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Eco-environmental susceptibility in Shangyi County, Northern Hebei Province, China*

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Abstract——In this paper, the eco-environmental susceptibility of Shangyi County, Northern Hebei Province of China has been calculated by using the weighted-addition method based on expert's giving a mark to each influencing factor according to their knowledge on the influence of all the factors on eco-environmental susceptibility. The eco-environmental classification and distribution map were reached based on the above results, its difference is mainly result from the physical conditions and human activity, however the value of eco-environmental susceptibility is only a relative index which can not completely reflect the quality of eco-environment. This work provided a basis for controlling the further development of desertification.

Keywords: eco-environmental susceptibility; weighted addition method.

The susceptibility have been used in many field to describe the response of one thing to another thing (Yu, 1991; Li, 1991; Zhang, 1991), however it is more difficult to evaluate the influence of human activity on eco-environment since the vague relationship between all the influencing factors and the eco-environmental susceptibility. Usually the AHP approach (Chen, 1995; Fu, 1992), fuzzy mathematical method (Chen, 1991; Deng, 1986) and grey system theory (Fu, 1993) are used to assess the uncertain phenomena.

1 Study area

The study area is located at the north-western part of Hebei Province of China belonging to the mesothermal semi-arid-steppe climate zone, which covers about 2649 km^2 with 185179 population. The gentle plateau-like landscape, lower beaches, depressions, the hillock developed very well in the northern part, the altitude is around 1280—1600m, and the moderately high hill and highly dissected plateau border zone developed in the southern part and the altitude is from 1050 to 1500 meters above sea level .

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2 The influencing factors of eco-environmental susceptibility

The major factors influencing the eco-environmental susceptibility comprise two aspects: the factors which are in direct proportion to the eco-environmental susceptibility, such as the drought hazards, soil erosion, flood hazards, and the negative factors which are favorable to improve the eco-environment and in negative proportion to the susceptibility, as the forest coverage, grass coverage, the percentage of irrigated farmland, control of soil erosion.

2.1 Drought hazards

The drought hazard is the principal hazard in the semi-arid steppe climate zone, which usually results from low precipitation, low permeability of the surface materials, low vegetation coverage and strong deflation. As the major factor to influence eco-environmental susceptibility, it happened quite often in the study area.

2.2 Windstorm and hailstorm disaster

Windstorm is defined as that the wind speed in one day is more than 17.0 m/s resulting in a lot economic loss and human death, it occurred particularly in winter in this area.

2.3 Flood disaster

Only a little flood disaster takes place in this area, which taking about 3.6% of the total hazards on frequency, usually occurred at the poor-drainage region when most rain falls in summer.

2.4 Water loss and soil erosion

The intensity of soil erosion is associated mainly with the erodibility of earth surface and the erosivity of rainfall. The former one is related to the resistance of surface materials to erosion, geomorphologic setting and landcover, and the erosivity of rainfalls is influenced by the intensity and time of the precipitation.

Even though the drought and desertification are the major factors for forming the sensitive eco-environment, the loose structure of surface materials, geological and geomorphologic setting, and highly concentrated precipitation in summer induce soil erosion occurred very frequently, especially in the south part of study area.

2.5 Human activity

The population density, livestock load of grassland and the land reclamation in this area play a very important role on desertification. There are a very high population growth rate, high population density, poor education, fast increase of cultivated land, irrational ratio among the agriculture, forestry and pasture, low land productivity and bad economic effect in this area, which are unfavorable for eco-environment improvement (Table 1).

