Evaluation of development patterns based on water resources carrying capacity calculation model in pastoral area

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Abstract

As the natural barrier, the health situation of grassland is relate to the change of social and economic development. According the natural environment of low rainfall and high evaporation, a comprehensive calculation model is established for evaluating the development patterns based on water resources carrying capacity. In present year, the social and grassland carrying capacity of BAILINGM is in the overload situation and there is a wide variance among different administrative region. By designing five different development patterns, we can find that carrying out the most strict water resources management policy can solve the overload problem of grassland carrying capacity effectively and the B-2 is the best development pattern. This paper show that the calculation results can provide reliable information and guide for macroscopic water resources management in large watershed and administrative region.

Keywords: development pattern, water resources, carrying capacity model, pastoral area

1 Introduction

China Pastoral area is mainly located in Inner Mongolia, Sinkiang, Qinghai and other province. It is easy to see worse nature conditions in these places, such as drought and less precipitation, higher frequent of sand and other natural disasters, more fragile ecological environment [1-3], so the quantity and quality of water resources can decide the suitable development of society and economy. Therefore, it is necessary to research the carrying capacity of water resources in pastoral area so that the protection of grassland ecology and environment can be strengthened.

2 Concepts and definition

2.1 CONCEPTS

The concept of water resources carrying capacity was introduced firstly by the teams of Shiyang Feng in the process of their investigating for water resources in Xinjiang Autonomous Region in 1992. The relative concept is given as "taking the change of society, economy and science technology as comprehensive index and selecting the population, the development and other factors as objective index [4]. Considering the principle of suitable development, Xu Xinyi pointed out that water resources optimization allocation is the key approach to improve water resources carrying capacity [5]. Then the expression of water resources carrying capacity was divided into direct evaluation and indirect evaluation by Ruan Benqing [6]. Jia Rong analysed the integration between the region and basin and the coordination between economy and ecology [7]. Wang Jianhua expanded the research into time and space scales [8]. Hui Yanghe considered the effects of both natural condition and human being activities [9].

2.2 DEFINITION

The concept of water resources carrying capacity should comply with the following requirement:

1) Space and time attribute. There are different grassland types, animal husbandry development level, the situation of water resources management, the grazing way with the change of water resources system in pastoral area.

2) Sustainable attribute. When the irrational development pattern surpass the recover ability of water resources, the water resources system will face the problems of quantity decreasing, poor quality and lower hydrology cycle stability.

3) Systematic attribute. The research of water resources carrying capacity is not only containing the subjective layer and objective layer, but also considering the coupling layer so that the relationship between the subjective layer and objective layer can be descried.

In some special period, taking the available water resources quantity as carrying subjective, considering the effects of history, policy, natural conditions, human activities and science technology, the water resources carrying capacity in pastoral area is described as the maximum carrying capacity of water resources system for supporting the balanced development of society, economy, ecology and environment.

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3 Basic theory

According the relationship between the carrying subjective and carrying objective, the calculation model based on supply-demand balance, which refer to the research fruit of Zuo Qiting [10], is established to calculate the water resources carrying capacity in pastoral area. The equations can be expressed as following:

$$\begin{cases} C_t = \varepsilon \cdot W_p / E_p \\ C_{GDP} = W_e / E_{GDP} \\ C_g = (W_a - W_i - W_s)/E_g \\ W_r = W_a + W_e + W_t + W_p \end{cases},$$

where C_t is the capacity of water resources for supporting the population growth, ε is effective water using coefficient. E_p is total quota per person. C_{GDP} is the capacity of water resources for supporting the economy development. W_e is economic water demand quantity, E_{GDP} is GDP water consumption per ten thousand yuan. C_g is the capacity of water resources for supporting the grassland protection. W_r is total water resources quantity, W_a is first industry water consumption. W_p is living water consumption. W_e is second and third industry water consumption. W_t is ecology water consumption. W_i is farmland irrigation water quantity. W_s is animal husbandry water consumption. E_g is water using quota per farmland or artificial irrigation area.

