Evaluation and Spatial Distribution of Soil and Water Conservation Efficiency in Shaanxi Province based on DEA Model

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Abstract: Soil and water conservation is an effective measure to ensure the sound operation of ecology, economy and society. The correct evaluation of the efficiency of soil and water conservation and its regional differences is an important prerequisite for optimizing soil and water conservation policies and measures. Taking Shaanxi Province as the research object, after counting and calculating the investment and total income of soil and water conservation from 2018 to 2019, the efficiency and spatial distribution of soil and water conservation in Shaanxi Province are analyzed by using the method of data envelopment analysis. The results show that the comprehensive technical efficiency of 18.2% of administrative regions in the province reached the best state, among which 82% of pure technical efficiency reached the optimal state and the gap between individuals was not large. Scale efficiency was the leading factor leading to the low comprehensive technical efficiency. There were obvious differences among cities (districts), showing the spatial distribution characteristics of high in the middle and low on both sides, high in the north and low in the south, high in the Yellow River Basin, and low in the Yangtze River Basin. Tongchuan was a key area to optimize the efficiency of soil and water conservation.

1 INTRODUCTION

Since the implementation of the western development strategy, Shaanxi provincial government has paid more attention to soil and water conservation. The whole province has thoroughly implemented the thought and concept of ecological civilization, firmly established the concept that "green water and green mountains are golden mountains and silver mountains", adopted preventive protection, comprehensive treatment and ecological restoration measures, and adhered to the comprehensive treatment of mountains, rivers, forests, fields, lakes and grasses with small watersheds as a unit. Significant achievements have been made in water and soil conservation, and promoted its economic and social development. Therefore, the corresponding evaluation work is particularly important.

In recent years, as the government attaches great importance to ecological construction, the research on the benefits of soil and water conservation has attracted extensive attention from the society. The change of soil organic matter content in different vegetation after rainfall is used to evaluate the ecological benefit of soil and water conservation by Hernandez et al. (2005). According to 11 economic and social indicators, market price method was used to evaluate the benefits of soil and water conservation measures by Balana et al. (2012). The GBAT toolkit was used to assess the feasibility of water conservation measures based on five upstream and downstream indicators of the watershed by Hunink et al. (2012). Mishra & Rai (2014) quantified the main costs and benefits of various soil and water conservation measures implemented in the study area through six indicators such as economy and environment. Based on the existing evaluation indexes and methods, Kang et al. (2002) used analytic hierarchy process to evaluate and analyze the soil and water conservation benefits of Typical Small Watersheds in the Loess Plateau. Yang et al. (2010) evaluated the benefits of water and soil conservation of hillside ditch, grass ditch and other technologies in red soil area. The CCR model and BBC model in data Envelopment analysis (DEA) are used to analyze and evaluate the efficiency of soil and water conservation

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in Changzhi Project in Sichuan by Wu Detao (2011). Jin Shilai (2012) analyzed the significance of monetization of soil and water conservation benefits, and tried to use the advantages of economics and ecology to explore a systematic scheme for monetization evaluation of soil and water conservation benefits. DEA method was used to analyze and evaluate the technical efficiency of soil and water conservation of black land in Heilongjiang Province from 2003 to 2012, and Tobit model was used to test and analyze it by Yang et al. (2015). Based on the accounting of ecological benefits of soil and water conservation, Qin et al. (2015) used DEA model to evaluate the efficiency of eleven counties and districts of San Jiangyuan and put forward the key points and relevant suggestions for future treatment work. Zheng et al. (2016) quantitatively evaluated the ecological, economic, social, flood control and disaster reduction benefits of small watersheds in Guangdong Province under water and soil conservation measures. As a social project, soil and water conservation is closely related to the development of social economy. Throughout the past research, more scholars tend to evaluate the benefits of soil and water conservation measures through various indicators, ignore the relevant research on the evaluation of their efficiency.

Figure 1: Schematic diagram of Shaanxi Province.

This paper studies the efficiency of soil and water conservation management and finds out the advantages and disadvantages of each region by scientifically and reasonably evaluating the benefits of soil and water conservation measures and comparing and analyzing the benefits of soil and water conservation among different regions, which can provide data support for the government to summarize the experience of soil and water conservation management in the past. It is also helpful to rationally adjust the planning and investment decision of soil and water conservation in the future. Therefore, taking Shaanxi Province, a key province of soil and water conservation, as an example, this study evaluated the efficiency of comprehensive soil and water loss control and analyzed the spatial distribution pattern of soil and water conservation efficiency of each city (district) in Shaanxi Province with the help of DEA model on the basis of calculating the benefits generated by soil and water conservation measures in 2018-2019. The research results are of significance for improving the quality of soil and water conservation in Shaanxi Province.

