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Original Research

Analysis on Comparative Advantage of Major Crop Types and Its Influencing Factors: a Case of Chongqing City

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Abstract

Crop production plays an important role in social and economic development. Exploiting the comparative advantages of major crop types has a profound effect on improving crop production. However, studies on these comparative advantages and their influencing factors are few. Here, the temporal variation characteristics of main crop types in Chongqing City from 1985 to 2021 were analyzed. The comparative advantages of these crop types were also evaluated, and the main factors that influenced them were determined using ordinary least square model. Results demonstrated that the temporal variation characteristics of sown area and comparative advantages in scale of six crop types in Chongqing City from 1985 to 2021 had obvious difference. The sown area of hemp crops showed the most variation among the six crop types. Tobacco, vegetable, and hemp crops had comparative advantages in scale in Chongqing City. GDP, pesticide usage, per capita disposable income of rural residents, agricultural film used, relative humidity, and atmospheric pressure were the major factors influencing the comparative advantages of the six crop types in Chongqing City from 1985 to 2021. These findings are useful for adjustment and optimization of planting structure, crop production management, and sustainable development of agriculture.

Keywords: temporal variation characteristics, crop types, influencing factors, comparative advantage, OLS model

Introduction

Chongqing City is a typical combination of big cities and big rural areas, in which agriculture plays an important role in its social and economic development strategy [1]. However, it has many hills and mountains, low comprehensive agricultural productivity, and obvious regional agricultural development differentiation [2]. Chongqing's "Fourteenth Five-Year Plan" for Promoting Agricultural and Rural Modernization (2021-2025) proposed to ensure effective supply of grain and other important agricultural products. Therefore, to improve crop-planting efficiency, ensure the supply of agricultural products, and optimize crop production, understanding the agricultural planting

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situation and comparative advantage of major crop types in Chongqing City is very important.

Many researchers have carried out research on the temporal variation characteristics of the sown area of crops or crop yield [3-8]. Kucharik et al. [3] examined changes in maize, soybean, and winter wheat yields and temporal variability in yields during the period 1970-2017 by using the United States Department of Agriculture county-level yield data and autoregressive moving-average models. Ji et al. [7] showed that the sown area of spring maize presented a continuous increase during the period 2002-2014, exhibited changes and decreases in response to the change during the period 2015-2017, and demonstrated optimization and recovery during the period 2018-2020. These researchers adopted statistical data of the sown area of crops or crop yield from different period and source such as the United States Department of Agriculture county-level yield data during 1970-2017 [3], the crop production data in China from 1985 to 2015 [4], sown area data for crops by province from the China Statistical Yearbook between 2002 and 2020 [7], and historical statistical data of sown area of main crops in Yunnan, Guizhou, Sichuan, Guangdong, and Guangxi from 1985 to 2015 [8], The results showed that these researches could well reveal the temporal variation characteristics of the sown area of crops or crop yield in different regions and period. Some researchers documented the influencing factors of the sown area of crops or crop yield [5, 8-12]. On the basis of a large yield dataset during the period 1978-2015 in 31 provinces and the related explanatory variables, Liu et al. [5] analyzed the spatiotemporal variation of different crop yield aggregations by using stepwise multiple linear regression. Zhang et al. [10] investigated the quantitative correlations between corn yield and its influencing factors, including effective precipitation, corn planting area, and chemical fertilizer and pesticide application rates in Daqing City, China, via Cobb-Douglas production function model. Gao et al. [12] analyzed how climate factors, including temperature, precipitation, and solar radiation, influence the spatial and temporal variation of yields of maize and wheat in China from 1985 to 2015. The above researches analyzed the different factors such as socio-economic factor [5, 8,10], and climate factors [9, 11-12] influencing on different crops such as various crops including cereals, beans, tubers, oil crop, sugar crop, fiber, tobacco, tea, vegetables, melons and fruits [5], economic crops [8], corn yield [10], maize [11] and maize and wheat [12]. Other researchers paid attention to the comparative advantage of different crops through indices, such as scale or efficiency advantage index [6, 13-14], domestic resource cost [15], and policy analysis matrix [16-17]. For example, Tu et al. [6] analyzed the evolution characteristics of the production pattern of four major crops, including grain, sugar, fruits, and vegetables, in Guangxi during the period 1995-2019 by using the location Gini coefficient, gravity center movement model, and comparative advantage index. In addition, Islam et al. [15] analyzed the comparative advantage of rice production by the Domestic Resource Cost on the basis of the time series data from 2010-2011 to 2020-2021. These researchers adopted different methods to analyze the comparative advantage of different crops and revealed regional advantages of crop production in different region. These results also showed that different methods had different advantages to reveal regional advantages in different crops. Some other researchers explored the influencing factors of the comparative advantage of different crops [13, 18]. Yu et al. [13] analyzed the influential factors of the regional comparative advantages of grain production by path coefficient analysis and demonstrated that the Engel coefficient of rural residents, the per capita value-added of the secondary industry, and the per capita gross regional product had negative impacts on the comparative advantage of grain production. This results could reveal the factors influencing scale and efficiency advantage of grain production in qualitative perspective, but found it difficult to determine the factors influencing comparative advantage of grain production from a quantitative perspective.

