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# Exploration on Temporal-spatial Difference of Cultivated Land Pressure and Influence Factor Analysis: A Case Study of Guangxi

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**Abstract** Based on related statistical data during 1980 – 2014, change rule of Guangxi cultivated land pressure level was studied. Taking each municipal administrative division as evaluation unit, temporal-spatial change trend of cultivated land pressure level was explored by establishing pressure index model of cultivated land, and principal component analysis was used to explore the driving force of cultivated land pressure. Results showed that from 1980 to 2014 in Guangxi, cultivated land pressure was at level one in 12 years, level two in 19 years and level three in 4 years; mean of cultivated land pressure in each city during 2005 – 2014 was taken as average level of cultivated land pressure in the city, in which cultivated land pressure values of Chongzuo City, Baise City, Laibin City, Liuzhou City, Fangchenggang City, Nanning City, Hechi City and Guigang City were all lower than average level in Guangxi at the same period. Driving factors of cultivated land pressure index mainly contained urbanization rate, Engel coefficient of rural households (ECRH), per capita cultivated land area, total population and rural per capita net income (RPFI).

**Key words** Cultivated land pressure, Principal component analysis, Temporal-spatial difference, Guangxi

## 1 Introduction

With urbanization development[1-3] and population growth[4] in China, cultivated land resources gradually decrease[5], and cultivated quality degenerates[6]. The pressure of social and economic development born by cultivated land further increases, and the research on pressure level of cultivated land increasingly becomes key point of current land science field. Overall situation of Guangxi cultivated land is less per capita arable land, low arable land quality, and insufficient reserve resources of arable land. With economy develops, cultivated land declines by agricultural mechanization and increased application amounts of chemical fertilizer and pesticide. Therefore, the research on Guangxi cultivated land pressure level and influence factor has an important actual significance for the protection and utilization of current land resources. Pressure index of cultivated land indicates the ratio of the minimum cultivated land area which must guarantee food needs of basic production and life in certain region to actual cultivated land area[7-9], which reflects tension degree of cultivated land resources in certain region. Because that the indicators involved in pressure index of cultivated land are all dynamic, such as population number, grain sown area, and grain yield, both the minimum cultivated land area and per capita actual area continuously change with different times and spaces[10]. Pressure index model of cultivated land proposed by Fan Qiumei *et al.* could explain dynamic equilibrium situation of regional arable land – grain – population system[11], which has been applied in national and provincial scale of China. At present, most researches stay in evaluating pressure value by pressure index model of cultivated land in time scale[12-13] or short-time prediction and analysis. When analyzing the change cause of pressure value, it only rounds the relevant influence factors involved in pressure index model of cultivated land, or only qualitatively proposes the relevant suggestions, while there is nearly not research on quantitative exploration of influence factors of cultivated land pressure. In this paper, pressure value of Guangxi cultivated land since 1980 was studied, and pressure values of cultivated land in 14 Guangxi prefecture-level cities during 2005 – 2014 were contrasted and analyzed. By integrating prior research results, 12 influence factors of pressure value were screened, and qualitative and quantitative analysis was conducted to explore key factor of affecting cultivated land pressure. The research could provide reference for the related departments making the policies of land use and agriculture development in Guangxi.

## 2 General situation of Guangxi cultivated land

Guangxi is located at the southernmost tip of China mainland, with the area of 23.76 million ha, and the terrain is dominated by hills and basins. Its climate is warm, and there is abundant rainfall and sunshine. Arable land type of Guangxi mainly contains dry land, paddy field and irrigated land. Area change of arable land in Guangxi experienced the fluctuation process of increase – decrease alternation, in which area of arable land declined during 2000 – 2007 and slowly rose during 2008 – 2014, and it was because that government enhanced protection intensity of cultivated land at the stage and vigorously carried out land consolidation and reclamation work. In 2014, the area of cultivated land was 4.43 million ha, and per capita cultivated land area was 0.09 ha.

