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Research Article

Agricultural Water Circulation Model based on Food Security of China

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Abstract: This study analyzed agricultural water circulation model based on the low agricultural water use efficiency. The agricultural water circulation model was proposed according to the fuzzy mathematics theory, then the fuzzy decision-making on water resources conservation patterns was done depending on MATLAB. Conclusions and the relative suggestions were represented at the end.

Keywords: Food security, fuzzy comprehensive evaluation, water circulation

INTRODUCTION

Water scarcity is now a common occurrence in many countries. The situation is particularly grave with the population growth, degraded water quality and pollution of surface and groundwater sources in China. With much less water, China has to face the problems about uneven distribution of water resources, increasingly crisis of water supply and demand due to the prominent rapid socio-economic development and global climate change, triggering a series of water problems of water shortage, water pollution and ecological degradation exacerbated. In recent years, the frequent occurrences of droughts happened in various regions seriously have affected the economic and social development, leading to the adverse effects of the food safety due to agricultural water shortage. Among all the water users, agriculture is a major user for many countries, e.g., China, where agricultural water consumption accounts for about 64.8% of the national total water consumption, of which 90-95% is for irrigation. More than 70% of food crops, 80% of cotton and 90% of vegetables are produced in irrigation land in China. The sever situation poses a great challenge to carry out agricultural water circulation work.

Previously, many works about flow of water resources, optimization of the water resources allocation have been addressed. For example, water users have the right to freely trade or collateral their holding water. In determining the issue of water rights on the basis of the definition, scholars began to focus on the issue of water rights transfer and the transfer intrinsic motivation of water resources. Hu (2010) studied the definition and efficiency implementation of agricultural water rights, studied the definition and efficiency implementation of agricultural water rights, he pointed that the right to agricultural water has obvious attributes of Club Property Rights which largely affected the efficiency of agricultural water use. To improve the allocation and use of agricultural water efficiency target, the ownership of water resources and water rights should be cleared defined and strengthen. Lai and Tian (2012) made a systemic economic description of water transfer in the dual economic structure system and obtains the conclusion that the water transfer in the dual economy is a process from unlimited-supply state to scarcity reflection.

Yang and Wang (2008) studied related cases about replacement of water rights in Ningxia, they discovered that water rights displacement should be done in the context of the orderly management between industries to achieve the optimization for the allocation of the water resources, then both the industry and agriculture could take into account of water demand. Meanwhile, another major motivation of the water circulation is the low agricultural water use efficiency. Jiang and Hu (2008) collected data Weishan Irrigation District in Shandong Province, the costs and benefits of agricultural irrigation water for power generation and water areas were compared, thus verify the efficiency of water use in the agricultural sector was lower than the fact that in the industrial sector. Howe and Goemans (2003) analyzed the system design, economic environment and specific form of water rights which would influence the water rights market in the water rights transfer process; Pei *et al*. (2007) and Li (2004) studied the pricing mechanism of water rights circulation.

However, the current researches focus on the efficiency of optimal allocation of water resources. To insure the irrigation water demand in the process of agricultural production is a top priority to protect our food security. Therefore, this study will be carried out on water circulation model in our research, try to improve the utilization of water resources and promote the development of agricultural and rural economic.

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MATERIALS AND METHODS

According to statistics of the government sectors, the average agricultural water use efficiency is an important agriculture indicator used to reflect the effectiveness of the water resource use efficiency, this indicator is currently about 0.4 in China and about 0.8 in high water use efficiency country, which means that other factors under the same premise, the efficiency of agricultural water only reached about half in China.

The condition of water supply and demand is much serious in China. More than 400 cities face the water shortage across the total 668 cities in this country, including 114 cities have the severer condition with daily shortage water 1600×104 t, the annual direct economic losses reach over 2000×108 Yuan due to water shortage, food produced has decreased 700×108~800×108 kg every year due to lack of water. The total amount of shortage water in the country is about 300×108~400×108 m^3 in the case of over-exploitation of groundwater does not occur. Water shortage has become a serious constraint in China, especially in northern areas where economic and social development behind the condition of the southern areas. From the perspective of food production and food security, the water resources in northern grain-producing areas are not surplus with the growth of food demand, the situation will lead to more severe water shortages in the north. The main grain-producing areas will become difficult to own sufficient water resources, which could affect China's food security.

