CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Peiyu Ren, Yancang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546094

An Analysis on Spatial Heterogeneity of Optimum Allocation Efficiency in Water-land Resources

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In order to analyze regional difference in optimum allocation efficiency of water-land resources, the article selected panel data of 2011 to make up input-output index system of optimum allocation efficiency on water-land resources. The results of super efficiency in data envelopment analysis show that: firstly, there are some differences among optimum allocation efficiency of water-land resources in different regions of China; secondly, Inner Mongolia, Chongqing, Sichuan, Shaanxi, Hubei, Hunan Guangxi, Liaoning and Shaanxi are located in national final nine; finally, the nine regions are all not relatively effective with less than 100% super efficiency value, and most of these nine regions has inputs redundancy in soil-water erosion controlling, Afforestation of grain for green projects, investment in fixed assets agriculture, forestry, animal, husbandry and fishery; investment in fixed assets management of water conservancy, environment and public facilities.

1. Introduction

Since there are large-scale population expansion and rapid development of economy, the contradiction between supply and demand of water-land resources is becoming more and more intense (Satoru Okubo et al. (2003)). Nowadays water-land resources are not only the scarce natural resources, but also the precious asset, so optimum allocation efficiency in water-land resources has become the hot spot and focus in research field.
At present, there were many researches on optimum allocation of water-land resources. Firstly, the research content included water, land and their coupling. Secondly, the methods included qualitative and quantitative research; especially there were so many quantitative researches such as models and decision support systems of optimal allocation (Bas Straatman et al. (2003); Khalid Eldrandaly (2010); Teresa Serra et al. (2009); Wei-Wei Yao et al. (2011)). And the models were based on systems engineering and system dynamics and constructed by linear programming, dynamic programming, multi-objective decision-making, SD model, etc. (M. A. Badr et al. (2010); A.H. El Nahry and E. S. Mohamed, (2011); Dionysis Latinopoulos (2009); Ines Winz et al. (2009)).
In order to analyze regional difference in optimum allocation efficiency of water-land resources, firstly the article considered water-land resources as a complex system consisting of population, resources, society, economy, ecology and environment, and these elements has interactive relationship; secondly, the article selected panel data of 2011 to make up input-output index system of optimum allocation efficiency on water-land resources, and make a comparative analysis of space on optimal allocation efficiency of 31 regions by data envelopment analysis (DEA); thirdly, the article provided some effective empirical suggestions based results of super efficiency DEA to improve macro management of water-land resources in China.

2. Data and method

2.1. Data

The data were results in 2011, and from China statistic yearbook in 2012, China rural statistic yearbook and China land resource statistic yearbook.

2.2 The index system on optimum allocation of water-land resources

The objects of optimal allocation in water-land resources should not be the single water, land resources, but the complex system of many interactive elements including resources, society, economy and ecological environment. And these elements could be divided into three aspects: water, land and other attendant

industries. The course of optimal allocation could be achieved by structural adjustment on use of water, land and other attendant industries. And the comparison between input and output index in the elements contributed to course of structural adjustment. Since index of the three aspects couldn't be strictly distinguished in input and output, the input index consist of social, economic and ecological benefits, while factors of production, fixed assets and fiscal expenditure make up the output index (J. Espinha Marques et al. 2011); Andrew W. K and Nicholas J. Conard, 2012)). In addition the index system had an overall consideration on the principle of availability, operability, science and dominance in data. The Specific index system was shown in table 1, and forward and backward of correlation were expressed in "+" and "-".
Since the best target of efficiency evaluation focused on "high output, low input", the output index were mostly forward correlation; while the input index were mostly backward correlation. However, there were also some backward correlation index in output index system, and these indexes should be transformed by formula below:

$$z_i = \frac{\max(x_i) - x_i}{\max(x_i) - \min(x_i)} \quad (1)$$

In order to keep the consistency of the data size at the same time, other indexes used the following formula:

$$z_i = \frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)} \quad (2)$$

Among them: zi meant for standardized index, xi meant for original index, min (xi) meant for minimum indicators for all samples, max (xi) meant for maximum indicators for all samples.