However, studies on the temporal variation characteristics and influencing factors of the comparative advantage of major crop types in quantitative perspective are few. Here, the temporal variation characteristics of main crop types in Chongqing City from 1985 to 2021 were analyzed, and the comparative advantages were determined using scale advantage index. Finally, the main factors that influenced these comparative advantages of six crop types in Chongqing City were elucidated by the ordinary least square (OLS) model. This study aims to (a) reveal the temporal variation characteristics of major crop types in Chongqing City during the period 1985-2021, (b) evaluate the comparative advantages of these major crop types during the same period, and (c) disclose the main factors that influenced the comparative advantages.

Materials and Methods

Data Collection and Processing

The statistical data of sown areas of grain, oil, sugar, hemp, vegetable, and tobacco crops; gross domestic product; population; highway mileage; air temperature; precipitation; wind speed; sunshine; evaporation; and humidity in Chongqing City were obtained from Chongqing Statistical Yearbook (1986-2022). The statistical data of sown areas of grain, oil, sugar, hemp, vegetable, and tobacco crops were obtained from China Agriculture Yearbook (1986-2022). By using SPSS 25, Pearson's correlation analysis was applied to analyze the correlation between the comparative advantages of six crop types in Chongqing City and their influencing factors, and the OLS model was applied to analyze the factors influencing these comparative advantages.

Scale Advantage Index

Scale advantage index could reflect the comparative advantage of a certain crop at production scale in a region [6]. It is expressed as follows [6, 13]:

$$SCAI_{ij} = \frac{S_{ij} / S_i}{S_j / S} \quad (1)$$

where $SCAI_{ij}$ is the scale comparative advantage index, it means the comparative advantages of crop types in Chongqing City; If $SCAI_{ij}$>1, it indicates that the crop type j in Chongqing City has a comparative advantage in scale, and the larger the value, the stronger the advantage; If $SCAI_{ij}$<1, it has a comparative disadvantage in scale; S_{ij} is sown area of crop type j in Chongqing City; S_i is total sown area of crops in Chongqing City; S_j is sown area of crop type j in China; S is total sown area of crops in China; The value of S_{ij}, and $S_{i,}$ are gained from Chongqing Statistical Yearbook (1986-2022); The value of S_j and S are gained from China Agriculture Yearbook (1986-2022); i is the total number of crop types in Chongqing City; j is the number of crop type studied in this paper, its value is 6.

Pearson's Correlation Analysis

Pearson's correlation coefficient is a measure of linear correlation between two variables x_i and y_i, and it is expressed as follows [19]:

$$r = \frac{\sum_{i=1}^{m}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{m}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{m}(y_i - \bar{y})^2}} \quad (2)$$

where r is the value of Pearson correlation coefficient between the comparative advantages of six crop types and its influencing factors; If r>0 indicates a positive correlation between the comparative advantages of six crop types and its influencing factors; If r<0 indicates a negative correlation between the comparative advantages of six crop types and its influencing factors; The closer r is to 1, the closer the correlation between the comparative advantages of six crop types and its influencing factors is, the closer r is to 0, the less closely the correlation between the comparative advantages of six crop types and its influencing factors is; x_i and y_i are the values of the comparative advantages of crop types and its influencing factors; $\bar{x}$ and $\bar{y}$ are the average value of the comparative advantages of crop types and its influencing factors, respectively; i is the number of variable x and y, its value is 37.

OLS Model

The OLS model is a multiple linear regression method that could determine the regression equation by minimizing the sum of the squared errors, where the error is the difference between the actual value and the predicted value of the dependent variable [20-21]. The OLS model is expressed as follows [20-21]:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_m x_m + \varepsilon \quad (3)$$

where y is the dependent variable; The dependent variable is comparative advantages of six crop types in this paper. β_0 is the intercept term; β_i (i = 1, 2, ..., m) is the regression coefficient; x_i (i = 1, 2, ..., m) is the independent variable; In this paper, the independent variable included meteorological factors such as rural power consumption, population, GDP, per capita disposable income of rural residents, highway mileage, and total energy consumption and socioeconomic factors such as air temperature, precipitation, wind speed, sunshine, evaporation, and humidity; ε is the error term; m is the number of independent variables.

