Research on Fertilizer Efficiency of Continuous Cropping Greenhouse Cucumber Based on DEA Model

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Abstract. Fertilizer efficiency directly affects the production of continuous cropping greenhouse cucumber. So analyzing the fertilizer efficiency is of great significance in providing decision-making support for fertilization of greenhouse cucumber. By establishing the DEA models of continuous cropping greenhouse cucumber and taking existing data samples as study objects, the problems of fertilizer efficiency in traditional fertilization, target yield fertilization and mathematical model fertilization were studied. And the technical efficiency, pure technical efficiency, scale efficiency and redundancy rates of the three types of fertilization methods have been obtained by analyzing the relationship of three inputs (N, P_2O_5, K_2O) and one output (Yield). Through analyzing fertilizer efficiency of the three types of fertilization methods, it could get the sort by the size of mathematical model fertilization, target yield fertilization and traditional fertilization. The results showed that the method of mathematical model fertilization is more reasonable in fertilizing and the DEA method is efficient and practical in analyzing the fertilizer efficiency.

Key words: Greenhouse cucumber, Fertilization, Efficiency, DEA method

1. Introduction

Due to the limited understanding, the dependence on experience and the lack of the guidance of scientific fertilization theory, problems, such as excessive fertilization and low fertilize efficiency, are universally existent in production practice of greenhouse cucumber in China. Meanwhile, owing to the higher economic benefits of planting greenhouse cucumber, the pursuit of high yield and utilization ratio of installations, the continuous cropping of greenhouse cucumber is fairly common. But continuous cropping causes many problems, such as soil nutrient imbalance and deterioration of soil properties. Fertilizing reasonably and balancing the soil nutrient are the fundamental ways to improve the fertilizer utilization ratio, reduce pollution, and solve the problem of continuous cropping in sunlight greenhouse. So the guidance of scientific fertilization theory should be needed to avoid fertilizer over-using and fertilizer improper-applying.

Data Envelopment Analysis (DEA) is an effective optimization method used for measuring the relative efficiency of Decision Making Unit (DMU) (Charnes, A., et al., 1978). C^2R model and BCC model are the two most commonly used DEA models. Suppose there are n DMUs, and each DMU has m inputs and k outputs, then the technical efficiency(TE), pure technical efficiency(PTE), scale efficiency(SE), redundancy rates(RR) of each DMU can be calculated by using the C^2R model and BCC model (Quanling Wei ,et al., 2004; Shoukang Qin, et al., 2003).

In this paper, the fertilize efficiency analysis models of continuous cropping greenhouse cucumber were established. Based on the samples from [1] (Liying Wang, et al., 2008) and DEA method (Charnes, A., et al., 1978), the fertilization efficiency of input and output of three fertilization methods (mathematical model fertilization, target yield fertilization and traditional fertilization)were studied from the vews of TE, PTE, SE and RR. Where TE and PTE reflect the relation between fertilizer rate and the yield of greenhouse cucumber under the assumption of that the scale benefit is constant and mutative, respectively. SE

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is the ratio of TE to PTE. And RR is the ratio of input slacks to the actual input. And the efficiency of three fertilization methods were compared and analyzed. This paper aims at finding out methods to improve the fertilization efficiency of greenhouse cucumber and provide information for fertilization decision-making and practice.

2. Materials and methods

2.1. Data resources

In this paper, six 3-years continuous cropping plots were used for example to analyze the fertilize efficiency of greenhouse cucumber with the help of DEA Solver3.0 software. And the data of three inputs (N, P_2O_5, K_2O) and one output (Yield) from [1] were took as samples. The calculation formulas for the fertilizer rate of mathematical model fertilization and target yield fertilization are available from [5] (Lunshou Chen, Jingling Lu, 2002) and [6] (Yancai Zhang, et al., 2005).