Table 1: The evaluation index system on optimum allocation of water-land resources

Category	Dimension	Index	Unit	The correlation
Output	Social benefits	Number of employed persons by rural areas	10^4USD	+
		Coverage Rate of Urban Population with Access to Tap water	%	+
		Accumulative benefit population of water improvement in rural areas	10^4 USD	+
	Economical benefits	Gross regional product by primary industry	10^8 USD	+
	Ecological benefits	cultivated land area	hm^2	+
		Depression area	hm^2	-
Input	Input and remold of production factors	Area of soil erosion under control	hm^2	-
		Afforestation area of grain for green projects	hm^2	-
		Amount of investment on hydropower construction completed this year in rural areas	10^8 USD	-
	Fixed assets investment	Investment in fixed assets agriculture, forestry, animal, husbandry and fishery	10^8 USD	-

2.3 Method

In order to analyze regional difference in optimum allocation efficiency of water-land resources, the article had to evaluate optimum allocation efficiency of water-land resources in different regions basing on the input-output index system. Nowadays production efficiency was described by the form of leading surface, and Data Envelopment Analysis (DEA) was one of the most commonly used methods of leading surface estimation.
The thought of paper was: firstly, choosing 31 regions as decision making units; secondly, making up make up input-output index system of optimum allocation efficiency on water-land resources in 2011; thirdly, calculating super efficiency values using efficiency measurement software; fourthly, evaluating and ranking the 31 decision making units basing on results. If super efficiency value was less than 100%, the decision making unit was relative effective.

3. Results and analysis

3.1 The analysis on optimum allocation efficiency in water-land resources of 31 regions

According to the results of the EMS analysis, the super efficiency values of Tianjin, Shanghai, Hainan and Tibet four regions are infinitely great, and the super efficiency values of remaining 27 regions are shown in Table 2 and Figure 1. The overall results show that:

Firstly, there are some differences in optimum allocation efficiency on water-land resources in different regions of China and the situation is general. Since the super efficiency values of 12 regions are greater than 1 and less than 2 with the proportion of 38.71%, and the super efficiency values of 10 regions are greater than 2 with the proportion of 32.26%.Secondly, the super efficiency values of 22 areas are greater than 100% with the proportion is 70.97%, while the other 9 areas are relatively effective accounted for 29.03%.

In general, the status of soil and water conservations turns better but still worse in part. The reasons may come from the following several aspects: the public's awareness of soil and water conservation is significantly improving; the control on soil and water loss is strengthened step by step; the ability of prevention supervision is being improved; the man-made destruction is dropping sharply; and the pressure of ecological environment is gradually reducing.

Table 2: The evaluation on optimum allocation efficiency of water-land resources in different regions during 2011

Region	Super efficiency value	Returns to scale	Area	Rank
Ningxia	1305.67%	Invariant	Northwest	1
Qinghai	573.52%	Invariant	Qinghai-Tibet	2
Xinjiang	345.80%	Invariant	Northwest	3
Jiangsu	279.64%	Invariant	East China	4
Heilongjiang	249.98%	Invariant	Northeast	5
Shandong	210.66%	Invariant	North China	6
Beijing	187.46%	Invariant	North China	7
Fujian	180.93%	Invariant	South China	8
Guangdong	147.11%	Invariant	South China	9
Anhui	145.24%	Invariant	East China	10
Guizhou	140.49%	Invariant	Southwest	11
Zhejiang	128.47%	Invariant	East China	12
Gansu	124.51%	Invariant	Northwest	13
Henan	120.66%	Invariant	North China	14
Yunnan	115.02%	Invariant	Southwest	15
Jiangxi	109.49%	Invariant	Central China	16
Hebei	107.99%	Invariant	North China	17
Jilin	104.02%	Invariant	Northeast	18
InnerMongolia	94.65%	Diminishing	North China	19
Chongqing	88.21%	Diminishing	Southwest	20
Sichuan	86.15%	Diminishing	Southwest	21
Shanxi	85.65%	Diminishing	North China	22
Hubei	81.37%	Diminishing	Central China	23
Hunan	79.97%	Diminishing	Central China	24
Guangxi	75.40%	Diminishing	South China	25
Liaoning	72.81%	Diminishing	Northeast	26
Shanxi	71.22%	Diminishing	Northwest	27

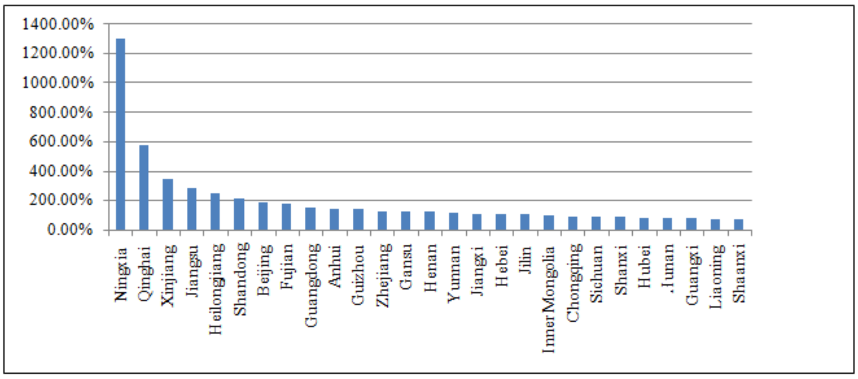

Figure 1: The comprehensive evaluation on optimum allocation efficiency of water-land resources in different regions during 2011