Results and Discussion

Temporal Variation Characteristics of Six Crop Types in Chongqing City from 1985 to 2021

Fig. 1 shows that the temporal variation characteristics of the sown area of main crop types in Chongqing City from 1985 to 2021 varied differently. The temporal variation characteristics of the sown area of grain crops presented an overall trend of slow decrease. The largest, smallest, and average sown areas of grain crops were 2,900,656 hm^2 in 1998, 1,999,278 hm^2 in 2019, and 2,459,547.32 hm^2, respectively.

Meanwhile, the temporal variation characteristics of the sown area of oil crops demonstrated a trend of gradually slow growth in general. The largest and smallest sown areas were 337,983 hm^2 in 2021 and 174,643 hm^2 in 1994, respectively. The sown area of sugar crops from 1985 to 2021 obviously decreased first, increased slowly, and finally decreased. The largest and smallest sown areas were 6406.67 hm^2 in 2021 and 1863 hm^2 in 1994, respectively. In addition, the sown area of hemp crops fluctuated greatly from 1985 to 2021. The largest sown area was 11476 hm^2 in 2008, and the smallest sown area was 1123 hm^2 in 1995. The difference between the largest sown area of hemp crops and the smallest sown area of hemp crops exceeded about 10 times and reached 10353 hm^2. The sown area of vegetable crops showed a trend of continuous growth from 1985 to 2021 and increased to 650,809 hm^2 during this period. The largest sown area was 791,378 hm^2 in 2021. The temporal variation characteristics of tobacco