2 STUDY AREA AND DATA

2.1 Overview of the Study Area

Shaanxi Province is mainly divided into three regions: Northern Shaanxi (Yulin City and Yan'an City), Guanzhong (Xi'an City, Xianyang City, Baoji City, Weinan City, Tongchuan City and Yangling District) and southern Shaanxi (Hanzhong City, Ankang City and Shangluo City), and spans the Yangtze River and the Yellow River. As shown in the figure 1. Among them, Northern Shaanxi and Guanzhong belong to the Yellow River Basin and southern Shaanxi belongs to the Yangtze River Basin. At the same time, Shaanxi Province has complex terrain and various types of soil erosion, which is one of the most serious areas of soil and water loss in China. The Yellow River has less water and more sediment, and 90% of the coarse sediment deposited in the middle and lower reaches comes from Shaanxi. This undoubtedly makes soil and water conservation and ecological restoration in Shaanxi very important (Xiu et al., 2018). Since the 21st century, Shaanxi Province has comprehensively promoted the comprehensive control of soil and water loss, strengthened the ecological restoration of soil and water conservation, effectively controlled the soil and water loss in the Loess Plateau, pushed the green territory of Shaanxi northward by 400km, reduced the sediment entering the Yellow River by 5.9 billion tons, and realized the fundamental transformation of the regional ecological environment from "overall deterioration and local improvement" to "overall improvement and local virtuous circle".

By the end of 2019, the total area of water and soil loss in 11 cities (districts) in the province had been reduced to 64747.96 square kilometers, accounting for 31.49% of the land area of the province. From 2018 to 2019, eleven cities (districts) in the province completed a total area of 5935.89 square kilometers of comprehensive control and ecological restoration of water and soil loss, 54 new water and soil conservation science and technology demonstration parks, 126.90 square kilometers of clean small watershed control area, and 56 water and soil conservation monitoring stations covering the province, with a total investment of 3.511 billion yuan.

2.2 Research Data

Collect and sort out the data related to water and soil conservation of cities (districts) in Shaanxi Province from 2018 to 2019.The main sources are the bulletin of soil and water conservation of Shaanxi Province (2018-2019) (http://sthjt.shaanxi.gov.cn/) and the statistical yearbook of Shaanxi Province (http://tjj.shaanxi.gov.cn/).

3 RESEARCH METHODS

3.1 Benefit Accounting of Water and Soil Conservation

Soil and water conservation has achieved remarkable results in Shaanxi Province, and its benefits mainly include water storage and soil conservation benefits, economic benefits, ecological benefits and social benefits. The relationship between the four is as follows: based on the benefits of water storage and soil conservation, economic benefits, social benefits and ecological benefits are generated (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China & China National Standardization Administration Committee., 2009). At the same time, in order to comprehensively quantify the benefits of soil and water conservation in Shaanxi Province, nine indexes are selected according to the principles of objectivity, independence, hierarchy, operability and quantification. The detailed indicator system is shown in Figure 2.