2.6 Grassland coverage

About 18100 hectares grassland have been planted since 1989 for improving the eco-environment, it reaches 31.4% on grassland coverage. A high grassland coverage is usually helpful for protecting the eco-environment, nevertheless it is in negative proportion to eco-

Table 1 The situation of pasture-load and deterioration in Shangyi Country, Northern Hebei Province

Region	Total area, ha.	Usable area, ha.	Area of degraded grassland, ha.			Livestock-carrying capacity, number			Average grass yield, kg/ha.	Used area of grass land of each goat, ha./goat	Percentage of livestock overload, %	Percentage of deteriorated grassland, %	Land productivity, RMB Y./ha.	Capita income, RMB Y/p.
			Slight	Mod.	High	Theory	Practical	Potential						
Dayingpan	5860	4293	307	3967	20	9866	28129	−18269	3450	0.153	185	73.3	39.2	294
Dashuji	3153	2540	20	2173	347	5818	24763	−18945	6435	0.103	325	80.5	54.2	292
Houshi zhuang	2807	2467	1280	920	260	4695	29478	−24783	3480	0.084	528	87.8	54.0	296
Daqinggou	3760	3127	573	2006	547	5984	35107	−29123	3480	0.089	487	83.2	61.4	290
Halagou	1720	1460		1460		2783	17797	−15014	3480	0.082	539	84.9	58.2	290
Badaogou	3060	2607	1260	993		7414	35912	−28498	5190	0.073	384	85.2	61.1	290
Qijia	1287	1033	353	2020		2169	15187	−13018	3840	0.068	600	80.3	65.3	329
Kangleng	4953	4687	580	3727	380	5375	28222	−22847	700	0.166	425	94.6	49.4	279
Nanhaoqian	5287	4567		4567		10368	36163	−25795	3390	0.126	249	86.6	63.3	316
Yongshengdi	7993	6700	847	5600	240	29408	19080	9328	8010	0.351	32	84.8	36.5	287
Tumulu	5653	4593		3813	780	21716	13964	7752	8625	0.329	36	81.3	32.8	299
Taolizhuang	3373	3160	240	1993	913	3725	17846	−14121	2160	0.177	379	93.7	50.0	299
Jiashihe	5180	4593		3060	1533	6835	16082	−9847	2715	0.286	144	88.6	37.4	276
Xiaosuangou	13587	11200	3393	5320	2480	39330	21821	17509	6390	0.513	44	82.4	16.1	300
Xiamaquan	8560	5320	833	3573	2120	18012	10533	6479	5040	0.62	36	62.1	33.0	304
Wuluangou	5740	5280	1060	1707	250	23379	9904	13475	8085	0.53	58	91.9	25.4	326

environmental susceptibility.

2.7 Forest coverage

The forest coverage increase fast with plantation recently, about 10300 hectares trees have been planted in 1982, and 74.5% of the hill have been planted with trees. Up to now, the forest coverage in this area reaches 6.37%, whereas much difference existed for the different area, which influence the eco-environmental susceptibility greatly.

2.8 Irrigation

Usually it is subjective to desertification for those area with the loose surface materials or with the arid or semi-arid climate zone when the dry season and gale take place simultaneously (Zhu, 1993). The percentage of irrigated farmland in some extent will influence the eco-environment, a good irrigation is helpful for preventing the environment from degradation.

There are about 1660.2 km^2 lower flood plain and 125 small lakes, nearly about 1161 km^2 area covered by water with 167728 m^3 water capacity in this area, however the percentage of irrigated farmland is only 5.25%. How to utilize the water resource effectively is significant for keeping the local ecosystem from further deterioration.

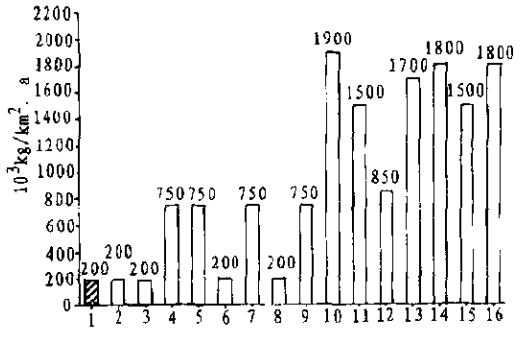

Fig. 1 Soil erosion intensity map of Shangyi County, northern Hebei Province

1: Dayingpan 2: Houshizhuang 3: Dashuji 4: Daqinggou 5: Halagou 6: Badaogou 7: Qijia 8: Kangleng 9: Nanhaoqian 10: Yongshengdi 11: Tumulu 12: Taolizhuang 13: Jiashihe 14: Xiaosuangou 15: Xiamaquan 16: Wuluangou

2.9 Land productivity

How to use the land resource reasonably are important for increasing the ecological and economic effects in the semi-arid land. A high land productivity is usually helpful to decrease the eco-environmental susceptibility. In this region, the land productivity is very low, which is only about 450.3 RMB/ha. according to the statistic data of 1989—1990.