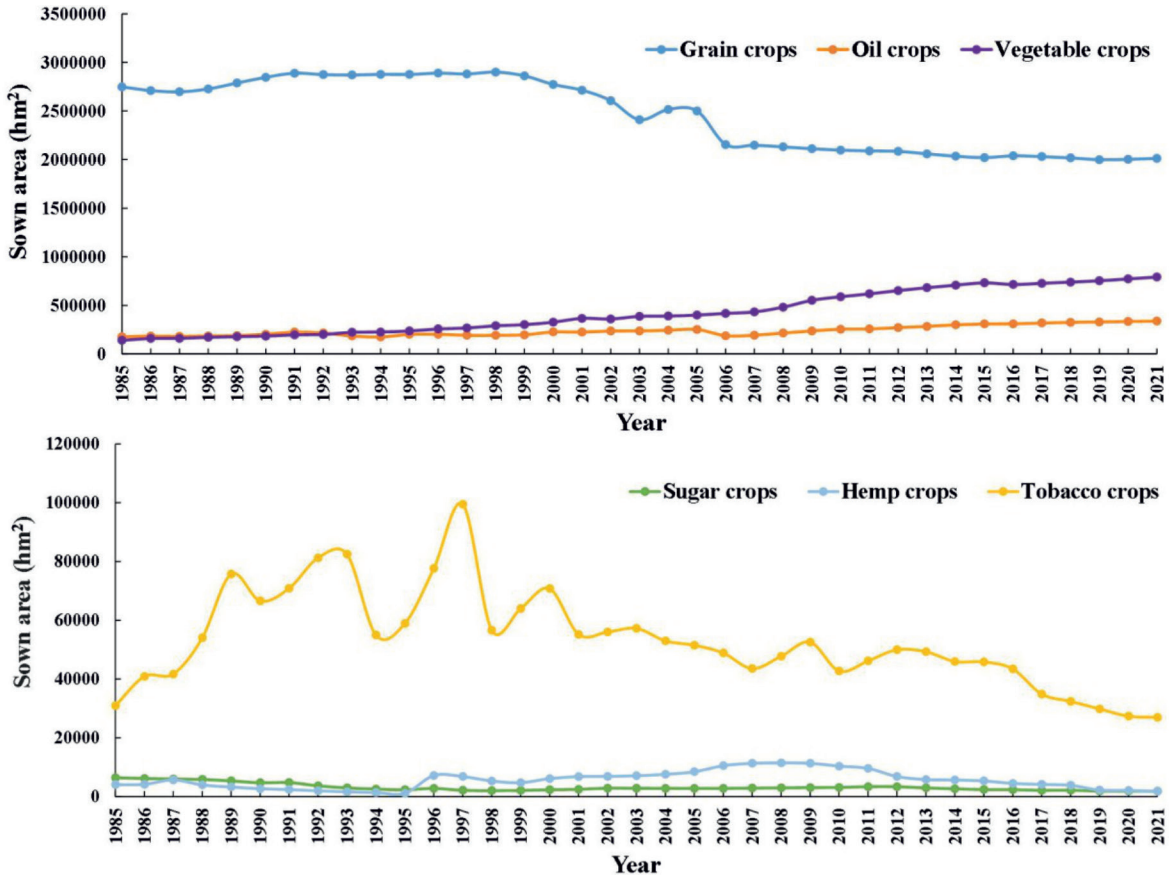

Fig. 1. Temporal variation characteristics of main crop types in Chongqing City during 1985-2021.

crops increased first and then decreased during the period 1985-2021. The largest, smallest, and average sown areas were 99,482 hm^2 in 1998, 26,988 hm^2 in 2021, and 53,179.62 hm^2, respectively.

The coefficients of variation of grain, oil, sugar, hemp, vegetable, and tobacco crops were 0.15, 0.22, 0.41, 0.54, 0.52, and 0.31, respectively. The sown area of hemp crops showed the most variation among the six crop types, followed by that of vegetable crops. The result indicates that the proportion of the sown area of grain and sugar crops in the sown area of total crops generally decreased from 85.50% in 1985 to 59.50% in 2021 and from 0.20% in 1985 to 0.05% in 2021, respectively. On the contrary, the proportion of the sown area of oil and vegetable crops in the sown area of total crops generally increased from 5.50% in 1985 to 9.91% in 2021 and from 4.37% in 1985 to 23.21% in 2021, respectively. The proportion of the sown area of hemp and tobacco crops in the sown area of total crops fluctuated greatly from 1985 to 2021. The proportion of the sown area of hemp crops decreased first, increased, and finally decreased during this period, whereas that of tobacco crops increased first and then decreased. Previous research also showed that the sown area or yield of crops, such as foxtail millet, in China [4]; maize, soybean, and winter wheat in the USA [3]; and the major crop production, including grain, sugar, and vegetable crops and fruit, in Guangxi [6] could change over time. The sown area is one of the two direct factors that determines the grain yield, and a stable sown area is an important guarantee for the realization of China's food security [22]. Therefore, the temporal variation characteristics of the sown area of six crop types in Chongqing City have important implications.

Comparative Advantages of Six Crop Types in Chongqing City during 1985-2021

The scale advantage index of the six crop types in Chongqing City during the period 1985-2021 was calculated using Formula (2), and the results are shown in Fig. 2. The temporal variation of comparative advantages of the six crop types had obvious differences. The scale advantage index of grain crops generally remained stable first from 1985 to 2002 and then decreased from 2003. During the period 1985-2006, the grain crops in Chongqing City had comparative advantages in scale. After 2006, they had no comparative advantages in scale and decreased slowly. The highest, lowest, and average scale advantage indices of grain crops were 1.13 in 1985, 0.85 in 2019, and 1.02, respectively. The scale advantage index of oil crops gradually rose from 1985 to 2021 in general. Before 2013, this scale advantage index was always below 1, indicating no comparative advantages in scale of oil crops in that time. However, from 2013, Chongqing City started to demonstrate comparative