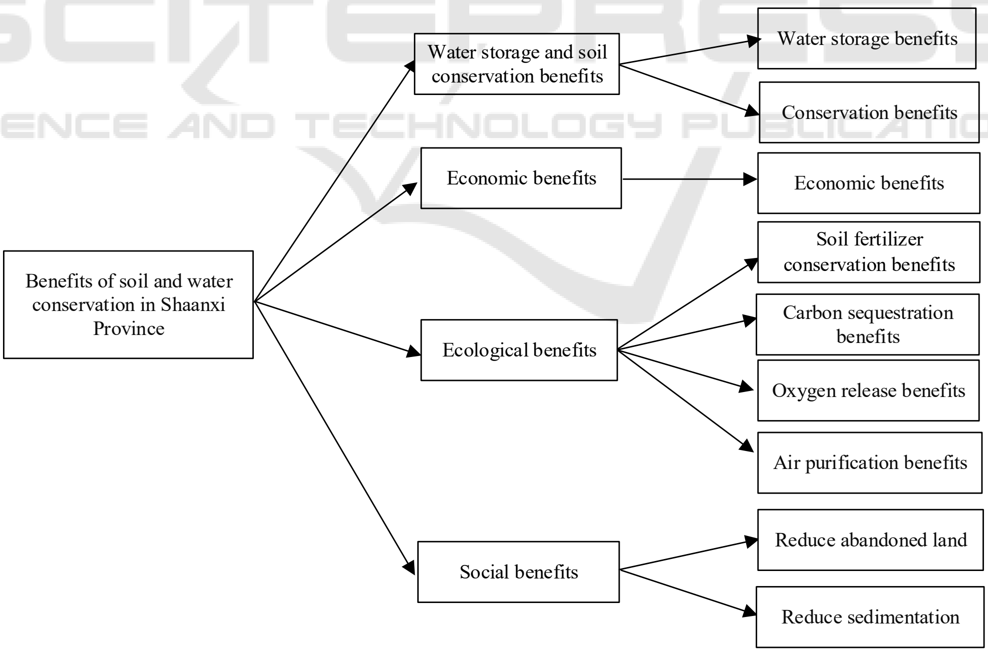

Figure 2: Index system of soil and water conservation benefit in Shaanxi Province.

3.1.1 Benefits of Water Storage and Soil Conservation

There are two main methods to calculate the benefits of water storage and soil conservation: water conservation and hydrology. The water conservation method refers to the comprehensive calculation of soil and water conservation benefits of the whole basin by using single measures of soil and water conservation. Hydrological method is based on rainfall, runoff and sediment data measured at hydrological stations or runoff stations, and uses statistical correlation analysis to calculate the efficiency of water storage and soil conservation after the implementation of soil and water conservation measures in the whole basin (Xu et al., 2018). Based on the characteristics of the above methods, this paper mainly uses the water conservation method to calculate.

(1) Water storage benefits

$$B_1 = \sum W_{1i} \times P_1 \tag{1}$$

Where: B_1 is water storage benefit; $\sum W_{1i}$ is the total amount of water stored by various treatment measures; P_1 is the price per unit of water storage. Among them:

$$W_{1i} = F_{1i} \times \Delta\gamma_{1i} \tag{2}$$

Where: W_{1i} is the storage capacity of measure i; F_{1i} is the treatment area of measure i; $\Delta\gamma_{1i}$ is the runoff modulus reduced by measure i.

(2) Conservation benefits

$$B_2 = \sum S_{2i} \times P_2 \tag{3}$$

Where: B_2 is soil conservation benefit; $\sum S_{2i}$ is the total amount of soil preserved by various treatment measures; P_2 is the average income per unit area. Among them:

$$S_{2i} = F_{2i} \times \Delta\gamma_{2i} \tag{4}$$

Where: S_{2i} is the soil conservation amount of measure i; F_{2i} is the treatment area of measure i; $\Delta\gamma_{2i}$ is the runoff modulus reduced by measure i.

3.1.2 Economic Benefits

Based on the control area of each measure and combined with the income per unit area, the economic benefits of water and soil conservation are calculated as follows:

$$C = \sum S_i \times P_i \tag{5}$$

Where: C is economic benefit; $\sum S_i$ is the treatment area of measure i; P_i is the average income per unit area of measure i.

3.1.3 Ecological Benefits

The ecological benefits of soil and water conservation refer to the added values of soil fertilizer conservation, carbon fixation, oxygen release and atmospheric purification after a period of ecological construction activities of soil and water conservation.

(1) Soil fertilizer conservation benefits

$$V_1 = p \times h \times S_3 \times \rho \times k \tag{6}$$

Where: V_1 is the soil fertilizer retention benefit; S_3 is the newly added woodland area; ρ is soil bulk density; h is soil thickness; p is the unit price of soil nutrients and organic matter; k stands for soil organic matter content.

(2) Carbon sequestration benefits

According to the photosynthesis equation, forest photosynthesis can fix CO_2, that is, the system can fix 1.63g CO_2 per 1.00kg plant dry matter produced. Namely:

$$V_2 = 1.63 \times Z_c \times P_c \times S_3 \times R_c \tag{7}$$

Where: V_2 is carbon sequestration benefit; Z_c is the productivity of the protected area; P_c is the carbon tax price; S_3 is the newly added woodland area; R_c is the carbon content of CO_2, which is 27.27%.

(3) Oxygen release benefits

The simultaneous release of 1.20g O_2 by forest photosynthetic fixation of CO_2 adopts the alternative market value method, and the calculation formula is:

$$V_3 = 1.19 \times Z_O \times P_O \times S_3 \tag{8}$$

Where: V_3 is the benefit of oxygen release; Z_O is the productivity of protected areas; P_O is the price of producing oxygen; S_3 is the newly added woodland area.