2.10 Control of soil erosion

About 86.4% to 99.5% of this area is influenced by soil erosion, which is mainly distributed in the southern part, however a small part has been controlled and much difference on control of soil erosion existed for different areas because of the geological and geomorphologic surroundings, such as the controlled area of soil erosion in Wuluangou is only about 1.5%—1.7% of the total eroded area while it reaches 44.9%—69.1% in Dashuji and Qijia areas (Fig. 1).

3 The method on evaluation of eco-environmental susceptibility

All the factors associated with the eco-environmental susceptibility are described as follows:

A: Eco-environmental susceptibility; B_1: Positive factors for eco-environmental susceptibility; C1: Drought hazards; C2: Flood hazards; C3: Windstorm and hailstorm disaster; C4: Soil erosion rate; C5: Soil erosion intensity; C6: The percentage of grassland degradation; C7: The percentage of cereal yield reduction; C8: Land reclamation; C9: Population growth rate; C10: The percentage of over-load of livestock. B2: Negative factors for eco-environmental susceptibility; C11: Control of soil erosion; C12: Forest

coverage; C13: Grassland coverage; C14: Land productivity; C15: The percentage of irrigated farmland; C16: Capita income.

3.1 The determination of the weight of influencing factors on eco-environmental susceptibility

Among all the influencing factors, some are related to natural environment and the others are related to human activity, it is difficult to describe quantitatively the importance of each factors for eco-environmental susceptibility. For evaluating the real influence of each factor on eco-environmental susceptibility, the average value of the points (equations 1a, 1b) given by experts was used to determine it based on comprehensive analysis. Then the value was standardized by using the equations (2a), (2b) for keeping sum of weight of positive factors and negative factors respectively equaling to 1.

$$Pi = \sum Pj/U, \tag{1a}$$

$$Pk = \sum Pj/U. \tag{1b}$$

Among them, Pj is the point given by j-th expert; U represent the number of experts; Pi is the average value of the i-th positive factor given by the experts; Pk is the average value of the k-th negative factor given by experts.

$$gi = \frac{Pi}{\sum_{m} Pi}, \tag{2a}$$

$$gk = \frac{Pk}{\sum_{n} Pk}, \tag{2b}$$

where, gi is the weight of i-th positive factor; gk is the weight of k-th negative factor; m is the number of positive factors on eco-environmental susceptibility; n is the number of negative factors on eco-environmental susceptibility.

The weight value of each factor is listed in Table 2.

Table 2 The weight of influencing factors on eco-environmental susceptibility in Shangyi County, Northern Hebei Province

Factors	Weight
Drought hazard	0.1230
Flood hazard	0.0615
Windstorm and hailstorm hazard	0.0884
Soil erosion rate	0.1031
Soil erosion intensity	0.1040
Grassland degradation	0.0991
Cereal yield reduction	0.083
Land reclamation	0.1220
Population growth rate	0.0964
Livestock over-load	0.1200

Table 2 (continued)

Control of soil erosion	0.161
Forest coverage	0.170
Grassland coverage	0.214
Land productivity	0.159
Percentage of irrigated farmland	0.156
Capita income	0.1399

3.2 Calculation of eco-environmental susceptibility

The practical value of all factors in different areas are obtained based on the "Collected compilation of statistic data of Shangyi County" and "Statistic of Shangyi County", however the value must be processed with equation (3a) and (3b) for calculating the eco-environmental susceptibility since the different order of each factor.

$$C'_{ij} = \frac{C_{ij}}{Max\ (C_{ij})} \times 100\ , \tag{3a}$$

$$C'_{kj} = \frac{C_{kj}}{Max\ (C_{kj})} \times 100. \tag{3b}$$

Among them, C_{ij} is the practical value of i-th positive factor in j-th area; $C'ij$ is the value of C_{ij} after standardization and Max(C_{ij}) is the maximum value of i-th factors among m areas. C_{kj} is the practical value of k-th negative factors in j-th area; C'_{kj} is the value of C_{kj} after standardization; Max (C_{kj}) is the maximum value of k-th factors among m areas.