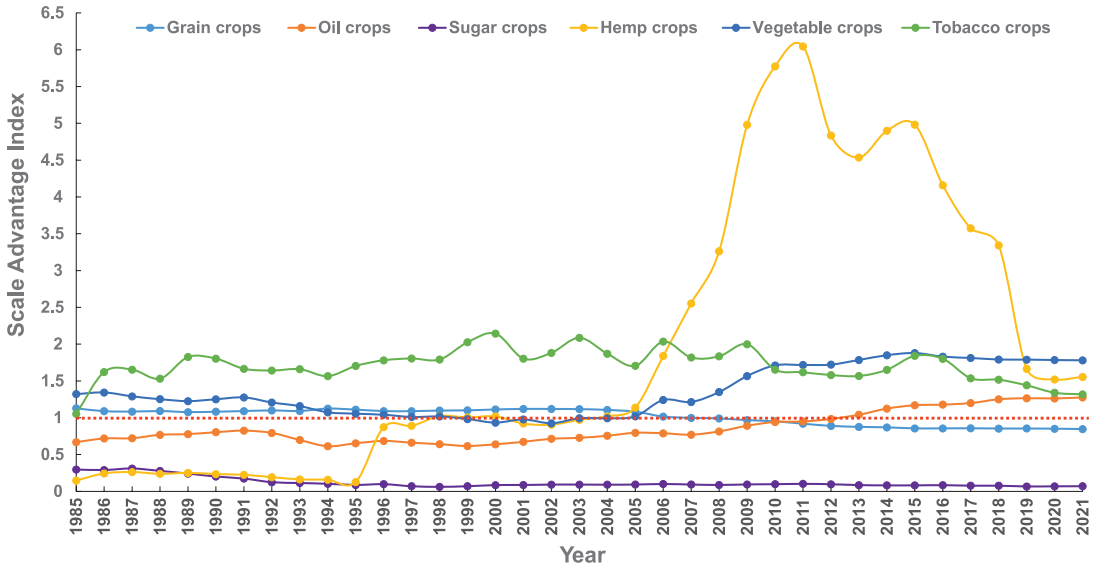

Fig. 2. Temporal variation characteristics of comparative advantages of six crop types in Chongqing City during 1985-2021.

advantages in scale of oil crops, and such comparative advantages increased with time. The highest, lowest, and average scale advantage indices of oil crops were 1.28 in 2021, 0.61 in 1994, and 0.86, respectively. Meanwhile, the scale advantage index of sugar crops was low, far below 1, and gradually decreased during the same period. These results indicated that Chongqing City had no comparative advantages in scale of sugar crops. The highest scale advantage index of sugar crops was only 0.297 in 1985. The scale advantage index of hemp crops showed a trend of first increasing and then decreasing from 1985 to 2021. During the period 1985-1995, the scale advantage index was very low and far below 1. From 1995, it increased and reached the peak in 2011. Chongqing City had comparative advantages in scale of hemp crops during the periods 1998-2000 and 2004-2021. The highest and lowest scale advantage indices of hemp crops were 6.045 in 2011 and 0.127 in 1995, respectively. By contrast, the scale advantage index of vegetable crops in most years during the period 1985-2021 exceeded 1, indicating Chongqing City generally had comparative advantages in scale of vegetable crops during this period. The trend of scale advantage index showed a decrease first and then increase. The highest, lowest, and average scale advantage indices of oil crops were 1.88 in 2015, 0.93 in 2002, and 1.36, respectively. Meanwhile, the scale advantage index of tobacco crops changed frequently during the period 1985-2021. However, it always exceeded 1, indicating Chongqing City constantly had comparative advantages in scale of tobacco crops during this period. The highest, lowest, and average scale advantage indices of oil crops were 2.14 in 2000, 1.05 in 1985, and 1.71, respectively.

The coefficients of variation of scale advantage index of grain, oil, sugar, hemp, vegetable, and tobacco crops were 0.11, 0.25, 0.60, 0.98, 0.25, and 0.13, respectively. The scale advantage index of hemp crops showed the most variation among the six crop types, followed by that of sugar crops. Previous studies on the comparative advantages of different crops were conducted using the domestic resource cost [15], the policy analysis matrix [16-17], and the scale or efficiency comparative advantage index [6, 13-14]. Yang et al. [1] showed that main crops, including rice, potato, rapeseed, tobacco, and vegetables, had comparative advantages in scale in Chongqing city during the period 2005-2011. In the present study, tobacco and vegetable crops had comparative advantages in scale during the same period, consistent with the results in Yang et al. [1]. However, the grain and oil crops in the present study included all types, whereas in the study of Yang et al. [1], the grain crops only included rice and potato, and the oil crops only included rapeseed.

Factors that Influenced the Comparative Advantages of Six Crop Types in Chongqing City during 1985-2021

Table 1 indicates that the comparative advantages of the six crop types were influenced by many factors, including meteorological and socioeconomic. These comparative advantages mainly had correlation with socioeconomic factors, such as rural power consumption, agricultural fertilizer used, agricultural plastic film used, population, GDP, per capita disposable income of rural residents, highway mileage, and total energy consumption and with some meteorological factors. Grain, sugar, and tobacco crops had negative correlation with socioeconomic factors, whereas oil, hemp, and vegetable crops had positive correlation.

The variance impact factor (VIF) was used to judge the collinearity between explanatory variables on the six crop types. After the explanatory variables with collinearity were removed, the OLS model was

Table 1. Correlation analysis results between comparative advantages of six crop types in Chongqing City and its influencing factors during 1985-2021.