(4) Air purification benefits

The benefits of air purification mainly include the benefits of SO_2 absorption by forest and dust retention. The calculation formula is:

$$V_4 = \sum K_{3i} \times S_{3i} \times P_{3i} \tag{9}$$

Where: V_4 is the annual air purification benefit of the protected area; $\sum K_{3i}$ is the air purification capacity of the i-type forest; S_{3i} is the area of the i-type forest land; P_{3i} is the price of the i-type forest land to reduce pollutants.

3.1.4 Social Benefits

Social benefits refer to the benefits brought by the implementation of water and soil conservation measures, such as reducing drought and flood disasters, improving agricultural production conditions, improving disaster prevention and reduction capacity, reducing siltation on rivers, reservoirs and ponds, protecting transportation, industrial and mining, water conservancy, electric power, tourism facilities, urban and rural construction, safety of people's lives and property, and promoting regional economic development. Therefore, this paper mainly considers the social benefits from two aspects: reducing abandoned land and reducing sediment accumulation.

(1) Reduce abandoned land

$$L_1 = S_2 \times P_4/(\rho \times h) \tag{10}$$

Where: L_1 is to reduce the value of abandoned land; S_2 is the amount of soil and water conservation; P_4 is the average opportunity cost of abandoned land; ρ is soil bulk density; h is soil thickness.

(2) Reduce sedimentation

$$L_2 = S_2 \times \emptyset \times P_5 \tag{11}$$

Where: L_2 is the value of reducing sediment deposition; S_2 is the amount of soil and water conservation; $\emptyset$ for sedimentation ratio; P_5 is the cost of manual cleaning of sediment deposition.

3.2 Evaluation of Soil and Water Conservation Efficiency

DEA model is a nonparametric statistical method proposed by Charnes et al. in 1978 to evaluate the relative effectiveness between different decision-making units (DMU) with the same type of multi-input and multi-output by using mathematical programming model (Inverno et al., 2018). It mainly projects the input-output values of all DUM in the efficiency space, and finds the efficiency envelope frontier. DUM located on the frontier (its efficiency value is 1), and the input-output combination reaches the optimal state, that is, the minimum input under a given output or the maximum output under a given output. At the same time, according to the distance between each DMU and the effective production front, determine whether each DMU is DEA effective, and then use the projection method to point out the reason of DEA invalid and the direction and degree of improvement.

DEA method includes many models. In this study, variable scale Output-DEA-BCC model is adopted, which takes into account the changes of Output scale and marginal effect, and is more suitable for analyzing the benefits of soil and water conservation. In this model, the comprehensive technical efficiency value (CTE) is the product of pure technical efficiency (PTE) and scale efficiency (SE), where PTE represents the production efficiency of DMU at a certain scale, and SE represents the gap between the actual scale and the optimal production scale. The form of the model is as follows:

$$max\theta \tag{12}$$

$$\sum_{j=1}^{n} x_j\lambda_j + s^- = \theta x_0 \tag{13}$$

$$\sum_{j=1}^{n} y_j\lambda_j - s^+ = y_0 \tag{14}$$

$$s^+ \geq 0, s^- \geq 0 \tag{15}$$

$$\sum \lambda_j = 1, j = 1, 2, \cdots n \tag{16}$$

Where, θ is the efficiency value of the JTH DMU, and it satisfies 0≤ θ ≤1; x_0 and y_0 are respectively the input and output of DMU; s^+ is the relaxation variable, that is, the quantity of output to be increased; s^- is the residual variable, that is, the input amount that needs to be reduced to achieve the optimal configuration; λ is the weight coefficient.

Taking formula (12) as the objective function and formula (13) ~ formula (15) as the constraint function, the θ value obtained is CTE; Formula (12) is the objective function, formula (13) ~ formula (16) is the constraint function, and the θ value obtained is PTE. We can find SE by the ratio of CTE to PTE. Among them:

When $CTE = 1$ (DEA is valid), it indicates that the DMU is valid in resource configuration.

When $CTE < 1$ (DEA is invalid), if the PET is 1 and the SE is less than 1, it indicates that the scale of DMU does not match the input and output, and the scale needs to be increased or decreased. If the PTE and SE are less than 1, if there is $S_j^- > 0$, it indicates that the j-th input index is redundant; If there is $S_i^+ >$ 0, the output of the i-th output index is insufficient.