The weighted-addition method was used to calculate the eco-environmental susceptibility which was expressed as follows:

$$R_j = \sum_{i=1}^{m} g_i \times C'_{ij} - \sum_{k=1}^{n} g_k \times C'_{kj}. \tag{4}$$

Where, R_j is the value of eco-environmental susceptibility of the j-th area and the others are the same to above. The results are displayed in Table 3.

Table 3 The value of eco-environmental susceptibility in different area of Shangyi County, Northern Hebei Province

Area	Value	Area	Value
Dayingpan	18.29	Nanhaoqian	40.27
Dashuji	36.87	Yongshengdi	32.70
Houshizhuang	17.67	Tumulu	20.28
Daqinggou	29.47	Taolizhuang	46.75
Haligou	31.44	Jiashihe	35.11
Badaogou	20.99	Xiaosuangou	7.51
Qijia	17.75	Xiamaquan	11.76
Kangkeng	31.99	Wuluangou	21.30

4 Result and Discussion

4.1 Result analysis

Even though the eco-environment of this area is subjective to deteriorate of the loose soil structure and frequently occurring hazards, five classes could be divided based on the results (Table 4 and Fig. 2).

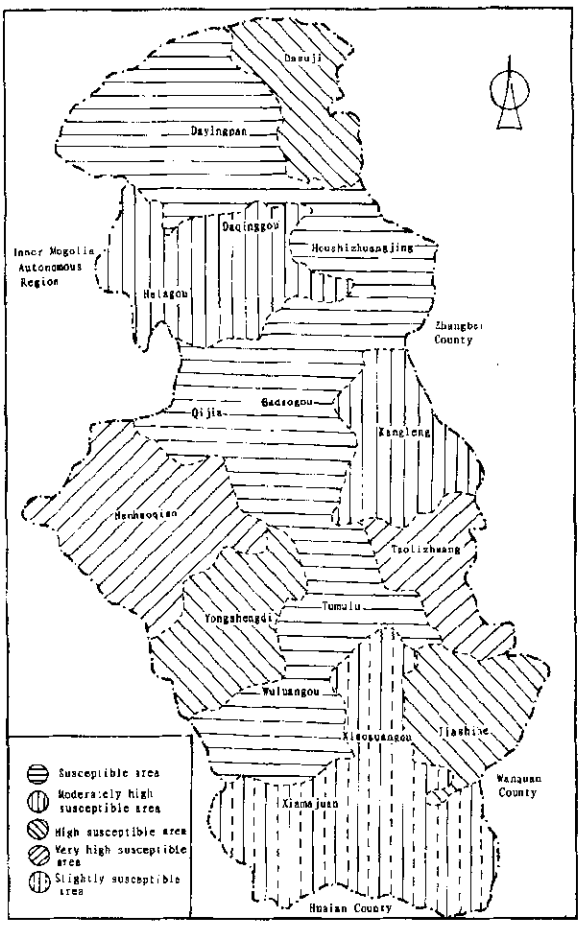

Fig. 2 Distribution map of eco-environmental susceptibility in Shangyi County, Northern Hebei Province, China

Table 4 Classification of eco-environmental susceptibility in Shangyi County, Northern Hebei Province

Classes	Field of eco-environmental susceptibility	Areas
A	7.0—15.0	Xiaosuangou, Xiamaquan
B	15.0—23.0	Dayingpan, Badaogou, Qijiaxiang, Housizhuang, Tumulu, Wuluangou
C	23.0—31.0	Daqinggou, Halagou, Kangleng
D	31.0—39.0	Dashuji, Yongshengdi, Jiashihe
E	>39.0	Nanhaoqian, Taolizhuang

