Research Article
Evaluation of Production Efficiency of the County-level Crop Farming in He'nan Based on GIS and DEA

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Abstract: The aim of this study is to reveal the resource utilization pattern of county-level crop farming production in He'nan in 2010, which can provide scientific basis for formulation of crop farming production policies and adjustment of production elements. The empirical analysis of the production efficiency of 126 country-level crop farming in He'nan in 2010 is conducted by applying GIS software and DEA model from three aspects of "combined efficiency", "technical efficiency" and "scale efficiency" and non-DEA effective states of mechanical power input, pesticide input, effective irrigation area and so on are revealed. The results show that: the average value of the combined efficiency of crop farming in the research period is 0.69 and the county-level spatial differentiation is remarkable; the technical efficiency is the main factors influencing the combined efficiency and its spatial pattern is basically consistent with the spatial pattern of the combined efficiency; the average value of the scale efficiency of crop farming is 0.95, which indicates that the overall scale efficiency of crop farming in He'nan is at a higher level; it further reveals looseness of various input elements in various counties. It is suggested to optimize and adjust the element input amount and input structure by type and improve the combined efficiency of crop farming.

Keywords: Crop farming, DEA model, He'nan, production efficiency, spatial pattern

INTRODUCTION

China is an agricultural power and crop farming is always the overall strategic problem which is related with national economic development, social stability and national independence (National Food Security and Long-Term Planning Framework (2008-2020), 2008; Liu and Zhai, 2009). The reverse change of increase in population and decrease in cultivated land resource aggravates the contradiction between production and food. In the background that increase in population and decrease in cultivated land are inevitable and it is difficult for rapid improvement of the natural conditions for crop production, the important means to guarantee regional agricultural product safety are to increase production element input in crop farming and improve the output efficiency (Wang *et al.*, 2010; Yang *et al.*, 2013; Lin *et al.*, 2014). At present, people in various regions pay attention to input of production element quantity during crop farming production, but ignore element utilization efficiency. If the input element utilization efficiency is low, it may even cause wasting of resources or environmental pollution. Therefore, the problems to be solved urgently are to scientifically evaluate and reveal the spatial differentiation pattern of the revealed crop farming production efficiency and provide the scientific and

reasonable suggestions for production element input optimization based on it.

At present, the research methods of crop farming production efficiency of in China mainly include CD function, data envelopment analysis and other methods (Song *et al.*, 2010; Shen and Yan, 2011). Data Envelopment Analysis (for short DEA) is a new method to evaluate relative efficiency between objects of the same type (Wei, 2004), which is widely applied in research of crop farming production element configuration efficiency. For example, Wang *et al.* (2010) and other scholars apply DEA model in combination with Malmquist index to evaluate the county-level food production efficiency in Hebei; He (2011) applies DEA method to evaluate the agricultural production efficiency of various prefecture-level cities in He'nan. According to literature retrieval, there have been researches concentrated in analysis of the full-element efficiency, technical efficiency and technical progress efficiency of crop farming production and researches in pure technical efficiency and scale efficiency of crop farming production are relatively insufficient; there are more researches at the provincial and city-level, but there are less researches on spatial pattern of the county-level crop farming production efficiency. It is difficult to provide decision making support for crop farming production efficiency in the

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mid-scopic scale. Therefore, based on GIS software and DEA model, the paper reveals resource utilization pattern of county-level crop farming production in He'nan in 2010, which provides scientific basis for formulation of crop farming production policies and adjustment of production elements.

RESEARCH METHOD AND DATA SOURCE

DEA evaluation model: As the nonparametric method, DEA is a kind of effective method to evaluate the multiple-input and multiple-output decision making unit efficiency (Guo *et al*., 2009). Whether there is any efficiency is judged according to the distance between each DMU and the effective production leading surface, including the constant returns to scale model, variable returns to scale model and Malmquist index model. DEA sets the determinacy boundary and all deviations from the production frontier or cost boundary are due to low efficiency. Therefore, there are certain defects (Färe *et al*., 1992). However, through DEA method, the optimum weight is obtained with the actual data of decision making unit input and output, no weight assumption is required and many subjective factors are eliminated; data is not combined directly; there are no special requirements for dimension of input-output indicators. Therefore, it is widely applied in efficiency evaluation of various fields (Sun and Dong, 2010). DEAP2.1 is adopted in the research to calculate the combined efficiency, technical efficiency and scale efficiency of 126 county-level crop farming production in He'nan and the purpose is to analyze relation between strength of crop farming sustainability and production efficiency.