4 Case study

4.1 GENERAL SITUATION

Damao County, which located in the middle-west of Inner Mongolia Province, is taken as studying area in this paper. Damao County is an area, which less precipitation and longer winter period, the average temperature per year is 4.34℃, the average precipitation per year is about 260.73mm, but the average evaporation is as high as 2480.57mm, and the evaporation value is 9.5 times than precipitation value. The grassland can be classify as four types: the fist type is type grassland which mainly including xerophytes herbs. The second type is desert grassland, which is less sparse distribution than the first and filled with xerophytes shrubs. The third type is grassland's desert that is filled with less bunch grass and is located in river basin. The last type is non-regional grassland among above three types. Damao County not only is a boundary county and animal husbandry base, at the same time, but also contains a lot of mineral resources. With the development of society and economy, the average disposable income in urban city has rose by 14.9 increasing rate per year, and the net income in village also has 12.5 increasing rate, and the industrial outcome has get to the level of the 10 billion RMB.

4.2 DEVELOPMENT PATTERNS

According to the national grassland protection construction development planning, national grassland ecological construction planning and the need of protecting typical grassland environment, natural grassland grazing level must be controlled within the appropriate scope of grazing capacity, the problem of excessive grazing must be prohibited so that the natural grassland can recover the original balance between ecology and environment. As we known, there is not a conflict between the development of ecology and society and the protecting of grassland environment, and the key solution is the development pattern of typical grassland. From the successful experience of the development patterns in the domestic and foreign countries. We can find that the suitable development road of grassland animal husbandry is decided by planning the scientific animal husbandry carrying capacity and choosing the appropriate grazing way, such as increasing higher production or better quality grass, improving the supply ability of artificial forage, developing the rotational, seasonal or regional grazing way, controlling the grazing frequency.

Under the above background, many problems will appear and we have to solve these difficulties, such as the protecting of grassland environment, population increasing, the change of grassland utilization way, the augment of pastoral economic aggregate, the improving of herdsman's net income, the irrigation scale of the artificial grassland.

Based on the practical situation of water resources conditions in typical grassland and the development need of economy and society in pastoral area, this paper mainly consider five different development patterns to forecast the future situation of pastoral area, and all the subsystem must be contain in the pattern in 2009 and 2019.

The present development pattern maintain the practical level in Damao County, and then the present water carrying capacity will be calculated for analysing the water consumer level and water using structure in different industries.

The planning year can be designed as following:

1) The subjective layer: assuming the initial water rights have been obtained, the available water resources use the present calculation results with considering the change of precipitation and evaporation.

2) The objective layer: in future water supplying conditions, the living water using and ecological water using should be satisfied first. In short, the living water using containing the third industry water using, the ecological water using including artificial and controlled water resources beyond the scale of river. Considering the vulnerable of ecology and environment conditions in pastoral area, the water supplying order of industry, animal husbandry and artificial grassland irrigation are superiority to farmland irrigation.

3) The coupling layer: water using efficiency and the net quantity of each unit are the primitive influence factors

in water resources coupling layer. Water using efficiency can be determined according to the development of industry standard. Based on the present standard, the net quantity of each unit will be improved with taking advance coefficient into account, other factors also be considered, such as the adjustment of agriculture farming structure, water saving irrigation upgrade.

TABLE 1 Typical Grassland Development Pattern in Planning Year

Pattern	Water Resources	Society	Economy	Ecology
A-1	$W=W_r$	E_p(+1.0%)	E_{GDP}(-2.0%)	E_g(-1.0%)
A-2	$W=W_r$	E_p(+1.0%)	E_{GDP}(-5.0%)	E_g(-2.0%)
B-1	$W=0.9 \cdot W_r$	E_p(+0.8%)	E_{GDP}(-2.0%)	E_g(-1.0%)
B-2	$W=0.9 \cdot W_r$	E_p(+0.8%)	E_{GDP}(-5.0%)	E_g(-1.0%)
C	$W=1.1 \cdot W_r$	E_p(+1.0%)	E_{GDP}(-2.0%)	E_g(-1.0%)

W is the designed total available water resources quantity

4.3 RESULTS

4.3.1 Present year

The evaluation results of calculation model show that the water resources carrying capacity of supporting economic development in Bailingm Town and Mandul Town is overloading, because the distribution of the second and third industry in these two towns is intensive. Bailingm Town is the centre capital area of Damao County and its population density is high, so the population carrying capacity is overloading. However, in grassland ecology and environment aspect, the grassland carrying capacity of many towns is overloading expect the Bayinh Town and Mandul Town. Table 2 is the evaluation results of calculation model.