4.1.1 A —— the slightly susceptible area

Two small areas, Xiaosuangou and Xiamaquan are belong to this class, which are mainly slightly dissected moderate-high hill to low hill, distributed in the southern part of this area. The intensity of soil erosion reaches 1800 ton/km^2, the drought hazard happened seldom and the irrigation is very high because of the developed river system and broad flood plain. There are a slight grassland degradation and a very low population density which is only about 31 to 34 persons/km^2. So, it is possible for this area to increase the human activity properly under the circumstance of not deteriorating the eco-environment.

4.1.2 B —— the susceptible area

This type susceptible area contains Dayingpan, Houshizhuang, Badaogou, Qijia, Tumulu and Wuluangou areas, which distribute along the lower flood plain. There are a good grassland coverage, low population density, and plentiful water resource that are favorable for developing pasture.

4.1.3 C —— the moderately high susceptible area

The small areas, Daqinggou, Halagou and Kanglenggou belong to this type area. In this area, the agriculture take a very important role of the strong human activity which results in high reclamation, low grassland and forest coverage, and high over-load of grassland. The regional ecosystem is susceptible to deteriorate with human activity.

4.1.4 D —— the high susceptible area

There are three small areas belonging to this type, Dashuji, Yongshengdi and Jiashihe. The first one locates at the north-eastern part of the study area with a large gentle plain. The highly developed agriculture, poor soil materials, high population density, high over-load on pasture and the scare water resources are the major features of this area. The other two locate at the hilly area of southern part in study area, nearly 65% of the precipitation concentrates in summer, the intensity of soil erosion is up to 1700—1900 t/(km^2. a) while the population density is very low which is only about 29—54 persons/km^2.

4.1.5 E —— the very high susceptible area

It includes the Nanhaoqian and Taoli areas which distribute near the water divide in the central part of study area. There are a very high population density about 65 persons/km^2, and nearly 63.3% of these areas have been reclaimed as the farmland. The over-load of the pasture is very serious which is up to 249% and 399% respectively in Nanhaoqian and Taoli, and the gale occurred frequently.

4.2 Discussion

Even though the whole area belongs to the semi-arid climate zone, the difference of geological and geomorphologic setting, water resource, current land use and human activity still exist for the different areas which results in the difference of eco- environmental susceptibility. It is mainly associated with the drought hazards, soil erosion intensity, grassland degradation, grassland coverage, situation of soil erosion controlling.

The study area is favorable for developing pasture from the climate and landscape, however, most area has been reclaimed as the farmland which easily engender the degradation of

eco-environment. Except the A and B type area, all the other areas have an extremely high over-load on pasture, some area reaches 500%, of which the local ecosystems are subjective to desertification.

The fast population growth is also a very important factor on influencing the regional eco-environmental susceptibility, which strengthen the pressure on utilization of land resources, accelerate the deterioration of grassland, raise the reclamation, and decrease land productivity. Therefore, controlling the population growth, utilizing the land resources properly, and developing the ecological agriculture for improving the economic and social effects to reach the sustainable development of this area are imperative and significant(Fig. 2).

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References

Chen LD, Fu BJ. Advances In Environmental Sciences, 1995; 3(4):33

Chen SY, Chen XB. Acta Scientiae Circums, 1991; 11(1):1

Deng JL. Decision and forecast by using grey theory. Beijing: Technology and Sciences University of Central China. 1986

Fu BJ, Chen LD. Journal of Soil and Water Conservation, 1993; 7(2):16

Fu BJ, China Population, Resources and Environment, 1992; 2(2):48

Li RX, Environmental Sciences, 1991; 12(1):75

Yu KJ. Geographical Research, 1991; 11(2):38

Zhang JG. Environmental Sciences, 1991; 12(2):77

Zhu ZD, Wang T. Quaternary Geology. Beijing: Science Press. 1993:97

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