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## The Implications of Ecological Sensitivity on Exploitation of Unutilized Land: A Case Study in Ji'nan City, China

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### Abstract

As the cultivated land reserve resources, the unutilized land should be exploited to get the best benefits based on its suitability, meanwhile the exploitation should avoid ecological destruction for the aim of ecological security. Taking of unutilized land in Ji'nan city as a case, the paper established ecological sensitivity analysis model and suitability evaluation model to calculate the exploitation potential of unutilized land. The results showed that limited by environmental factors, the unutilized land located in severely sensitive area and extremely sensitive area accounted for 39.99% of the total unutilized land; 65.87% of the unutilized land are suitable for cultivated land. From the spatial distribution, the unutilized land suitable for cultivated land is mainly distributed in the northern plain region and the south area along the Yellow River region.

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*Keywords:* unutilized land; ecological sensitivity analysis; suitability evaluation; exploitation potential; Ji'nan city

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### 1. Introduction

Land is a kind of important and finite resource. The situations of cultivated land conservation and food security in China are always severe due to the largest population in world and limited land resource. China is undergoing the fast urbanization and industrialization now. With the economic development, it is inevitable that the increasing construction land will continue to occupy more land resource, especially cultivated land, and to further aggravate the relationship between population and land resource. Lack of land resource and its irrational use have become the key factors limiting the development of economy and society. Therefore, in order to realize the sustainable land use and relieve the increasing demographic pressure on land resources, a great number of studies have been focused on the rational land use and management<sup>[1-2]</sup>. Despite of being influenced by the specific conditions in different countries and regions,

by their historical and more recent political and social development, and also by the natural conditions<sup>[3-6]</sup>, the objectives and methodology of land exploitation and consolidation are very useful measurements for increasing land use effectiveness, for erosion control in rural landscapes<sup>[7]</sup>, for dealing with nature conservation and environmental issues<sup>[8]</sup>, for rationalizing urban development<sup>[9]</sup> and for other social and economic issues in managing the development of rural areas<sup>[10-11]</sup>. Due to the shortage of cultivated land in most regions, the aim of exploiting unutilized land is mainly for increasing cultivated land. The exploitation potential of unutilized land was calculated by the natural or economical suitability evaluation, and its feasibility was analyzed by comparing the cost and the revenue of land exploitation activity without considering the ecological factors<sup>[12-14]</sup>. Recently, the issues of ecological environment and land degradation, which are caused by the intensification of human activities and the irrational development, and utilization of land resources are becoming more serious and have drawn much attention<sup>[15-17]</sup>. Ensuring ecological system security has become the guidelines to the resource development and utilization. Therefore, the exploitation of unutilized land should be limited in the ecological permit. Before making a land exploitation decision, it should be considered that whether land exploitation would cause land degradation and affect environments.

This study adopted the land status quo map and environment information as data sources to analyze the ecological sensitivity of land utilization and determine the ecologically sensitive areas by using advanced integrated evaluation model, and further to evaluate land suitability for unutilized land exploitation based on land natural characteristics. According to the evaluation results, the appropriate land use types are determined in order to acquire more benefits considering economic, social and ecological factors and to avoid repeating the vicious circle of destroying ecological environment during land exploitation.

## 2. Materials and methods

### 2.1. Study area

This paper took Ji'nan city as the study area, which is the capital of Shandong Province and locates at 36° 40' N and 116°57' E. The city locates in the transition zone between the southern Taishan Mountain and the valley of the Yellow River, with the terrain gradually declining from south to north. The total land area of Ji'nan city is about 8154 km<sup>2</sup> including ten districts or counties.

