Assessing the Carrying Capacity Threshold of Soil Water in Cultivated Land in Hebei Province

Xia Hui, Wang Hongsheng, Gao Huiyan, Yang Luhua

College of Urban and Rural Construction, Agricultural University of Hebei; Baoding, 071001, China

Abstract — On the basis of the previous research, an evaluation index system of soil water carrying capacity in cultivated land in Hebei Province has been established. In this paper, the concept, connotations, requirements of the threshold values of the evaluation index system will be introduced and analyzed, and methods to determine the threshold values will be studied. By analysis and classification of these indicators, 4 methods are proposed to determine the threshold values, they are: i) Investigation method, ii) Statistical analysis method, iii) Analogy and iv) Expert experience method. Also, the procedure to determine the threshold values for each method is detailed, and the threshold value for each secondary indicator is calculated.

Key words - Threshold; Soil water resources carrying capacity of cultivated land; Hebei Province

Ⅰ. INTRODUCTION

The determination of the threshold value is an important procedure to an assessment, and the accuracy of the values will influence the scientific importance, objectivity and practicability of the assessment result directly. As a result, it is significance to determine the index threshold values reasonably. At present, many scholars are making a study on the determination methods of the threshold values, for example, Li Hua et al. constructed the system dynamics model of eco-security on the basis of the subsystems of economy, population, resources, environment, ecology in Chongming, and determined the eco-security threshold [1]. Liu Zhenhuan et al. analyzed the relationship between urban landscape change and water quality degradation by using the nonlinear regression, and developed a new method to estimate the threshold based on cross-section statistics [2]. Chen Xiaohua et al. analyzed the eutrophication features and differences in main lakes in Southern of Jiangsu Province using Comprehensive nutrition state index method, Box-drawing method, and Inflection point detection analysis method, and studied the threshold value between the mild eutrophication and moderate eutrophication [3]. Zhao Axing promoted the conception of the calamity damage threshold value (CDTV), and described CDTV with step function to reflect the damage degree of hazard carrying body [4]. Based on the earlier research, Feng Yan et al. referred the international treaties related to water allocation in 1864-2002, collected the key hydrological data of the 28 rivers, and calculated the threshold of the indicators [5], and so on.

On the basis of the previous research, the evaluation index system of the soil water resources carrying capacity in cultivated land in Hebei Province has been established [6]. And in this article, all of the research is carried on the threshold values of the above-mentioned evaluation index system.

Ⅱ. MATERIAL AND METHODS

A. Concept And Connotations Of The Evaluation Index Thresholds

A threshold means the sill of a door, which is the boundary of a field or a system in scientist, and the value is called a threshold value. During the evaluation of the soil water resources carrying capacity in cultivated land in Hebei Province, the evaluation result will be affected by many factors, such as natural conditions, economic development, social conditions, national policies, economic efficiency of agriculture, soil water utilization technology, and so on. In this paper, there are two connotations in the conception of the threshold. Firstly, a threshold is the maximum or minimum value which can be reached within the planning period according to the law of economic development and practical production experience of agriculture, economy and population in Hebei Province in recent years. Secondly, the threshold is the indicator need to achieve the limit to meet the requirements of the national and provincial policies, regulations, standard and planning within the planning period.

B. Requirements Of The Evaluation Index Threshold Values Determination

Evaluation index threshold values should meet the requirements of science, objectivity and feasibility, at the same time, the different in evaluation stages and regions about evaluation objects should be taken into consideration during the determination of the threshold values of the assessment of soil water resources carrying capacity in cultivated land in Hebei Province. The requirements are as following:

1) The threshold values difference among the different evaluation objects

The evaluation index threshold values which have been determined in this paper can be applied only to the evaluation of soil water resources carrying capacity in cultivated land in Hebei Province, instead of assessment of others resources carrying capacity, such as assessment of
water resources carrying capacity, just because of the
differences between the soil water resources and other water
resources in carrying models, method of utilization, saving
water mode, and so on.

2) The threshold values difference among the different
regions
The evaluation index threshold values which have been
determined in this paper can be used only in the 11 districts
in Hebei Province, China. The reason is that all of the data,
design code, regulations and national policy have been used
during the determination of the index thresholds are about
this province. When the basic information of the index has
been changed, the threshold values will be changed consequently. So, the threshold values have obvious regional
characteristics, the difference among regions can be
reflected directly by the different index threshold values.