Crop types	Precipitation	Air temperature	Sunshine hours	Relative humidity	Wind speed	Atmospheric pressure	Rural power consumption	Agricultural fertilizer used	Agricultural plastic film used	Pesticide usage	Population	GDP	Per capita disposable income of rural residents	Highway mileage	Total energy consumption
Grain crops	0.089	-0.240	-0.253	0.464**	-0.302	0.180	-0.933**	-0.783**	-0.896**	-0.377*	-0.879**	-0.931**	-0.923**	-0.952**	-0.968**
Oil crops	-0.107	0.158	0.295	-0.381*	0.354*	-0.153	0.870**	0.671**	0.825**	0.228	0.808**	0.957**	0.949**	0.913**	0.942**
Sugar crops	-0.070	-0.389*	-0.139	0.176	-0.549**	0.420**	-0.610**	-0.809**	-0.671**	-0.839**	-0.733**	-0.454**	-0.474**	-0.489**	-0.523**
Hemp crops	-0.075	0.322	0.126	-0.495**	0.080	-0.161	0.805**	0.815**	0.818**	0.635**	0.779**	0.550**	0.541**	0.715**	0.732**
Vegetable crops	-0.135	0.135	0.243	-0.458**	0.158	-0.020	0.806**	0.593**	0.751**	0.143	0.707**	0.838**	0.822**	0.847**	0.866**
Tobacco crops	0.053	0.271	-0.163	0.215	-0.069	-0.498**	-0.171	0.102	-0.087	0.420**	-0.046	-0.416*	-0.403*	-0.305	-0.291

**. Significant correlation at 0.01 level (bilateral), *. Significant correlation at 0.05 level (bilateral).

adopted to analyze each explanatory variable and the six crop types in Chongqing City during the period 1985-2021. The results are shown in Tables 2 and 3. As shown in Table 2, each explanatory variable presented strong statistical significance. Table 3 shows that the combined F value was 0.001, indicating that the model was statistically significant. Table 2 demonstrates that the VIF of each explanatory variable was under 7.5, indicating no redundancy explanatory variables in the model and no multilinear relationship between explanatory variables. Table 2 also shows that sugar and hemp crops had the same explanatory variables, including GDP and pesticide usage. However, these variables had a negative impact on sugar crops and a positive impact on hemp crops. Grain, oil, vegetable, and tobacco crops had common explanatory variables (per capita disposable income of rural residents). Moreover, the per capita disposable income of rural residents had a positive impact on these crops and a negative impact on tobacco crops. Pesticide usage was one of the explanatory variables of oil, sugar, hemp, and vegetable crops. It had a positive impact on hemp, oil, and vegetable crops and a negative impact on sugar, oil, and vegetable crops. Meteorological factors were the explanatory variables of grain and tobacco crops only. Table 3 indicates that the OLS model fitted well with the six crop types in Chongqing City during the period 1985-2021. However, different fitting results were obtained. The best fitting results were found in oil crops, with R^2 and Adjusted R^2 of 0.914 and 0.909, respectively. Meanwhile, the worst fitting results were obtained in hemp crops, with R^2 and Adjusted R^2 of 0.529 and 0.502, respectively. Yu et al. [13] showed that social and economic factors, such as the Engel coefficient of rural residents and per capita gross regional product had negative impacts on the comparative advantages of grain production. Xu et al. [18] also showed that social and economic factors, including agricultural chemical fertilizer usage, per capita consumption level of residents, and proportion of agricultural GDP, had negative impacts on the comparative advantages of maize. These results were basically consistent with those of the present study. The OLS model is the most widely used regression model in many fields [23-25], and it could obtain the best relationship of data by minimizing the sum of the squared error [20].

In addition, we compared our results with main references. The results was showed in Table 4. Table 4 indicated that there are many differences between our results and references in view of crop type, study area, method, influencing factors and key results. Especially in methods, compared to other methods, our methods could reveal the longer temporal variation characteristics of comparative advantages of main crop types, and analyze more comprehensive influencing factors including socio-economic factor and meteorological factors of the comparative advantage of major crop types. In addition, we could determine influencing factors of the comparative advantage of major crop

Table 2. Results of OLS model of comparative advantages of six crop types in Chongqing City during 1985-2021.