Brown first published an article entitled “China's water shortage will affect world food security” on World Watch in 1998. Brown pointed that the situation of declining groundwater levels occurred in China would soon lead to rising food prices in the worldwide. Due to extremely differences in the distribution of water resources between the north and south areas in China, the pattern of food transfer from south to north has long formed. In the 1980s, this pattern has changed radically. From the statistical data analysis, in the 1950s, the total food production of 15 provinces in north of the Yangtze River accounted for 40% of total food production, water resources accounted only 19% of the country's total water resources. In contrast, the total food production of 15 provinces in south of the Yangtze River accounted for about 60% of total food production with only 81% water resources in China. In the 1990s, the proportion of total food production in the south of the Yangtze River has dropped to about 52%, by contrast, the proportion of total food production in the north of the Yangtze River has risen to around 48%. From the aspect of increasing food production, in the 1950s, the increasing food production in the northern region accounts only about 42%, while the southern region accounts for about 58%. Since the year of 1984, proportion of food incremental production has risen to 66% in northern, while the southern food incremental production fell to 34% which food production in the southeast region presented negative growth in 1984 and 1993. Dramatic changes of this pattern will have an important impact on total food production growth in the next 50 years. The current water shortage conflict in northern has been very sharp, next year if the fundamental pattern change of total food production does not occur, then the future of the north, especially in North China contradiction water shortage will become more acute, water restraining effect on food production shortfall will be more significant. In the case of water shortage, it is really difficult for China to face the 1.5×108 t food production increasing capacity in 30 years or so.

In order to solve the serious water shortage in China, Chinese government put forward “the strictest water resources management system” in 2010 and set up “the three red lines” to assure this system implemented. During the year of 2011-2015, the total water investment is expected to reach 1.8 trillion Yuan, including 20% will be used in the construction of water conservancy investment for national food security, which is vital part of the investment to reverse the hysteresis condition of irrigation facilities. By 2030, the country's total water will be controlled within less than 700 billion m^3; water efficiency will reach the world advanced level, effective utilization coefficient of irrigation water will increase to 0.6 or more; water quality compliance rate in water functional areas will reach to more than 95%.

Theory of fuzzy comprehensive evaluation and fuzzy decision making: This study attempts to introduce a comprehensive evaluation of fuzzy decision theory and fuzzy optimization of water circulation. Multi-objective decision problem (also known as multi-objective programming problem) is a decision-making process to determine the quality of a program in the case of multi-objective criteria. Decision-making is mainly to solve the scheduling problems with multiple targets which are the decision-makers in the decision-making practical problems often encountered. The specific algorithm steps are as follows.

Establish programs set: Suppose the number of decision schemes is n, expressed as:

$$U = \{u_1, u_2, \ldots \mathrm{u_n}\}$$

Determine the factors of evaluation program set: Express the field of the factors of evaluation program set:

$$V = \{v_1, v_2, \ldots \mathrm{v_m}\}$$

Index vector of the factors of evaluation program set is:

$$u_j = \{v_{1j}, v_{2j}, \ldots v_{mj}\},\ j = 1, 2, \ldots,\ n$$

Determine the decision matrix: Determine the Decision Matrix F, including m of factors and n of programs, set F_{ij} as the i-th program of j-th set:

$$F=\begin{bmatrix} F_{11} & F_{12} & \cdots & F_{1n} \\ F_{21} & F_{22} & \cdots & F_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ F_{m1} & F_{m2} & \cdots & F_{mn} \end{bmatrix}$$

Normalization of the decision matrix: As data units of different attributes index are often different, if the data's of attribute indicators do not be normalized, the attributes between them are not comparable. Methods commonly used normalized are as follows.

Normalization of the vectors: The formula is:

$$\mu_{ij} = \frac{F_{ij}}{\sqrt{\sum_{j=1}^{n} F_{ij}}}$$

Scale conversion method: The method for different types of attributes using different conversion.
For income property index, Conversion formula is:

$$\mu_{ij} = \frac{F_{ij} - F_{\min,j}}{F_{\max,j} - F_{\min,j}}$$

For cost property index, Conversion formula is:

$$\mu_{ij} = \frac{F_{\max,j} - F_{ij}}{F_{\max,j} - F_{\min,j}}$$

From the above formula:

$$F_{\max,j} = \max\left\{F_{1,j}, F_{2,j}, \ldots F_{n,j}\right\}$$

$$F_{\min,j} = \min\left\{F_{1,j}, F_{2,j}, \ldots F_{n,j}\right\}$$

Determine the weight coefficient vector W: Consider various options, in order to reflect importance of various objectives affecting the decision, introduce the target weight. In a multi-objective fuzzy decision, the weight of each factor in a comprehensive decision reflects its position, directly affect the decision results. Therefore, the program is essential to determine the weights.