3) The threshold values difference among the different
evaluation stage
Economy development will bring a change to the basic
data, design code, regulations, and even the national policy,
and following the change of the basic information, the index
threshold values will be changed. Therefore, not only the
difference among the regions but also the difference among
the evaluation stages should be considered when the
evaluation index threshold values have been determined.

In this paper, 2010 has been selected as a base year, and
2030 has been selected as a planning year, thus the
evaluation index threshold values which have been
determined in this paper should be utilized from 2010 to
2030.

C. Determination Methods Of The Evaluation Index
Threshold Values

According to the definition and explain of threshold
value as mentioned above, the index threshold values of the
assessment of soil water resources carrying capacity in
cultivated land in Hebei Plain should be the ideal values and
expected values during the evaluation stage (2010-2030).
Meanwhile, the threshold values should be considered with
national and provincial policies, design code, regulations,
the actual situation in developed countries and areas, and
combined with the results which the related experts have
forecasted depending on the experiences in this field and the
development trend in the utilization of soil water resources
in Hebei Province.

Therefore, 4 kinds of methods of the determination of the
index threshold values will be introduced in this paper: 1) Inves-
tigation method. In this method, all of the national and
provincial policies and planning, design code, regulations
which are associated with the research will be collected as
the reference and basis of the threshold values; 2) Statistical
analyses method. In this method, the related yearbooks about
soil water and agriculture in Hebei Province and other
provinces will be found, then all of the data derived from
these yearbooks will be analyzed by SPSS software to
simulate the regression equations and have the significance
test on these equation, at last, the regression equations are
used to calculated the index threshold values in 2030; 3) Analogy. When the data which are utilized to simulate the
regression equations cannot be found in Hebei Province,
analogy will be a method to determine the index threshold

values. Compared the economic development level between
Hebei Province and other developed countries (or areas), or
developed provinces, and the threshold values can be
predicted; 4) Expert experience method. This is another
method to determine threshold values while lacking basic
data or files, and the process is: Firstly, sending the
investigation questionnaire to the expert in the related fields.
After the questionnaire has been filled by experts, collecting
all the threshold values together. To avoid the influence by
the maximum and minimum, the maximum and the
minimum of a threshold value will be removed, and average
of the left data as an indicator threshold value.

III. RESULTS

The evaluation index system of the soil water resources
carrying capacity in cultivated land in Hebei Province has
been established. The index system includes 4 primary index
and 17 secondary index, the primary index are water supply, water utilization, management and benefit, and the
secondary index include the ratio of the agricultural water
supply, the ratio of the irrigated area, the ratio of the area of
film covering, water use efficiency, and so on, and the
calculation formula of each indicator has been formed. The
17 secondary index will be grouped into 4 as following, and
the threshold values of these index will be determined by the
4 method as mentioned above.

A. Investigation Method

Among the 17 secondary index, there are 2 index
threshold values which need to be determined by this
method, they are "fulfilling rate of the water supply ability
of the water conservancy project (A11)" and "utilization
coefficient of irrigation water (A21)".

1) Filling rate of the water supply ability of the water
conservancy project (A11)
To determine the threshold value of this indicator, "Hebei Province Water Conservancy Statistical Yearbook" from 2000 to 2012 have been found to collect the water
supplying amount and capacity of each water conservancy
project in Hebei Province. Based on the water conservancy
meeting in this province, South-to-north Water Transfer
Project, Yellow River Diversion Project and Shuangfengsi
reservoir will be promoted, and the construction of
unconventional water resources project will be developed
from 2011 to 2015. All of the projects can add water
supplying 4.28 billion m³ per year, therefore the total water
supplying in Hebei Province can be reached 34.6 billion m³
per year. The national water resources management policy
requires the total water consumption in Hebei Province
should be less than 24.6 billion m³ per year. So, using the
calculation formula of this indicator, the threshold value
calculation result is 71.10% [7] [8] [9].

2) Utilization coefficient of irrigation water (A21)
In early 2012, the State Council in China issued the
"Three Red Lines" policy to limit the total water
consumption should be less than 700 billion m³/year, water
use efficiency can reach or approach advanced international
level, water consumption for industrial added value per 10
thousand Yuan will be less than 40 m³ and the utilization
coefficient of irrigation water will be more than 0.60, and water quality up to the standard rate of water function area up to 95% [10].