3.2 The analysis on optimum allocation efficiency of water-land resources in different regions

According to table 3, the provinces with better overall situation in allocation efficiency of water-land resources are mostly in north China, followed by east China, south China and northwest have minority provinces at first. Secondly, the better regions of higher allocation efficiency mostly have resources advantage and are focused on by country finance, but aren't equipped with high level of economic development. Thirdly, there are some regions having better performance in optimum allocation of water-land resources and being equipped with high level of economic development at the same time, such as Shanghai, Tianjin, Jiangsu and so on.

As a result, there is a better situation in optimum allocation of water-land resources of China, which is due to most areas attaching more and more importance to improving water and soil erosion (Stephen C Newbold (2002)). Since harmonious development between economy and water-land resources have a worse performance, the regions with worse performance in economic development should attach more importance to improving policy support and infrastructure construction (Grace Muriuki G et al. (2011)), while other regions with better performance in economic development should focus on industrial restructuring of water, land and other resources to realize sustainable development between economy and resources (Guangjin Tian et al. (2012)).

Table 3: The distribution on dea efficiency in different districts

DEA efficiency	North east	North China	East China	South China	Central China	Qinghai-Tibet	North west	South west
>=3	—	Tianjin	Shanghai	Hainan	—	Tibet Qinghai	Ningxia Xinjiang	—
Greater than 2 and less than 3	Heilongjiang	Shandong	Jiangsu	—	—	—	—	—
Greater than 1 and less than 2	Jilin	Beijing Henan	Anhui Zhejiang	Fujian Guangdong	Jiangxi	—	Gansu	Guizhou Yunnan
<=1	Liaoning	Inner Mongolia	—	Guangxi	Hubei Hunan	—	Shaanxi	Chongqing Sichuan
In all	3	7	4	4	3	2	4	4

3.3 The improvement on optimum allocation efficiency of water-land resources in regions with not relative effective efficiency

The super efficiency value of Inner Mongolia, Chongqing, Sichuan, Shaanxi, Hubei, Hunan, Guangxi, Liaoning and Shaanxi are less than 100% and the improved range of optimization efficiency in that nine regions can be calculated according to the input redundancy in results shown in Table 4 and Figure 2.

Table 4: The improvement of regions with relative effective efficiency

Region	Area of soil erosion under control	Amount of investment on hydropower construction completed this year in rural areas	Afforestation area of grain for green projects	Investment in fixed assets agriculture, forestry, animal, husbandry and fishery	Investment in fixed assets production and supply of electricity, gas and water	Investment in fixed assets management of water conservancy	Fiscal expenditure for agriculture, forestry and water	Fiscal expenditure for affairs of land and weather
Inner Mongolia	0.04	0	0.06	0.1	0	0	0	0.24
Chongqing	0.14	0.14	0.1	0.31	0	0.18	0	0.11
Sichuan	0.07	0.81	0	0	0.09	0	0.12	0
Shanxi	0.03	0	0.14	0	0	0.01	0	0.75
Hubei	0.19	0.33	0.05	0.22	0	0.15	0	0
Hunan	0	0.47	0.07	0.21	0	0.06	0.06	0
Guangxi	0	0.26	0	0.09	0	0.1	0	0
Liaoning	0.06	0	0.08	0.25	0	0.32	0	0.2
Shaanxi	0.46	0.06	0.19	0.17	0	0.16	0	0.05