4 RESULTS AND ANALYSIS

4.1 Benefits of Soil and Water Conservation in Shaanxi Province

According to the bulletin of soil and water conservation of Shaanxi Province (2018-2019) and the statistical yearbook of Shaanxi Province, the comprehensive control of soil and water loss in Shaanxi Province from 2018 to 2019 is shown in Table 1.

According to the calculation formula of the above benefit indicators and the relevant data found on the official website of Shaanxi Provincial Department of ecological environment and Shaanxi Provincial Bureau of statistics, the water and soil conservation, economic, ecological and social benefits generated by soil and water conservation measures in Shaanxi Province from 2018 to 2019 are 680 million yuan, 894 million yuan, 248 million yuan and 46.004 billion yuan respectively, with a total benefit of 47.826 billion yuan. Among them, the highest benefit is 17.723 billion yuan in Northern Shaanxi, 14.958 billion yuan in Guanzhong and 15.145 billion yuan in southern Shaanxi. See Table 2 for detailed calculation results.

Table 1: Statistics of comprehensive control of soil and water loss in Shaanxi Province (2018~2019).

Administrative region	Control measures(km^2)						Input(10^4CNY)	
	terrace	soil and water conservation forest	economic forest	artificial grass planting	closed treatment	Other measures	Central and provincial	Local
Xi'an	8.6	100.72	14.66	1.29	86.41	6.39	406.89	45.11
Baoji	66.62	55.14	38.83	0.14	179.25	20.01	1327.65	137.35
Xianyang	56.96	133.5	61.58	1.69	196.95	2.32	6860.22	573.78
Tongchuan	17.68	81.1	29.46	0	68.18	0.73	1627.36	137.30
Weinan	54.08	146.67	63.25	16.47	173.06	78.11	6742.04	707.96
Yan'an	86.45	479.51	111.02	10.2	349.6	53.66	15176.09	1077.91
Yulin	163.27	640.91	156.89	35.73	296.28	32.8	18692.24	1672.76
Hanzhong	67.78	182.49	138.82	5.01	193.38	25.68	5534.65	518.35
Ankang	45.42	188.06	118.45	0.03	274.04	8.24	6346.19	686.81
Shangluo	43.04	127.41	49.01	0.48	289.09	0.31	5692.24	572.76
Yangling	0	1.8	0	0	1.2	0	159.94	35.06

Table 2: Estimation of soil and water conservation benefits in Shaanxi Province (2018~2019).

Administrative region	Benefits of soil and water conservation(10^4CNY)			
	Water storage and soil conservation benefits	Economic benefits	Ecological benefits	Social benefits
Xi'an	2154.04	2240.21	140862.70	203.89
Baoji	3189.81	5002.49	113624.66	516.12
Xianyang	6001.54	8041.00	517572.25	2620.28
Tongchuan	1986.63	3740.39	133485.73	392.55
Weinan	6844.98	8620.14	533334.25	3047.63
Yan'an	12110.32	15181.85	725297.43	4567.08
Yulin	16911.84	25191.68	966370.86	6622.63
Hanzhong	5779.62	5061.86	403985.75	1587.25
Ankang	6639.59	8154.87	570104.16	2665.68
Shangluo	6367.25	8012.58	493582.00	2525.22
Yangling	31.63	103.10	2173.25	50.88

4.2 Evaluation of Soil and Water Conservation Efficiency and Spatial Distribution Pattern

The DMU is the object of efficiency evaluation. Each DMU transforms a certain number of production factors into products in the production process and tries to achieve its own decision-making objectives. Therefore, they all show certain economic significance. In the performance evaluation of benefits of soil and water conservation in Shaanxi Province, this paper makes a horizontal comparison of multiple regions, so 11 soil and water conservation ecological restoration demonstration cities (districts) in Shaanxi Province during the same period (2018-2019) are selected as DMU to study its relative effectiveness.

Based on the above accounting of benefits of water and soil conservation in Shaanxi province, the input indexes of this evaluation are determined as: central and provincial input, local input; Output indicators include: water storage and soil conservation benefits, economic benefits, ecological benefits and social benefits. The specific values of each index are shown in Table 3.

Table 3: Input/output data of soil and water conservation project (unit: 10^4CNY).