Crop type	Explanatory variables	Regression coefficient	Standard deviation	t value	P value	Tolerance	Variance impact factor (VIF)
Grain crops	Constant term	0.553	0.220	2.510	0.017		
	Relative humidity	0.007	0.003	2.518	0.017	0.879	1.138
	Per capita disposable income of rural residents	0.00002	0.000	-13.391	0.000	0.879	1.138
Oil crops	Constant term	0.759	0.04	18.859	0.000		
	Per capita disposable income of rural residents	0.00004	0.000	18.502	0.000	0.873	1.146
	Pesticide usage	-0.06	0.026	-2.346	0.025	0.873	1.146
Sugar crops	Constant term	0.329	0.024	13.993	0.000		
	GDP	-0.000002	0.000	-2.031	0.050	0.884	1.131
	Pesticide usage	-0.123	-0.774	-8.263	0.000	0.884	1.131
Hemp crops	Constant term	-2.095	0.832	-2.518	0.017		
	GDP	0.00008	0.000	4.045	0.000	0.884	1.131
	Pesticide usage	2.135	0.528	3.025	0.005	0.884	1.131
Vegetable crops	Constant term	1.288	0.117	11.036	0.000		
	Per capita disposable income of rural residents	0.00006	0.000	8.794	0.000	0.873	1.146
	Pesticide usage	-0.128	0.075	-1.713	0.096	0.873	1.146
Tobacco crops	Constant term	1.724	0.065	26.523	0.000		
	Per capita disposable income of rural residents	-0.00005	0.000	-5.505	0.000	0.256	3.904
	Agricultural plastic film used	0.122	0.000	3.687	0.001	0.246	4.059
	Atmospheric pressure	-0.00007	0.033	-4.358	0.000	0.926	1.080

Table 3. Fitting coefficient of OLS model of comparative advantages of six crop types in Chongqing City during 1985-2021.

Crop types	R	R^2	Adjusted R^2	F	Sig
Grain crops	0.935	0.875	0.868	118.987	0.000
Oil crops	0.956	0.914	0.909	181.490	0.000
Sugar crops	0.858	0.736	0.720	47.380	0.000
Hemp crops	0.728	0.529	0.502	19.125	0.000
Vegetable crops	0.837	0.701	0.683	41.323	0.000
Tobacco crops	0.795	0.632	0.599	18.908	0.000

types in quantitative perspective by the OLS model. The OLS model could gained the best relationship between the comparative advantage of major crop types with its influencing factors in quantitative perspective. Therefore, we chose the OLS model to analyze the influencing factors of the comparative advantage of major crop types.

Conclusions

This research revealed the temporal variation characteristics of the sown area of major crop types in Chongqing City. The results indicated that the sown area of six crop types in this city from 1985 to 2021 varied differently.This research also revealed the comparative

Table 4. Comparison of our results with references.

Crop type	Study area	Study period	Method	Influencing factors	Key results	References source
Maize, soybean, winter wheat	United States	1970-2017	Autoregressive moving-average models	Not studied	The growth of wheat production lags behind that of corn and soybeans, most county-level production shows linear growth. The trends of accelerating yields were in more mesic regions east of the Great Plains, and decelerating yields were in the drier central and western United States.	[3]
Foxtail millet	China	1985-2015	Scale advantage index, efficiency advantage index, aggregated advantage index		The sown area of millet decreased first and then increased. The concentration of foxtail millet production in China had increased. The advantageous production areas tended to be stable and the yield had been gradually increased.	[4]
Grain, sugar, fruits, vegetables	Guangxi, China	1995-2019	Scale advantage index, efficiency advantage index, aggregated advantage index, Gini coefficient, gravity center movement model	Not studied	Grain production has no comparative advantages. Sugar production has the absolute scale and aggregated comparative advantages. Fruits and vegetables have a prominent scale comparative advantage	[6]
Spring maize	Northeast China (Liaoning, Jilin, and Heilongjiang)	2002-2020	Remote sensing indexes	Not studied	The sown area of spring maize was characterized by a continuous increase before 2002-2014, exhibited changes and reductions in2015-2017 and exhibited optimization and recovery after 2018–2020	[7]
Corn	Daqing City, China	2001-2014	The Cobb-Douglas production function model	The effective precipitation, corn sown area and chemical fertilizer and pesticide application rates	Current fertilizer and pesticide application rates, sown area and effective precipitation had positive relation with increasing corn yield.	[10]
Maize, wheat	China	1985-2015	Simple generic crop model	Climate factors include temperature, precipitation, and solar radiation	The temporal trends of maize and wheat yield gaps in China were mainly related to precipitation and temperature. The spatial variation in maize yield gap trends was mainly related to the variations in precipitation, while the spatial variation in wheat yield gap trends was mainly related to temperature or solar radiation.	[12]
Grain including cereals, beans, potato, and sweet potato	China	1997-2014	Scale advantage index, water use efficiency advantage index, comprehensive advantage index and path analysis theory	The Engel coefficient of rural residents, the per capita value-added of the secondary industry, and the per capita gross regional product	The level of regional development and per capita sown area of crops were main factors influencing the scale advantage; The efficiency advantage and water use efficiency of grain production were positively correlated with agricultural inputs.	[13]

Table 4. Continued.