Establish formula of fuzzy comprehensive evaluation:

$$B = WR = (W_1, W_2, \ldots W_n)\begin{bmatrix} \mu_{11} & \mu_{12} & \cdots & \mu_{1m} \\ \mu_{21} & \mu_{22} & \cdots & \mu_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ \mu_{n1} & \mu_{n2} & \cdots & \mu_{nm} \end{bmatrix}$$

where,
B = The evaluation matrix
W = Weighting coefficient vector
R = The total evaluation matrix

μ_{ij}, i = 1, 2, ……n; j = 1, 2,……m is evaluation membership.

Establish fuzzy evaluation factors: Establish the regional water circulation mode from the practical situation, characteristics of regional water should be took into account, including the costs, benefits and risks of water circulation mode. In these types of factors, referring to other resources circulation indicator system mode, we select capital investment, reserve risk, EPP, resource recovery, trade representative indicators for evaluating the possibility of five regional water circulation mode merits of factors set.

Principles of fuzzy evaluation: Subject for discussion is U, A_1, A_2, …… A_n is the fuzzy sets of U, for $\chi_0 \in U$, χ_0 can be considered relatively affiliated to A_K under the condition of:

$$\mu_{A_K}(\chi_0) = \max\left\{\mu_{A_1}(\chi_0), \mu_{A_2}(\chi_0), \ldots \mu_{A_n}(\chi_0)\right\}$$

When mention the water circulation mode, we can analyze the following eight types: Ground reservoir, water diversion, underground reservoir, deep groundwater, desalination, seawater directly used, replacement water and virtual water. Set all kinds of water circulation modes qualitative indicators as follows:

Establish the fuzzy evaluation matrix:

$$F = \begin{bmatrix} 5 & 0 & 6 & 7 & 1 & 3 & 2 & 4 \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 2 \\ 3 & 1 & 4 & 4 & 5 & 5 & 6 & 2 \\ 4 & 3 & 5 & 1 & 9 & 9 & 8 & 6 \\ 7 & 3 & 6 & 5 & 8 & 8 & 9 & 4 \end{bmatrix}$$

RESULTS AND DISCUSSION

According to the above discussion, from the indicators mentioned above, the EPP and resource recovery which are relative important deserve more attention, therefore their weights set are relatively large, their weights are set as 0.2. While Capital investment, risk, trade are relatively less important, so their weights are set as 0.1:

W = [0.1 0.1 0.2 0.2 0.1]

The following results can be got through the software of MATLAB.

Prioritization scheme:

$$S = \begin{bmatrix} 5 & 7 & 6 & 3 & 1 & 8 & 2 & 4 \end{bmatrix}$$

According to the fuzzy comprehensive evaluation results and the maximum membership principle, we get the priorities of water circulation mode.

CONCLUSION

As analyzed above, the content of this study can be concluded as follows: Introduce fuzzy decision theory based on fuzzy mathematics and fuzzy comprehensive evaluation model, established evaluation factors set reserve mode, consider the costs, benefits, risks and other factors to optimize water reserves mode decision.

The study area of virtual water diversion and other water circulation model is relatively weak. In short, the establishment of water circulation model in the study area should be a three-dimensional model of an integrated structure, the fundamental purpose of its establishment is to ensure the sustainable use of water resources.

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REFERENCES

Howe, C.W. and C. Goemans, 2003. Water transfers and their impacts: Lessons from three Colorado water markets. J. Am. Water Resour. As., 39(5): 1055-1065.

Hu, J.L., 2010. Definition of agricultural water rights and improving the efficiency of the implementation. Issues Agric. Econ., 20(11): 40-46.

Jiang, D.H. and J.L. Hu, 2008. Economical Analysis on phenomenal of water resources “agriculture transferring to non-agriculture. China Agric. Resour. Regional Plann., 29(3): 21-26.

Lai, C.F. and G.L. Tian, 2012. Water transfer of dual economy model in China. China Popul. Res. Environ., 8(1): 90-95.

Li, S.Q., 2004. Discussion about transfer price of water right structure. Inner Mongolia Water Res., 58(2): 17-18.

Pei, Y., H.J. Yin and T.M. Tie, 2007. Price study on water right transfer of Yellow River. China Water Conserv., 56(19): 56-58.

Yang, Y.M. and X.J. Wang, 2008. Water rights transfer and construction of water rights system path. Water Econ., 26(2): 18-21.