There are 11 types of unutilized land in Ji'nan including desert grassland, sandy land, saline-alkaline land, swamp, bare land, bare exposed rock or gravel land, shoal land, river water, lake water, reed land and other unutilized land. The unutilized land is 97299.71 hm<sup>2</sup> in 2008 which is about 11.93% of the total land area. The data of the unutilized land are offered as follows in detail. The desert grassland is 56726.89 hm<sup>2</sup> and is about 58.30% of the unutilized land area. The bare exposed rock or gravel land is 15202.67 hm<sup>2</sup> and is about 15.62%. The river water is 14051.72 hm<sup>2</sup> and is about 14.44%. The saline-alkaline land is 6448.12 hm<sup>2</sup> and is about 6.36%. The shoal land is 2802.75 hm<sup>2</sup> and is about 2.88%, and the area of other unutilized lands is smaller relatively.

### 2.2. Data sources

In the present work, the data of the unutilized land in Ji'nan was collected from the land utilization status quo map with a scale of 1:10000 in 2008 and the same scale of relief map, the maps of soil salinity, phreatic water salinity, ground water level, soil, soil and water loss intensity, and some statistical data from the Statistics Annual of Ji'nan and related survey, and statistics of cadastre data and eco-environment data. The data of the terrain were picked-up to create slope map. And the evaluation was finished by acquiring the data of the evaluation indicators and setting up spatial database accordingly.

### 2.3. Methods

#### 2.3.1 The eco-sensitivity analysis of land use in Ji'nan

8 indicators are selected to establish the eco-sensitivity analysis index system including ecological protection, protection areas of drinking water source, groundwater salinity, soil texture, topography, vegetation cover, soil erosion intensity, slope. As the study area is located in the transition zone between hilly area and alluvial plain, elevation is not included in the factors affecting the eco-sensitivity. The evaluation index system of eco-sensitivity analysis is shown in Table 1. An improved multiple index comprehensive evaluation method is adopted to analyze the ecological sensitivity of land use. The formula is as follows:

$$N = \max\left(\left(\sum_{i=1}^6 w_i n_i\right), n_7, n_8\right) \quad (1)$$

Where  $N$  is the score of the comprehensive evaluation of the eco-sensitivity,  $w_i$  and  $n_i$  are weight and score of the No.  $i$  index,  $n_7$  and  $n_8$  show that the 7th and 8th index of the eco-sensitivity analysis, which are based on single-factor calibration method.

Table 1. The evaluation index system of eco-sensitivity analysis of land use

evaluation index	id	weight	insensitive (score:2)	slightly sensitive (score:4)	moderately sensitive (score:6)	severely sensitive (score:8)	extremely sensitive (score:10)
ecological protection	1	0.18	ordinary forest	county-level forest reserves	municipal forest park	provincial forest park	first-level water source reserves or provincial nature reserves
protection areas of drinking water source	2	0.20	V grade surface water area	IV grade surface water area	III grade surface water area	II grade surface water area	I grade surface water area
groundwater salinity(g/l)	3	0.15	<1	1~3	3~10	10~50	≥50
soil texture	4	0.16	gravel, sandy soil	coarse sand, fine sand, clay	loamy soil	sandy loam, silty clay, loam clay	sandy silt, silt
topography	5	0.15	torrential plain	flood alluvial plain	valley plain	closed flow basin	mountains and hilly areas
vegetation cover	6	0.16	dense	moderate	less	sparse	extremely sparse
soil erosion intensity (t/km <sup>2</sup> )	7	single-factor calibration	<500	500~1000	1000~2000	2000~4000	≥4000
slope(°)	8	single-factor calibration	0~5	5~15	15~25	25~30	≥30

#### 2.3.2 The suitability evaluation for exploiting unutilized land in Ji'nan

According to the current land use situation in Ji'nan, some factors are selected to establish suitability evaluation system (Table 2). The weighted average method and ultimate condition method are used to evaluate the suitability grade of unutilized land. Formula is as follows:

$$P = \sum_{i=1}^n w_i p_i \tag{2}$$

Where  $P$  is the total score of the suitability,  $w_i$  and  $p_i$  are the weight and score of the factor  $i$ .