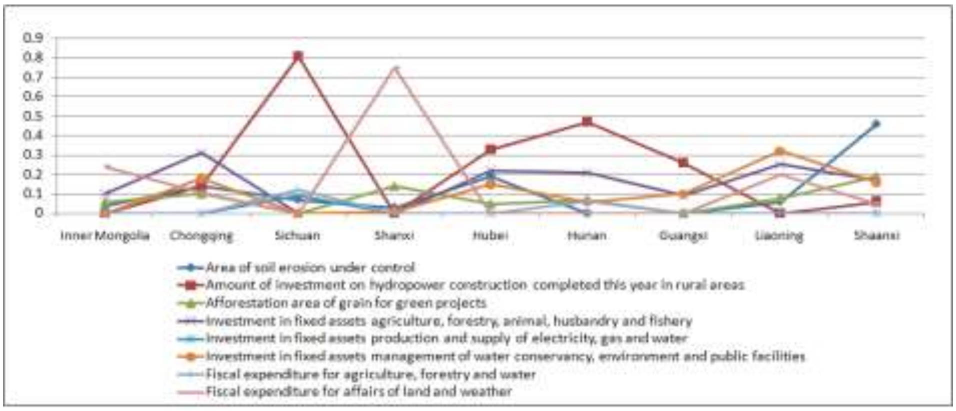

Figure 2: The improvement of regions with relative effective efficiency

In Table 4, the indicators of input redundancy are chosen, and the results show that:
Firstly, 7 regions have input redundancy in indicators of area of soil erosion under control, afforestation area of grain for green projects, investment in fixed assets agriculture, forestry, animal, husbandry and fishery and Investment in fixed assets management of water conservancy, environment and public facilities; and 6 regions have input redundancy in indicators of amount of investment on hydropower construction completed this year in rural areas. Secondly, Shaanxi and Chongqing have the most being improved indicators among the nine areas which are not relatively effective, and Shaanxi has the most input redundancy in area of soil erosion under control with 0.46 units, the least input redundancy in fiscal expenditure for affairs of land and weather with 0.05 units. While Chongqing has a little different situation: the most input redundancy in investment in fixed assets agriculture, forestry, animal, husbandry and fishery with 0.31 units, the least input redundancy in afforestation area of grain for green projects with 0.1 units. Hubei, Hunan and Liaoning have 5 indicators with input redundancy: Hubei has the most input redundancy in amount of investment on hydropower construction completed this year in rural areas with 0.33 units, the least input redundancy in afforestation area of grain for green projects with 0.05 units, and has good performance in investment in fixed assets production and supply of electricity, gas and water, fiscal expenditure for agriculture, forestry and water, fiscal expenditure for affairs of land and weather with no input redundancy; Hunan has a similar situation with Hubei, while having good performance in area of soil erosion under control, investment in fixed assets production and supply of electricity, gas and water, fiscal expenditure for affairs of land and weather with no input redundancy.

4. Conclusion and discussion

In order to evaluate optimum allocation efficiency on water-land resources, the article firstly make up input-output index system, then give a comprehensive evaluation and improving analysis for optimum allocation on water-land resources of 31 regions basing super DEA model; secondly, the research's innovation adoption focuses on spatial heterogeneity of optimum allocation efficiency in water-land resources; thirdly, the technical route has an effective fusion of different study scale, method and measure, and the research conclusions show status of areal distribution of optimum allocation on water-land resources in China truly which can give an empirical reference for Optimization strategy formulating. The empirical conclusions are as follow:
Firstly, according to comprehensive analysis of the paper, the rank of 31 provinces and regions in 2011 high to low is: Tianjin, Shanghai, Hainan, Tibet, Ningxia, Qinghai, Xinjiang, Jiangsu, Heilongjiang, Shandong, Beijing, Fujian, Guangdong, Anhui, Guizhou, Zhejiang, Gansu, Henan, Yunnan, Jiangxi, Hebei, Jilin, Inner Mongolia, Chongqing, Sichuan, Shanxi, Hubei, Hunan, Guangxi, Liaoning and Shaanxi. Secondly, there are some differences in optimum allocation efficiency on water-land resources in different regions of China and the situation is general; and the super efficiency values of 22 areas are greater than 100% with the proportion is 70.97%, while the other 9 areas are relatively effective accounted for 29.03%. According to regional distribution, north China has more provinces of better performance in optimum allocation efficiency and also has some provinces of worse performance, while central China has a worse performance in optimum allocation efficiency, and northeast, south China, northwest and southwest have a small number of provinces and cities of worse performance. Thirdly, the super efficiency value of Inner Mongolia, Shanxi, Chongqing, Sichuan, Hubei, Hunan, Guangxi, Liaoning and Shaanxi are less than 100% and relatively effective, and the 9 areas mostly have input redundancy in indicators of area of soil erosion under control, afforestation area of grain for green projects, investment in fixed assets agriculture, forestry, animal, husbandry and fishery and Investment in fixed assets management of water conservancy, environment and public facilities. As a result the relatively effective areas should attach more importance to these indicators. Finally, the study also has

some deficiencies, such as being insufficient in input-output index system, short of comprehensive analysis on space-time and so on which will be the direction that the author will work hard on in the later.

Acknowledgements

We thank Li Zhao for critical reading of the manuscript. The project was supported by Social science fund of Hebei Province (Grant No. HB14GL039) and Development research project on social science of Hebei Province (Grant No. 2014030224) respectively.

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