As a trial implementation province of the policy, the utilization coefficient of irrigation water has been 0.65 in 2012, and is higher than the national average about 15%. To meet the requirement of the policy of water resources management, the total water consumption should be less than 22.10 billion $m^3$/year and the utilization coefficient of irrigation water should be 0.67 in 2020, and this coefficient will be 0.72 in 2030 by carrying out the strict water resources management policy. Therefore, basing on the national and provincial policy, the threshold value of irrigation water use coefficient is 0.72.

B. Statistical Analysis Method

Among the 17 secondary index, there are 13 index threshold values can be calculated by this method, almost all kinds of yearbooks about agriculture and water resources in Hebei Province have been collected, such as "Rural Statistical Yearbook of Hebei Province" from 2000 to 2012 [11], "China agricultural statistics yearbook" from 2000 to 2012, "New China agricultural 60 years statistical data", and "Hebei Province Water Conservancy Statistical Yearbook" from 2000 to 2012 [12] and [13]. Besides searching for this yearbooks, some data can be searched on the Internet or some academic thesis. Each indicator differs greatly in the quality of the data which can be collected, thus the meaning of $x$ in the regression equations will be different. The regression equations, the significance test, and the simulated index values in 2030 have been show in Table 1.

The simulation for each indicator which used Statistical Analysis Method are shown from Fig 1. to Fig 7.

### TABLE 1. THE INDEX THRESHOLD VALUES DETERMINED BY STATISTICAL ANALYSIS METHOD

<table>
<thead>
<tr>
<th>Index</th>
<th>Regression equation</th>
<th>Significance test of regression equation</th>
<th>Index Value in 2030</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{12}$</td>
<td>$y = 82.316 - 0.6913x$</td>
<td>$F_{0.01}(1,19) = 30.56$</td>
<td>221.19</td>
<td>62.23% $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{21}$</td>
<td>$y = 52.898 \times x^{0.120}$</td>
<td>$F_{0.01}(1,17) = 8.40$</td>
<td>127.73</td>
<td>82.60% $x$=year, take 1990 as the first year</td>
</tr>
<tr>
<td>$A_{22}$</td>
<td>$y = \frac{0.8}{1 + \exp(-0.1x)}$</td>
<td>$F_{0.01}(1,8) = 11.26$</td>
<td>35.32</td>
<td>76.55% $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{23}$</td>
<td>$y = 22.261x^{0.277}$</td>
<td>$F_{0.01}(1,15) = 48.8$</td>
<td>120.76</td>
<td>49.89% $x$=year, take 1990 as the first year</td>
</tr>
<tr>
<td>$A_{24}$</td>
<td>$y = 1.3053 + 0.009x$</td>
<td>$F_{0.01}(1,20) = 8.10$</td>
<td>204.07</td>
<td>73.29% $x$=year, take 1990 as the first year</td>
</tr>
<tr>
<td>$A_{25}$</td>
<td>$y = 0.42 \ln(x) + 3.0188$</td>
<td>$F_{0.01}(1,8) = 11.26$</td>
<td>45.17</td>
<td>2.19% $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{26}$</td>
<td>$y = 20.381 + 1.2904x$</td>
<td>$F_{0.01}(1,10) = 10.04$</td>
<td>227.65</td>
<td>73.29% $x$=year, take 1990 as the first year</td>
</tr>
<tr>
<td>$A_{27}$</td>
<td>$y = 8.4287 \times x^{0.327}$</td>
<td>$F_{0.01}(1,10) = 10.04$</td>
<td>78.61</td>
<td>25.91% $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{28}$</td>
<td>$y = -0.0412 + 0.327x$</td>
<td>$F_{0.01}(1,4) = 21.20$</td>
<td>160.80</td>
<td>13.37% $x$=year, take 1990 as the first year</td>
</tr>
<tr>
<td>$A_{29}$</td>
<td>$y = 18.856x^{0.0497}$</td>
<td>$F_{0.01}(1,9) = 10.56$</td>
<td>115.68</td>
<td>22.37% $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{31}$</td>
<td>$y = 1.716x^{0.162}$</td>
<td>$F_{0.01}(1,8) = 11.26$</td>
<td>45.69</td>
<td>7800 Yuan per capita $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{32}$</td>
<td>$y = 7.689x^{0.1782}$</td>
<td>$F_{0.01}(1,10) = 10.04$</td>
<td>450.03</td>
<td>14.18t/hm$^2$ $x$=year, take 2000 as the first year</td>
</tr>
<tr>
<td>$A_{33}$</td>
<td>$y = 7.2057x^2 + 2.3932x + 836.69$</td>
<td>$F_{0.01}(1,9) = 10.56$</td>
<td>278.08</td>
<td>4.37% $x$=year, take 2000 as the first year</td>
</tr>
</tbody>
</table>