According to the distance between the plot and the main road around, road accessibility index was calculated with exponential decay model. When the plot is influenced by more than a road, the largest scores among all the influence scores should be selected as the road accessibility index of the plot. Formula is as follows:

$$c = \max(f_i^{(1-r_i)}) \tag{3}$$

Where  $c$  is the road accessibility index,  $f_i$  is the influence score of road  $i$ , and  $r_i$  is the distance between the plot and the road  $i$ .

Table 2. The evaluation index system of the unutilized land suitable for cultivated land in Ji'nan city

evaluation factor	weight	most suitability(score:10)	secondary suitability (score:7)	reluctant suitability (score:3)	unstuitability (score:0)
organic matter content (%)	0.14	≥1.2	0.6~1.2	<0.6	—
soil texture	0.14	light loam, medium loam	weight loam, clay	sandy loam	gravel, sandy soil
thickness of soil layer (cm)	0.15	≥80	40~80	20~40	<20
topsoil salinity (%)	0.13	<0.1	0.1~0.3	0.3~0.5	≥0.5
irrigation security	0.15	complete security	better security	poor security	no security
location(distance between the plot and the residential area around)	0.12	<500m	500~1000m	≥1000m	—
eco-sensitivity of land use	0.17	insensitive	slightly sensitive	moderately sensitive	severely sensitive, extremely sensitive

### 3. Results and discussion

The results of ecological sensitivity analysis and suitability evaluation are shown in Table 3-4 and Figure 1-2.

Table 3. The results of ecological sensitivity analysis of land use in Ji'nan city

division name		insensitive	slightly sensitive	moderately sensitive	severely sensitive	extremely sensitive	total
evaluation area	area (hm <sup>2</sup> )	293707.08	284329.98	49331.70	89694	98337.24	815400
	percent (%)	36.02	34.87	6.05	11	12.06	100
unutilized land	area (hm <sup>2</sup> )	12537.63	28958.43	16897.46	22705.18	16201.00	97299.71
	percent (%)	12.89	29.76	17.37	23.34	16.65	100

Table 4. The results of the suitability evaluation of unutilized land in Ji'nan city unit: hm<sup>2</sup>

suitability grade	Lixia district	Shizhong district	Huaiyin district	Tianqiao district	Licheng district	Changqing district	Zhangqiu city	Pingyin county	Shanghe county	Jiyang county	total	percent (%)
most suitability	18.6	437.07	170.76	539.18	3433.36	1348.16	876.27	2089.9	4293.46	1003.34	14210.1	14.60
secondary suitability	83.64	1755.1	30.67	1.82	5926.7	9396.11	1715.98	1864.86	392.78	341.11	21508.77	22.11
reluctant suitability	183.13	2588.37	73.06	0	13200.3	4305.16	5346.06	2679.96	0	0	28376.04	29.16
unsuitability	253.82	1071.8	327.3	652.11	6473.41	5163.48	11260.39	3284.95	3249.47	1468.07	33204.8	34.13