Indicator building and data source: Initial selection of indicators are conducted by consulting related literature and according to regional characteristics of crop farming production in He'nan; on this basis, 8 experts in related research fields are invited to conduct three rounds of screening. Finally, the unit labor force input (agriculture, forestry, animal husbandry and fishery labor force/cultivated land area, person/hm^2), unit mechanical power input (total output of agricultural machinery/cultivated land area, 10^4 kw/hm^2), fertilizer input (pure quantity of fertilizer/cultivated land area, kg/hm^2), pesticide input (pesticide input amount/cultivated land area, kg/hm^2) and effective irrigation area rate (effective irrigation area/cultivated land area, %) are selected as the input indicators and the increased value of unit crop farming (i.e., increased value of crop farming of each hectare of cultivated land at the current multiple cropping index, yuan/hm^2) as the output indicator. 126 county-level units, including 108 counties (cities) and 18 prefecture-level cities, are selected in the study finally and the crop farming production input-output data is from He'nan Statistical Yearbook in 2011 and He'nan Rural Area Statistical Yearbook in 2011.

RESULTS AND DISCUSSION

Analysis of combined efficiency of crop farming production: It is indicated from the calculation results of DEA model that the average value of combined efficiency of 126 county-level crop farming production is 0.69, the counties with the efficiency value above the average value account for 46.03% and the minimum value of Gongyi is only 0.278. It can be known from Fig. 1a that, the counties with higher combined efficiency values are mainly distributed in Kaifeng, Luoyang, Sanmenxia and Xinyang. Among them, the combined efficiency values of crop farming production in Luanchuan County, Xuchang, Yanling County, Mianchi County, Lushi County, Lingbao, Xin County, Shangcheng County, Huangchuan County, Xiangcheng and Xiping County other are equal to 1, reaching DEA effective and accouting for 8.73% of the number of research units. The technical level, management capability and operation scale of crop farming in these counties are matched with each other and the crop farming production element input configuration efficiency is the best. The combined efficiency values of other counties are less than 1 and the combined efficiency values of Gongyi, Fan County, Pingdingshan, Dengfeng, Jiaozuo, Puyang County, Luoyang, Shangcai County and other counties are less than 0.50, which, in a certain degree, indicates that the crop farming production input structures of these counties have not reached the reasonable combination.

Analysis of technical efficiency of crop farming production: The regional crop farming production is of great dependence on the cultivation technology and sustainability of crop farming production is stronger. The average value of technical efficiency of crop farming production in 126 counties is 72.78%, which indicates that there is still larger space for improvement of technical efficiency of crop farming production in He'nan. Meanwhile, the technical efficiency value of the county-level crop farming production is obviously lower than the scale efficiency value, which indicates that low efficiency of crop farming is mainly caused due to low technical efficiency. It can be known from Fig. 1b that the distribution pattern of technical efficiency of crop farming production is basically consistent with that of the combined efficiency. The technical efficiency values of Zhumadian, Yima, Zhengyang, Qinyang, Yanshi and other 20 counties are 1 and the looseness variable is 0, which indicates that these counties can effectively utilize the farming production technology, so as to maximize output. However, the technical efficiency values of Gongyi, Fan County, Pingdingshan, Jiaozuo, Dengfeng, Puyang County, Anyang and other counties are less than 0.4, which indicates that the input-output efficiency of these counties is relatively low and there is a large space for improvement of technical efficiency.
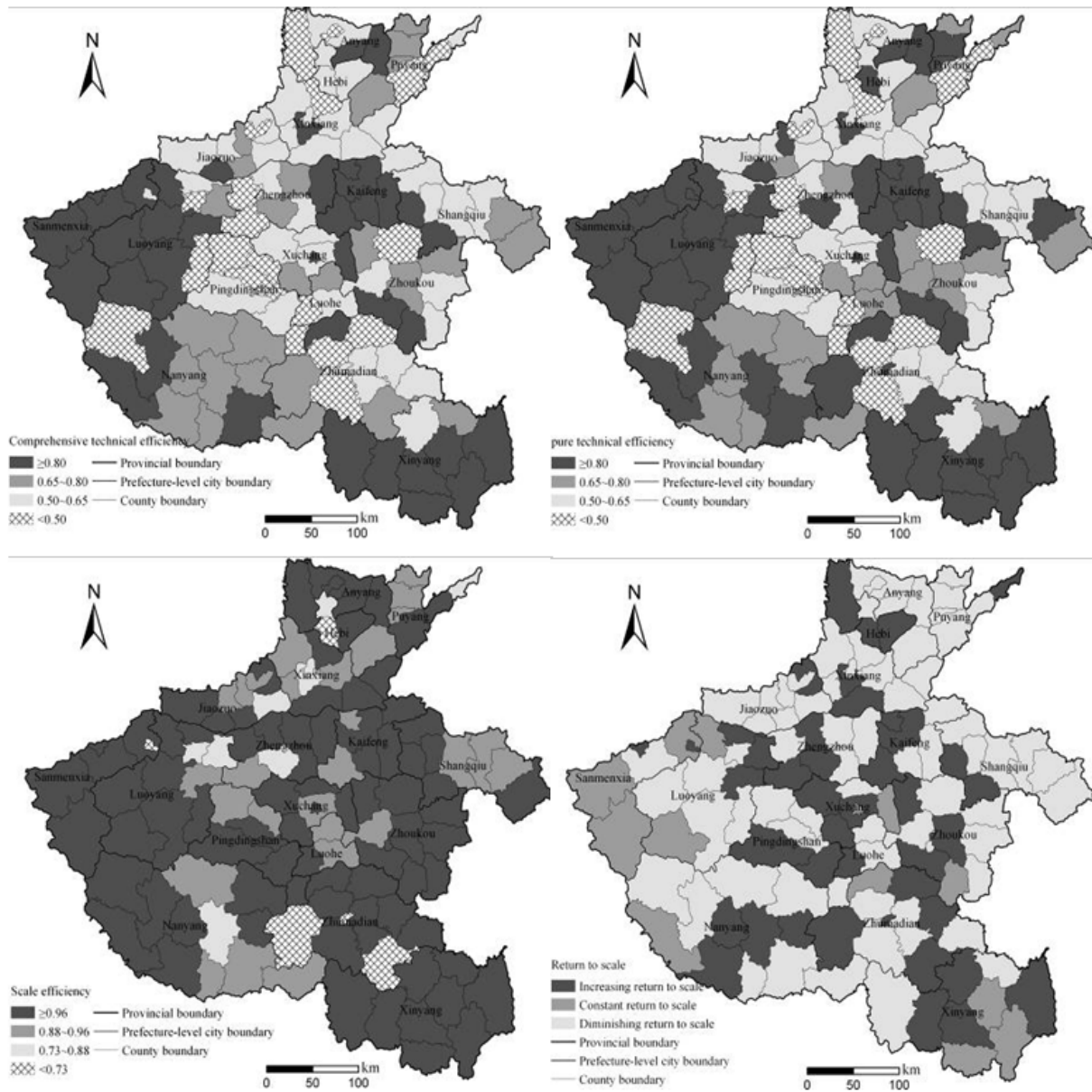
Fig. 1: Distribution pattern of county-level crop farming production efficiency in He'nan in 2010