Figure 1. The agricultural water supplying ratio (left) and the effective irrigation area ratio (right) in Hebei Province
Figure 2. The saving water irrigation area ratio (left) and the ratio of the irrigation area to the paddy field area (right) in Hebei Province

Figure 3. The multiple cropping index (left) and the ratio of the grain crops planting area to the economic crop planting area (right) in Hebei Province

Figure 4. The straw returning area ratio (left) and the film covered area ratio (right) in Hebei Province

Figure 5. The facility agriculture area ratio (left) and the ratio of the irrigation district management area (right) in Hebei Province
C. Analogy

There is only one indicator threshold value which needs to be determined by this method, and this indicator is "the radio of the agrotechnician (A31)".

To determine the threshold value of this indicator, the related data about the number of agricultural practitioner and the number of agricultural technicians in some advanced provinces and areas and in China have been collected by searching in Beijing Bureau of Statistics website, Shanghai Bureau of Statistics website, Guangdong Bureau of Statistics website, Fujian Bureau of Statistics website, Hebei Bureau of Statistics website and China Bureau of Statistics website. In addition, a part of data come from the second national agricultural census. The calculation result of the ratio of the agro-technician is shown in Table II.

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Agricultural Practitioner (thousand people)</th>
<th>Number of Agricultural Technicians (thousand people)</th>
<th>The Ratio of the Agro-technician (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>348740</td>
<td>2070</td>
<td>0.59</td>
</tr>
<tr>
<td>Beijing</td>
<td>656.6</td>
<td>22.3</td>
<td>3.40</td>
</tr>
<tr>
<td>Shanghai</td>
<td>585.5</td>
<td>4.0</td>
<td>0.69</td>
</tr>
<tr>
<td>Guangdong Province</td>
<td>14276.0</td>
<td>78.5</td>
<td>0.55</td>
</tr>
<tr>
<td>Fujian Province</td>
<td>6138.7</td>
<td>92.4</td>
<td>1.50</td>
</tr>
<tr>
<td>Hebei Province</td>
<td>22434.0</td>
<td>42.8</td>
<td>0.19</td>
</tr>
</tbody>
</table>

From Table II., it has been shown that the ratio of the agrotechnician in Hebei Province is less than 1/3 of the average ratio of China in 2006, and it is far lower than the ratio in Beijing agricultural technology personnel. With the economic development in Hebei Province and the Beijing-Tianjin-Hebei integration putting into effect, the ratio of the agrotechnician in Hebei Province will be greatly improved, and it can reach the current level in Beijing by 2030. Therefore, the threshold value of this indicator is 3.40%.

D. Expert Experience Method

If there is no one related datum can be found to an indicator, the threshold value of the indicator has to use expert experience method. In this paper, the indicator of "the utilization ratio of the soil water resources (A13)" will be used this method to determine the threshold value, and the process has been introduced in the foregoing.

To determine the threshold value, the questionnaires about the utilization of soil water resources have been sent to 20 experts who are in the fields of agriculture and water conservancy. By summary, analysis and calculation, the threshold value is 40%.
IV. CONCLUSION

The concept, connotations, requirements of the threshold values have been discussed. The threshold values in this paper have two connotations, one is the maximum or minimum value which can be reached within the planning in Hebei Province in recent years, another is the indicator need to achieve the limit to meet the requirement of the national and provincial policies, regulations, standard and planning within the planning period. The threshold values determination should pay attention to the difference existing in the different evaluation objects, the different regions and the different evaluation stages. At the same time, 4 methods which can be used to determine the threshold values have been put forward, they are Investigation method, Statistical analysis method, Analogy and Expert experience method, using these methods, the threshold values of the assessment of soil water resources carrying capacity in cultivated land in Hebei Province have been determined, and these have supplied the important and necessary basis and data for the evaluation.

ACKNOWLEDGMENT

This work is supported by Program of Study Abroad for Young Teachers by Agricultural University of Hebei, the project of Provincial Natural Science Foundation of Hebei (E2015204205), the research project of Hebei Provincial Department of science and technology (15963608ID), the education research project of Education Department of Hebei Province (2015GJG041), and Youth Fund of Agriculture University of Hebei (QN201324).

REFERENCES