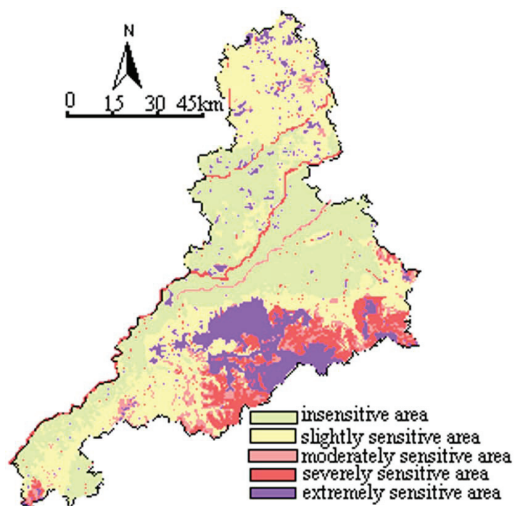


Fig. 1. Distribution of the ecological sensitivity zones

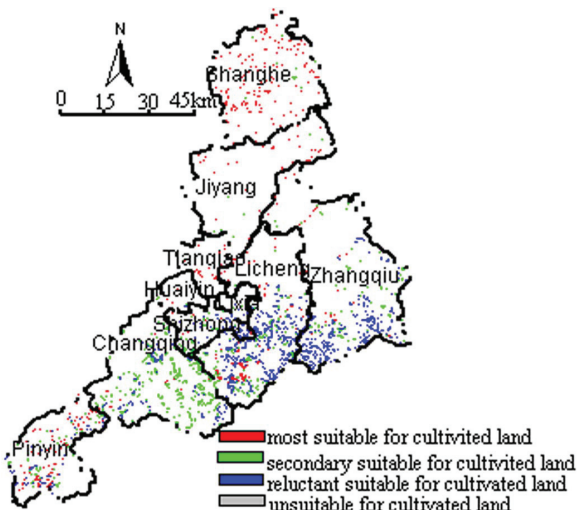


Fig. 2. Spatial distribution of suitability evaluation of unutilized land

Though the eco-limited area affecting land use is small in Ji'nan city, the unutilized land is poor because about 80% of the unutilized land is located in the south-central hilly area and the unutilized land, which belongs to severe sensitive area and extremely sensitive area, accounts for 39.99% of the total unutilized land area. These results showed that being limited by many environmental factors, exploitation of the unutilized land should be taken full account of the eco-environment effects to avoid the ecological destruction in this region.

The results of the suitability evaluation showed that the unutilized land which could be exploited accounts for 65.87% of total unutilized land area, and the other which could not be exploited accounts for 34.13%. From the spatial distribution (Fig.2), the unutilized land suitable for cultivated land are widely distributed in the insensitive or slightly eco-sensitive areas that are located in the northern plain region (Jiyang and Shanghe), the south along the Yellow River region (Pingyin) and central hilly area (Zhangqiu, Licheng, Changqing and Shizhong). The types of unutilized land are mainly the desert grassland, slightly saline-alkali land, wetland and shoal land. These lands are characterized by thicker soil layers, higher levels of soil organic matter, better irrigation conditions, and smaller slope, which will be better conditions for agricultural production after consolidation. The facilities of farmland irrigation and drainage should be strengthened when these lands are developed, and specially to prevent the lands in the plain areas from the secondary salinization to ensure the sustainable productive capacity of the new cultivated land. The unutilized land unsuitable for development, which are difficult to be developed at present economic and technological conditions, are mainly river water, lake water, reed land, bare exposed rock or gravel land with more than 70% exposed bedrock, saline-alkaline land with more than

1.0% salt content and the slope land over 35°. And these lands are mainly distributed in the northern plain region (Jiyang and Shanghe), south along the Yellow River region (Pingyin) and central hilly area (Zhangqiu, Licheng and Changqing).

#### 4. Conclusions and Discussion

In this paper, the eco-sensitivity analysis model and the suitability evaluation model have been established to determine the reasonable exploitation types of unutilized land. The following conclusions were drawn in the present work: (a) The results of this study showed that the quantity and quality of unutilized land in Ji'nan were not optimistic. 80% of the unutilized land restricted by the environmental factors in south-central hilly area should be exploited cautiously to avoid ecological destruction; (b) Limited by the natural factors, the distribution of the unutilized land suitable for cultivated land in various districts is different. The unutilized land suitable for cultivated land is mainly distributed in the northern plain region and the south area along the Yellow River region and its quality is better.

In the present work, it is the largest potential estimation of the unutilized land exploitation in Ji'nan. In practice, the realization of the potential depends on economic factors, i.e. the capital investment and benefits. Whether sufficient funds and satisfactory returns on investment can be achieved or not will directly affect the result of unutilized land exploitation. As some evaluation factors have dynamic characteristics, such as the gradual improvement of irrigation could improve land suitability in some area, therefore, these results only reflect the current exploitation of the unutilized land.

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