DMU	Input index (input)		Output index (benefit)			
	Central and provincial	Local	Water storage and soil conservation benefits	Economic benefits	Ecological benefits	Social benefits
Xi'an	406.89	45.11	2154.04	2240.21	140862.70	203.89
Baoji	1327.65	137.35	3189.81	5002.49	113624.66	516.12
Xianyang	6860.22	573.78	6001.54	8041.00	517572.25	2620.28
Tongchuan	1627.36	137.30	1986.63	3740.39	133485.73	392.55
Weinan	6742.04	707.96	6844.98	8620.14	533334.25	3047.63
Yan'an	15176.09	1077.91	12110.32	15181.85	725297.43	4567.08
Yulin	18692.24	1672.76	16911.84	25191.68	966370.86	6622.63
Hanzhong	5534.65	518.35	5779.62	5061.86	403985.75	1587.25
Ankang	6346.19	686.81	6639.59	8154.87	570104.16	2665.68
Shangluo	5692.24	572.76	6367.25	8012.58	493582.00	2525.22
Yangling	159.94	35.06	31.63	103.10	2173.25	50.88

The special DEA model calculation software DEAPVersion2.1 was used to solve the problem. Table 4 and Figure 3 were obtained after sorting out the results of program operation. In order to reasonably evaluate the benefit performance of soil and water conservation in 11 cities (districts), this paper carries out effectiveness analysis and projection value analysis in turn.

Table 4: calculation results of effectiveness of benefits of water and soil conservation.

DMU	CTE	PTE	SE	Scale reward	Remaining variables		Slack variable			
					S_1^-	S_2^-	S_1^+	S_2^+	S_3^+	S_4^+
Xi'an	1.00	1.00	1.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Baoji	0.83	1.00	0.83	drs	0.00	0.00	0.00	0.00	0.00	0.00
Xianyang	1.00	1.00	1.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Tongchuan	0.63	0.88	0.72	drs	214.62	0.00	1050.58	530.52	18933.02	169.02
Weinan	0.95	1.00	0.95	drs	0.00	0.00	0.00	0.00	0.00	0.00
Yan'an	0.93	1.00	0.93	drs	0.00	0.00	0.00	0.00	0.00	0.00
Yulin	0.87	1.00	0.87	drs	0.00	0.00	0.00	0.00	0.00	0.00
Hanzhong	0.67	0.94	0.72	drs	0.00	0.00	382.54	2852.16	26738.65	629.9
Ankang	0.86	1.00	0.86	drs	0.00	0.00	0.00	0.00	0.00	0.00
Shangluo	0.97	1.00	0.97	drs	0.00	0.00	0.00	0.00	0.00	0.00
Yangling	0.64	1.00	0.64	irs	0.00	0.00	0.00	0.00	0.00	0.00

4.2.1 Pure Technical Efficiency Analysis

Through PTE analysis, the management and technical input-output level of water and soil conservation projects in 11 cities (districts) can be analyzed and evaluated horizontally. It can be seen from table 3 that except Tongchuan City and Hanzhong City, the other 9 cities (districts) are pure technology effective (is 1), accounting for 82% of all DMU. This shows that in the process of soil and water conservation and ecological protection construction, the input and output of these areas are at the forefront of production, and their management level and technical input are relatively reasonable. For cities (districts) where pure technology is not effective (less than 1), the minimum value is 0.88 of Tongchuan City, indicating that the structure, management and technical level of investment need to be slightly adjusted in these two regions.

Figure 3(b) shows the distribution of PTE in Shaanxi Province. Northern Shaanxi is the key area of the comprehensive control of soil erosion in Shaanxi province and even the whole country. The local management measures and technical methods are relatively mature, and PTE in Yan'an and Yulin are both effective; In Guanzhong area, PTE is invalid only in Tongchuan City; Among the three cities in southern Shaanxi, only Hanzhong's PTE is invalid. At the same time, it shows that the Yellow River Basin in Shaanxi Province is better than the Yangtze River Basin.

4.2.2 Return to Scale Analysis

As can be seen from Table 4, among the 11 cities (districts) in Shaanxi Province, only Xi 'an and Xianyang have effective SE (return to scale remains unchanged), indicating that the scale of soil and water conservation matches the comprehensive benefits of input and output, and the scale is appropriate. However, only Yangling District has an increasing return to scale in SE invalid areas, which indicates that a higher proportion of benefit output can be brought by appropriately increasing the input on the basis of the existing input, so the input scale of soil and water conservation in Yangling District should be increased. The return to scale in other regions is regressive, indicating that if the input is appropriately increased on the basis of the existing input in these regions, the output of benefits will not increase by a higher proportion.