Analysis of scale efficiency of crop farming production: The average value of scale efficiency of crop farming production in 126 counties in He'nan is 94.77%, which indicates that the overall scale efficiency of crop farming in He'nan is at a higher level. It can be known from Fig. 1c that the scale efficiency values of crop farming production in the majority of counties are larger than 0.96. Among them, the scale efficiency values of Xin'an County, Xichuan County, Luanchuan County, Xuchang, Yanling County, Mianchi County, Lushi County, Lingbao, Xin County, Shangcheng County, Huangchuan County, Xiangcheng and Xiping County are 1, which indicates that the input-output proportion of crop farming in these counties are appropriate and they are at the stage of agricultural

production structure with constant returns to scale, realizing maximum output; the scale efficiency of other counties is less than 1, which indicates that the input-output proportion of agricultural production elements in these counties are biased, not realizing maximum output.

Analysis of scale efficiency of crop farming production: It can be known from Fig. 1b that the scale efficiency of Xin'an County, Xichuan County, Luanchuan County, Xuchang, Yanling County, Mianchi County, Lushi County, Lingbao, Xin County, Shangcheng County, Huangchuan County, Xiangcheng and Xiping County is unchanged, which indicates that the crop farming production scale is appropriate,
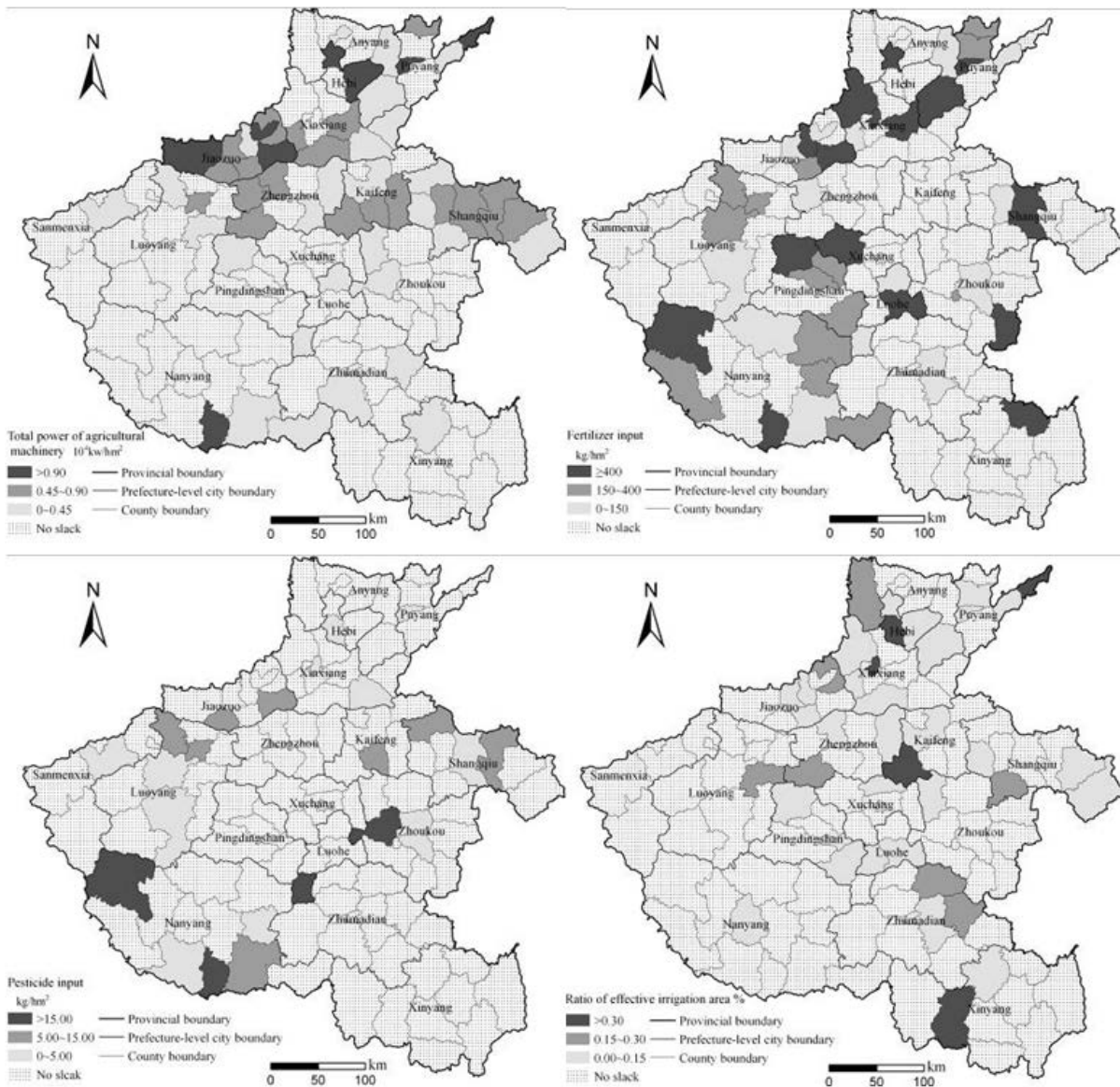
Fig. 2: Looseness variable of input in non-DEA effective county in He'nan

reaching the best returns to scale of that year; the returns to scale of 42 counties are increased progressively and the existing crop farming production scale can be expanded appropriately, so as to realize more output and benefits; the returns to scale of 72 counties are decreased progressively, which indicates that based on the current input, more proportion of output cannot be brought even if the input amount is increased. The main approach to obtain more output is to improve the technical efficiency.

Non-effective county-level adjustment: The county with the agricultural production technology efficiency and scale efficiency less than 1 is called as the technically non-effective county. The surplus value of the production element input amount of non-DEA