2.2. Hypotheses

To simplify, the fertilize efficiency analysis models of continuous cropping greenhouse cucumber were established under two hypotheses as follow: (1) N, P_2O_5, K_2O are the major factors that affect the yield levels of greenhouse cucumber. (2) For different planting years and seasons, soil nutrient of different plots is the same.

2.3. Procedures

The C^2R model and BCC mode were used to establish the fertilize efficiency analysis models of continuous cropping greenhouse cucumber. For each plot, its TE, PTE, SE and RR were evaluated and analyzed. Each field (DMU) has three inputs (N, P_2O_5, K_2O) and one output (yield). If θ =1 (θ is the score of fertilizer efficiency), it indicates that the field (DMU) is a DEA effective unit, and its TE or PTE reach the highest level. If θ <1, it declares that the field (DMU) is not a DEA effective unit and its input of fertilizer is unreasonable. For a non DEA efficient (C^2R or BCC) DMU, its input and output slacks and RR can be calculated by using the projection principle and related formulas.

Comparing the value of θ of the same field which was under the same continuous cropping years and three types of fertilization, it can find out that which type of fertilization is more reasonable or the unreasonable reasons of the irrational one. By comparing the RR of the same field, it can be analyzed how much input of N, P_2O_5, K_2O can be saved and which input should be adjusted. Besides, the fertilize efficiency of the same field under different types of fertilization and different continuous cropping years can be compared. The analysis steps were showed in the Figure 1.
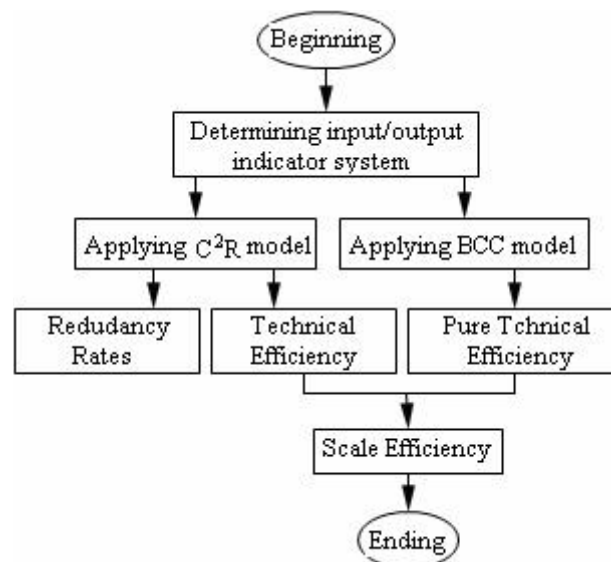

Fig.1 The frame of analysis model for the greenhouse cucumber input-output efficiency

3. Results and discussion

By calculating the TE, PTE, SE and RR of greenhouse cucumber of three types of fertilization, the results were reported in table 1.In addition, the fertilization efficiency of three types of fertilization was described in the figure 2, figure 3 and figure 4.

3.1. The fertilization efficiency without considering the diversity of fertilize methods

According to the table 1 and regarding the technical efficiency, there are 4 DEA effective units, accounting for 22.22 percent of the total samples. And the technical efficiency of 9 units exceeds the average of the samples' TE which is 0.6826, about half of all. To the pure technical efficiency, there are 7 DEA effective units, accounting for 38.89 percent of the total samples. And the pure technical efficiency of 14 units outperforms the average of the samples' PTE which is 0.8579, about 77.78 percent of all. And to the scale efficiency, there are 4 DEA effective units, accounting for 22.22 percent of the total samples. And the scale efficiency of 9 units exceeds the average of the samples' SE which is 0.7734, about 50 percent of all.