As can be seen from the spatial distribution of SE (Figure 3(c)), the overall distribution pattern of SE decreases from the central part to both sides, and the distribution pattern of SE in northern Shaanxi is better than that in southern Shaanxi.

4.2.3 Comprehensive Efficiency Analysis

CTE reflects the effectiveness of DEA, and PTE and SE are its influencing factors. For the convenience of analysis and comparison, the partial running results of DEAP software are translated here as shown in Figure 4. Among them, The CTE is 1 in Xi'an City and Xianyang City, indicating that the relative efficiency of soil and water conservation benefits reached the best state. The DMU with invalid DEA includes two types: one is caused by SE is less than 1, which accounts for about 82% of the whole region, including Baoji City, Weinan City, Yan'an City, Yulin City, Ankang City, Shangluo City and Yangling District. Their PTE is 1, and their low CTE is caused by low SE. Therefore, it is necessary to take corresponding measures (see return to scale analysis) to change their SE in order to improve the CTE. Second, the PTE and SE are less than 1, including Tongchuan City and Hanzhong City. It shows that the scale of water and soil conservation in these urban areas is improper and the management technology level needs to be improved. Each urban area can change the input scale or input-output structure and improve the management technology level according to its own specific situation, so as to increase the comprehensive benefits of soil and water conservation.

The spatial distribution pattern of CTE in Figure 3(a) also shows a gradually decreasing distribution pattern from central to north and south, but Tongchuan City and Yangling District with the lowest CTE are located in Guanzhong Region. The CTE in the Yangtze River basin of Shaanxi province is high in the east and low in the west.

4.2.4 Projection Value Analysis

According to the calculation results of DEAP software and the above effectiveness analysis. The nine effective DMU of PTE constitute the enveloping front of comprehensive benefit data of soil and water conservation. However, the other two regions do not reach the data envelope frontier. Through the analysis of projection values, the causes of the problems can be found out and the improvement methods can be sought. As can be seen from Table 4, the two regions with invalid DEA both have the problem of insufficient output of comprehensive benefits, and Tongchuan City also has input redundancy. From the specific data, Hanzhong City needs to take relevant measures to improve the water storage and soil conservation benefits of 3.8254 million yuan, economic benefits of 28.5216 million yuan, ecological benefits of 267.3865 million yuan and social benefits of 6.299 million yuan, respectively, in order to achieve the effective DEA. In order for Tongchuan, which has diminishing returns to scale, to achieve a relatively effective state, its central and provincial investment needs to be reduced by RMB 2.1462 million, and its water storage and soil conservation benefits, economic benefits, ecological benefits and social benefits should be improved on the basis of strengthening management and introducing new technologies. It should increase by 10.5058 million yuan, 5.3052 million yuan, 189.3302 million yuan and 1.6902 million yuan respectively.