TABLE 2 Results of Water Resources Carrying Capacity Calculation in Present Year

Town	C_t	Present	Overload	C_{GDP}	Present	Overload	C_g	Present	Overload
	10 thousand people			*10 million RMB*			*km²*		
WUKE	4.4	3.1	-1.3	5.2	11.7	-40.6	882.2	984.4	102.2
SHIBAO	4.7	3.1	-1.6	56.0	8.2	-47.8	764.6	827.4	62.8
MINGAN	1.7	0.5	-1.2	20.6	8.0	-12.6	1591.9	1646.6	54.7
BAILINGM	2.7	3.6	0.8	32.6	58.3	25.7	2045.7	2846.4	800.7
BAYINH	0.8	0.4	-0.3	9.4	9.5	0.1	2289.2	2192.7	-96.4
MANDUL	0.3	0.2	-0.1	3.7	4.2	0.5	2330.7	1542.2	-788.5
DAERHAN	1.6	0.4	-0.1	19.1	5.4	-13.7	1799.9	3961.6	2161.6
XILAMR	1.6	0.5	-1.1	18.9	1.4	-17.5	987.8	1098.7	110.9
DAMAO County	14.4	12.0	-2.4	170.5	106.9	-63.7	12691.9	14500.0	1808.1

4.3.2 Planning year

Based on proper stocking rate and the natural rehabilitate by the recover ability of grassland itself, the income and the living level of herdsman should be considered the calculation model. When the grassland carrying capacity supported by water resources is in the overload situation, the surpass part can be supplied by artificial irrigation fodder grass.

The whole Damao County is taken as the average calculation unit of rainfall and economic development so that the administrative region is ignored. Forecasting the change of social and economic conditions, the carrying capacity of society, economy and grassland supported by water resources is be calculated and analysed in the planning year. The calculation results are shown in Table 3.

TABLE 3 Results of Water Resources Carrying Capacity Calculation in Planning Year

Patterns	C_t (10 thousand people)		C_{GDP} (10 thousand people)		C_g (km²)	
	Result	*Variant*	*Result*	*Variant*	*Result*	*Variant*
Present Year	12.0	0.0	106.9	0.0	14500.0	0.0
A-1	13.7	1.7	188.6	81.7	13346.0	-1154.0
A-2	13.8	1.8	220.3	113.4	14040.9	-459.1
B-1	13.1	1.1	209.3	102.4	13338.9	-1161.1
B-2	13.3	1.3	245.8	138.9	14787.5	287.5
C	15.7	3.7	242.4	135.5	14680.6	180.6

Compared with the present development patterns, the calculation results show that all carrying capacity of Damao County is in higher level. The *C* pattern is mostly improving the carrying capacity of society, economy and grassland due to the adding of water resources supplement. The *A*-1 and *A*-2 pattern, which is representing the current development situation is in higher social and economic carrying capacity but the grassland carrying capacity remain in the overload situation leaded by the irrational water demand structure and low ecological water available quantity. By limiting the water using in first and second industry, the *Cg* of *B*-1 and *B*-2 pattern is up to 13338.9 and 14787.5 km^2 respectively. Although *C* pattern can solve the problem on excessive grazing activities, *B*-2 pattern is more suitable than *C* pattern in considering the management cost and technological feasibility. Therefore, putting on the strict water resources management policy is the most effective way to optimize the distribution of water resources supplement and comprehensive carrying capacity supported by water resources systems.

5 Conclusions

5.1 GENERAL SITUATION

Analysing the above calculation results, some conclusions can be summed as following:

1) The results of present year show that there is a wide variance among different administrative region, the water resources carrying capacity of supporting economic development in Bailingm Town and Mandul Town is overloading. And the population carrying capacity of Bailingm Town is overloading. In ecology and environment aspect, the grassland carrying capacity of many towns is overloading. Lower water resources carrying capacity is meaning the little water utilization effective, and the practice value of water resource, which is very limited, has not been revealed.

2) Damao County is located in the north of China, and its characteristic is low rainfall and high evaporation. Because of lacking the controlling the project of surface water, improving water resources system carrying capacity itself is the only way to remiss the overload situation. Considering the current development situation in pastoral area, five different development patterns are designed for representing the social, economic and ecology conditions. As the natural barrier, the health situation of grassland is relate to the change of social and economic development. By calculating five different development patterns, the results show that *B*-2 pattern, which is designed for carrying out the most strict water resources management policy, can solve the overload problem of grassland carrying capacity compared with other development patterns.

3) From the research work, we can see that the calculation model of water resources carrying capacity is available and feasible at the aspect of management cost and technology, and the calculation results can provide reliable information and guide for macroscopic water resources management in large watershed and administrative region.

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