Table 1 The analysis results of fertilization efficiency of the continuous 3 years cropping greenhouse cucumber

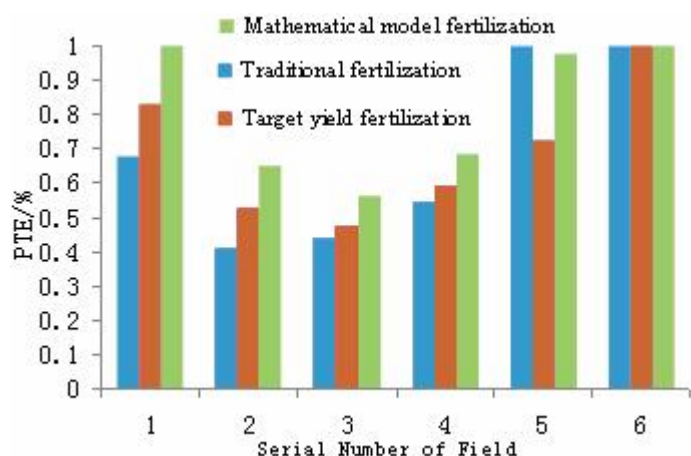|	Serial Number of Field	Technical Efficiency	Pure Technical Efficiency	Scale Efficiency	Redundancy Rates (%)		
					N	P_2O_5	K_2O
Traditional fertilization	1	0.5126	0.6771	0.7570	48.74	48.74	48.74
	2	0.2123	0.4111	0.5160	78.77	82.63	78.77
	3	0.2331	0.4400	0.5300	76.69	85.69	76.69
	4	0.4330	0.5455	0.7940	56.70	56.70	69.88
	5	0.8820	1	0.8820	11.8	31.72	61.00
	6	1	1	1	0	0	0
Target yield fertilization	1	0.8328	0.9839	0.8460	22.42	0	16.72
	2	0.5234	0.9802	0.5340	47.66	47.66	47.66
	3	0.4746	0.8753	0.5420	52.54	52.54	52.54
	4	0.5915	0.8616	0.6860	40.85	40.85	40.85
	5	0.7266	0.9017	0.8060	27.34	0	27.34
	6	1	1	1	0	0	0
Mathematical model fertilization	1	1	1	1	0	0	0
	2	0.6467	1	0.6467	35.33	0	35.33
	3	0.5589	0.8716	0.6410	44.11	0	44.11
	4	0.6846	0.8952	0.7650	31.54	31.54	34.92
	5	0.9746	1	0.9746	2.54	0	25.53
	6	1	1	1	0	0	0

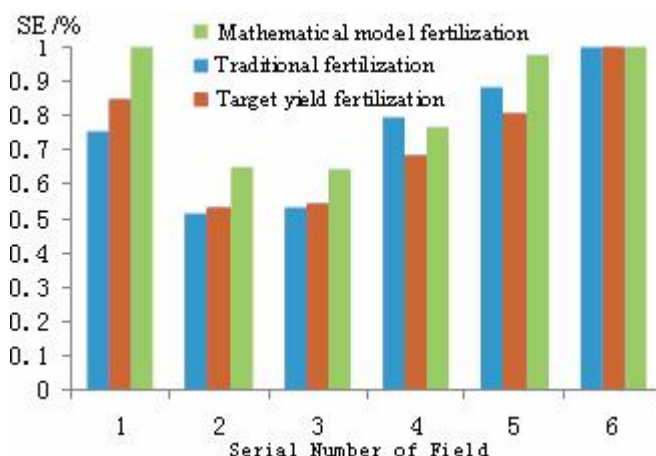Fig.2 The pure technology efficiency of the continuous 3 years cropping greenhouse cucumber

Fig.3 The scale efficiency of fertilizer-output of the continuous 3 years cropping greenhouse cucumber

Regarding the average of efficiency, the average of pure technical efficiency is the maximum (0.8579), the scale efficiency second, and the technical efficiency the minimum (0.6826). And the average of redundancy rates of N, P_2O_5, K_2O is 32.06%, 26.56% and 36.67% respectively, which can led to the preliminary inference that the unreasonable degree of the inputs was in the increasing order of P_2O_5, N, K_2O.