effective county is calculated through C2R model. The results indicate that the labor force input in the urban area of Pingdingshan, Jia County, Xinxiang, Qi County, Lushan County, Taiqian County, Nanzhao County and Xixia County is loose and the labor force input in the rest 119 counties is not loose, which indicates that the labor force input in the overwhelming majority of county-level crop farming in He'nan in 2010 is relatively insufficient, but is not increased with increase in other element input. It can be known from Fig. 2a that the agricultural machinery input in 72 counties is not loose and that in 54 counties is loose, mainly distributed in the mid-north part of He'nan, which indicates that agricultural machinery input in these counties is excessive and rational allocation with other elements is not formed. The counties with loose

fertilizer input, pesticide input and effective irrigation area are 44, 23 and 40, respectively, i.e., the input elements are loose, which indicates that the input element configuration in these counties is unreasonable, causing waste in input elements and there is significant difference in spacial distribution pattern (Fig. 2). It is suggested to reasonably adjust the element input amount and input structure in connection with surplus degree of the specific input elements of various counties and improve the scale efficiency of crop farming production.

CONCLUSION

The crop farming production efficiency is the important guarantee for regional agricultural product safety. The crop farming production efficiency in 126 counties in He'nan in 2010 is measured and calculated by utilizing GIS software and DEA model and the distribution pattern is discussed. The results indicate that the crop farming production efficiency can be objectively and truly calculated based on DEA model and GIS spatial analysis technology, the spatial pattern of crop farming production efficiency and surplus degree of various production element input amount can be displayed in a quantified and visualized way, to provide decision making support for targeted optimization of input amount and input structure of crop farming production elements in different counties.

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