and grassland with vegetation coverage $\geq$ 10% in invisible sandy land were excluded.

5. Conclusions

In this study, Hangjin Banner was taken as the research area, and all sandy land was taken as the research object. The restricted factor exclusion method was used to investigate and evaluate arable sandy land in arid and semiarid areas. The results show that the total area of visible sandy land and invisible sandy land in Hangjin Banner is 1,274,935.9 hm^2. Among this area, the total area of arable sandy land is 97,550.1 hm^2, accounting for 7.7% of all sandy land. On the basis of invisible arable sand land and visible arable sand land, according to the land use type, invisible arable sand land can be divided into arable land, inland beach arable sand land, other grassland arable sand land, saline-alkali arable sand land, and very-low-coverage grassland (natural grazing grassland and artificial grazing grassland), accounting for 66.7%, 2.1%, 1.3%, 0.2%, and 5.8% of the area of arable sand land, respectively.

We believe that the research method of this paper is effective, which can provide a valuable reference for the sustainable development and utilization of arable sandy land and desertification control in arid and semiarid areas. Meanwhile, it should be noted that the development and utilization of arable sandy land is a systematic project, and the close cooperation and overall arrangement of all links of investigation and evaluation, planning and layout and engineering design are very necessary. We hope that this study can provide the arid and semiarid areas with similar development conditions as Hangjin Banner in the world, combined with the local actual situations, to use the restrictive factor exclusion method to determine the development and utilization area of arable sand, and formulate a more practical development and protection scheme of arable sand.

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