3.2. The fertilization efficiency with the consideration of the diversity of fertilize methods

Fig.4 The technical efficiency of the fertilizer-output of he continuous 3 years cropping greenhouse cucumber output

In the table 2, the fertilization efficiency of three types of fertilization was analyzed. According to the figure2, figure3 and figure4, the average of TE, PTE, SE of mathematical model fertilization are obviously highest (0.8108, 0.9611, 0.8379, respectively) among that of target yield fertilization and traditional fertilization. And the fertilization efficiency of target yield fertilization is the second highest with that of traditional fertilization following behind. Furthermore, the average of redundancy rates of the three fertilize methods were also showed in table 2. Obviously, the average of redundancy rates of N, P_2O_5, K_2O were the lowest (18.92%, 5.26%, 23.32%, respectively) while using mathematical model fertilization. And the average of redundancy rates of target yield fertilization comes next while that of traditional fertilization turns out to be the maximum.
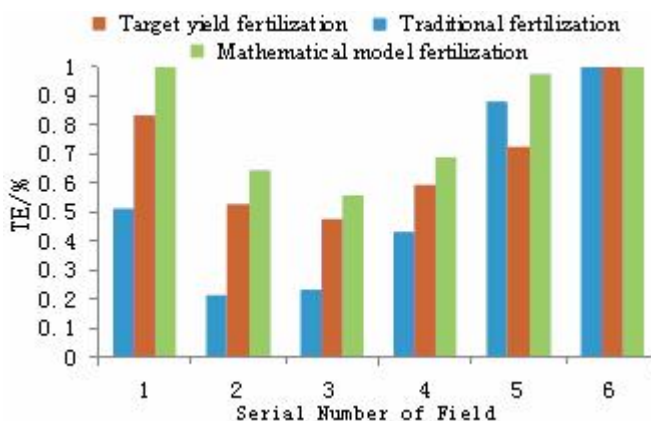
Table 2 The comparison of the fertilization efficiency of three fertilize methods

	The Average of TE	The Average of PTE	The Average of SE	The Average of Input Redundancy Rates (%)		
				N	P_2O_5	K_2O
Traditional Fertilization	0.5455	0.6790	0.7465	45.45	50.91	55.85
Target yield Fertilization	0.6915	0.9338	0.7357	31.80	23.51	30.85
Mathematical Model Fertilization	0.8108	0.9611	0.8379	18.92	5.26	23.32

4. Conclusions

The fertilizer efficiency of continuous cropping greenhouse cucumber was researched by using DEA. Based on two assumptions (N, P_2O_5, K_2O are the major factors that affect the yield levels of greenhouse cucumber. For different planting years and seasons, soil nutrient of different plots is the same) and the analysis of technical efficiency, pure technical efficiency, scale efficiency and redundancy rates of three types of fertilization methods, it can come to conclusion that the fertilizer efficiency of mathematical model fertilization is the highest, and the second is target yield fertilization(the exception was that the average of SE lower than that of traditional Fertilization) while the traditional fertilization is the lowest.

References

1. Liying Wang, Yancai Zhang, Caixia Zhai, et al.: Effect of Balanced Fertilization on Yield and Quality of Sunlight Greenhouse Cucumber and Soil Characteristics under Continuous Cropping. Chinese Journal of Eco-Agriculture, 16(6), 1375--1383(2008)

2. Chrnes, A., Cooper, W.W., Rhodes, E.: Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, 429--444(1978)

3. Shoukang Qin, et al.: Principle and Application of Comprehensive Evaluation. Publishing House of Electronics Industry, Beijing (2003)

4. Quanling Wei.: Data Envelopment Analysis. Science Press, Beijing (2004)

5. Lunshou Chen, Jingling Lu.: Fertilizer Application Technique on Vegetable Nourishment. China Agriculture Press, Beijing (2002)

6. Yancai Zhang, Caixia Zhai, Qiaoyun Li, et al.: Study on the Optimum Fertilization Technology of Cucumber. Journal of Hebei Agricultural Sciences, 9(1), 75--78(2005)