Rice	Bangladesh	2010-11-2020-21	Domestic resource cost	Paddy yield, marketing spread between the wholesale and retail level, border price of rice, urea, triple super phosphate, and muriate of potash	Bangladesh has a comparative advantage in modern variety rice production in the Aman season at import substitution.	[15]
Edible oils including animal fats, vegetable oils, margarine, and oil cake	Bangladesh,India, Pakistan, and Sri Lanka	2014	the Policy Analysis Matrix approach	Plant and animal sources, extraction, wearing, electronic manufactures, labor and capital	India, Pakistan, and Sri Lanka have a comparative advantage which is attributed to the low cost of non-tradable inputs. Bangladesh does not have a comparative advantage in edible oil production.	[16]
Grain, oil, sugar, hemp, vegetable, tobacco	Chongqing City, China	1985-2021	Scale advantage index, Pearson's correlation analysis, OLS model	GDP, pesticide usage, per capita disposable income of rural residents, agricultural film used, relative humidity, and atmospheric pressure	The temporal variation characteristics of sown area and comparative advantages in scale of six crop types in Chongqing City from 1985 to 2021 had obvious difference. Tobacco, vegetable, and hemp crops had comparative advantages in scale in Chongqing City. GDP, pesticide usage, per capita disposable income of rural residents, agricultural film used, relative humidity, and atmospheric pressure were the major factors influencing the comparative advantages of the six crop types in Chongqing City from 1985 to 2021.	Our results

advantages of the major crop types in Chongqing City. The results indicated obvious differences in the temporal variation of the comparative advantages of six crop types from 1985 to 2021. In general, tobacco, vegetable, and hemp crops had comparative advantages in scale. Meanwhile, grain crops had comparative advantages in scale at first, and then it gradually decreased, whereas oil crops had no comparative advantages in scale at first and then showed comparative advantages in scale after 2013. Sugar crops had no comparative advantages in scale during the period 1985-2021.

In addition, this research revealed the major factors that influenced the comparative advantages of six crop types in Chongqing City. The results indicated that the comparative advantages had obvious correlation with rural power consumption, agricultural fertilizer used, agricultural film used, population, GDP, per capita disposable income of rural residents, highway mileage, and total energy consumption and with some meteorological factors. The results also showed that the social and economic development level had a negative impact on grain, sugar, and tobacco crops and a positive impact on oil, hemp, and vegetable crops. In view of meteorological factors, only relative humidity, wind speed, and atmospheric pressure did not have very obvious impact on some crop types, such as grain, sugar, oil, and hemp. By using the OLS model, the main factors that influenced the comparative advantages of the major crop types in Chongqing City were determined. The results demonstrated that GDP and pesticide usage were the major factors that influenced the comparative advantages of sugar and hemp crops. Pesticide usage was also one of the major factors in oil, sugar, hemp, and vegetable crops. The per capita disposable income of rural residents was found to be a common major factor that influenced the comparative advantages of grain, oil, vegetable, and tobacco crops. Meteorological factors, including relative humidity and atmospheric pressure, were the major factors in grain and tobacco crops, respectively. In addition, the results indicated that the OLS model generally fitted well with the six crop types in Chongqing City during the period 1985-2021. The OLS model of oil crops had the best fitting results, with R^2 and Adjusted R^2 reaching 0.914 and 0.909, respectively. The worst fitting results were observed in hemp crops, with R^2 and Adjusted R^2 of 0.529 and 0.502, respectively.

The results could supply a reference for the adjustment and optimization of planting structure in Chongqing City. The government may rapidly develop the crop types with comparative advantages, such as tobacco, vegetable, and hemp crops. The government may also formulate reasonable management measures for the production of different crop types. For example, pesticide usage should be reduced to improve the comparative advantage in scale of oil, sugar, and vegetable crops and increased to improve that of hemp crops.

This research has some limitations. First, the comparative advantage of the six crop types was

analyzed using the scale advantage index due to lack of per unit area yield. Other indices, such as efficiency advantage index, comprehensive advantage index, and the policy analysis matrix, may be considered in the future. Second, this research was carried out in Chongqing City only, so more cities should be considered in the future to gain further extensive and accurate results because of China's vast territory.

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Conflict of Interest

The authors declare no conflict of interest.

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