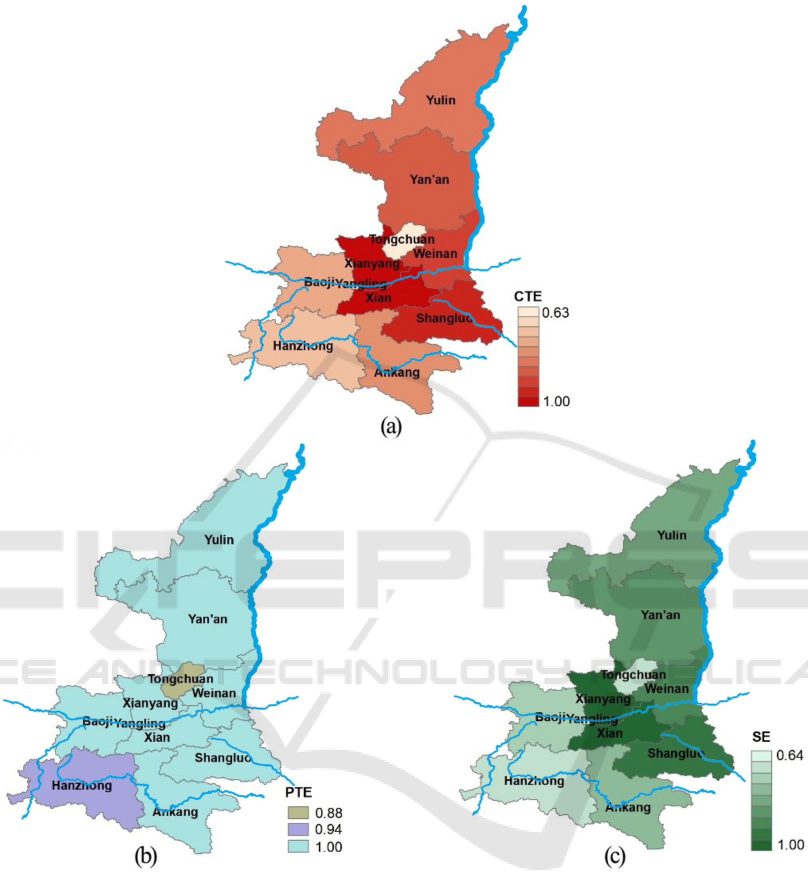

Figure 3: Spatial distribution of water and soil conservation efficiency in Shaanxi Province.

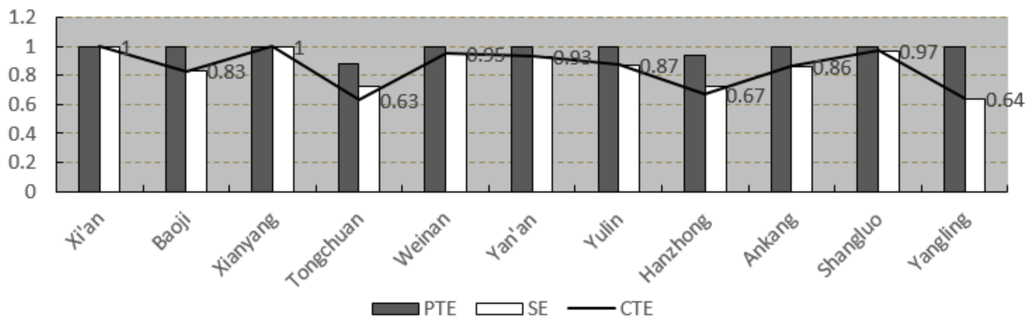

Figure 4: Analysis and comparison of comprehensive efficiency of water and soil conservation in 11 cities (districts) of Shaanxi Province.

5 CONCLUSIONS

(1) From 2018 to 2019, the benefits of water and soil conservation investment in Shaanxi Province were divided into four categories: water and soil conservation, economy, society and ecology, which were 680 million yuan, 894 million yuan, 248 million yuan and 46.004 billion yuan respectively, with a total benefit of 47.826 billion yuan.

(2) In 11 cities (districts) of Shaanxi Province, the effective ratio of comprehensive technical efficiency of input and output benefits of soil and water conservation was only 18.2%;The cities (districts) with pure technical efficiency accounted for 82%, and the overall technical and management level of the whole province was relatively high; Cities (districts) with effective scale accounted for 18.2%.Based on the analysis of three kinds of efficiency and projection value, optimizing the investment scale and investment structure was the focus of soil and water conservation in the province in the future. Tongchuan City should not only optimize the investment scale and structure, but also improve the management means and technical level of soil and water conservation.

(3) The comprehensive technical efficiency and scale efficiency of soil and water conservation in Shaanxi Province showed the spatial distribution characteristics of high in the middle and low on both sides, high in the north and low in the south, high in the Yellow River Basin and low in the Yangtze River Basin; There was little difference in pure technical efficiency among cities (districts), and the level of the Yellow River Basin was slightly higher than that of the Yangtze River Basin.

(4) This paper tried to analyze the situation of soil and water conservation management in Shaanxi Province by means of efficiency evaluation. Compared with the previous evaluation methods, the evaluation results of this method were more intuitive and more adaptable to the changes of governance factors.

(5) In this paper, DEA model was used to construct the evaluation system of soil and water conservation efficiency in Shaanxi Province. The research conclusion was basically consistent with the monitoring situation of soil and water conservation in shaanxi province, which had certain theoretical and practical significance. The evaluation results not only confirmed the achievements of soil and water conservation management in Shaanxi Province, but also pointed out the direction for the allocation and management of governance factors in the future. However, there are also shortcomings in this study. Due to the lack of existing market price and monitoring data related to soil and water conservation, there may be some errors in the calculation method and results. At the same time, this study only focuses on the efficiency of the input and output ends, without considering the interference of process factors such as rainfall. In the next step, a complex "input-process-output" multi-link evaluation system will be constructed, and the mutual influence relationship among them will be clarified, so as to provide reference for soil and water conservation management in Shaanxi Province.

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