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## 3 Data source and research methods

**3.1 Data source** Data were mainly from the *Guangxi Statistical Yearbook*(1984 – 2014) and *Guangxi Water Resources Bulletin* (2009 – 2014). Vector data were provided by Land and Resources Information Center of Guangxi Zhuang Autonomous Region.

**3.2 Research methods** In this paper, pressure index model of cultivated land was used to analyze change of cultivated land pressure in Guangxi. The "minimum per capita cultivated land area" index indicates the area of cultivated land required by food consumption meeting everyone's normal production and living in the region under the condition of certain food self-sufficiency ability and comprehensive output of cultivated land[11], namely the base line of cultivated land guaranteeing grain safety in certain region. Influence factors of "minimum per capita cultivated land area" mainly contain food self-sufficiency ratio, multiple-crop index and grain yield, and its formula is as below.

$$S_{min} = \beta \frac{G_r}{P \cdot q \cdot k} \quad (1)$$

where $S_{min}$ is the minimum per capita cultivated land area(ha/person); $\beta$ is food self-sufficiency rate(%); $G_r$ is per capita food demand(kg/person); $P$ is grain yield per unit area(ha/ kg); $q$ is the ratio of grain sown area to total sown area (%); $k$ is multiple-crop index(%).

Pressure index of cultivated land is the ratio of the minimum per capita cultivated land area to actual per capita cultivated land area(shown by $K$), and $K$ could reflect pressure status of cultivated land(Table 1), and its calculation formula is as below.

$$K = \frac{S_{min}}{S} \quad (2)$$

where $K$ is pressure index of cultivated land, and $S$ is actual per capita cultivated land area(ha/person).

**Table 1 The pressure index of cultivated land and the state of cultivated land**

| Pressure index | Meaning | Status |
|---|---|---|
| $K<1$ | The minimum per capita cultivated land area is less than actual per capita cultivated land area | Without cultivated land pressure |
| $K=1$ | The minimum per capita cultivated land area is equal to actual per capita cultivated land area | On the edge of pressure |
| $K>1$ | The minimum per capita cultivated land area is more than actual per capita cultivated land area | Obvious cultivated land pressure |

## 4 Results and analysis

### 4.1 Dynamic analysis on pressure index of Guangxi cultivated land

**4.1.1** Temporal variation analysis of cultivated land pressure (1980 – 2014). When measuring per capita grain demand, based on the research of Hu Jing[14], combining nutrition standards recommended by Ministry of Health, heat, protein and fat needed by annual average life of everyone were all converted into 248.56 kg of grain amount. In the measurement process, 250 kg of annual average grain demand of each person could be selected. Pressure index of cultivated land was divided into three grades, and there were 7 token statuses(Table 2).

**Table 2 The class of cultivated land pressure index**

| Item | Level one | | | Level two | | Level three | |
|---|---|---|---|---|---|---|---|
| Pressure index | <0.50 | 0.51 – 0.90 | 0.91 – 1.00 | 1.01 – 1.10 | 1.11 – 1.50 | 1.51 – 2.00 | >2.01 |
| Representation state | Small | Smaller | Slightly small | Slightly large | Larger | Large | Very large |

Seen from Fig. 1, fluctuation trend of cultivated land pressure index in Guangxi during 1980 – 2014 was roughly divided into three stages. The first stage was from 1980 to 1989, and it was stable stage of pressure, and pressure index was basically below 0.80; the second stage was from 1990 to 1999, and it was increase stage of pressure. Pressure index increased from 0.811 in 1989 to 1.116 in 1999, and the pressure index at the stage continuously floated. The third stage was from 2000 to 2014, and it was stage stage of pressure, and pressure index fluctuated near 1. Therefore, pressure value of cultivated land in Guangxi during 1980 – 2014 was all within 1.30, and overall cultivated land pressure was relatively smaller, in which cultivated land pressure quickly increased from 1990 to 1992, and pressure value of cultivated land in recent 10 years had no obvious change trend. Relative pressure condition was stable, and pressure value fluctuated near 1, which posed a threat to cultivated land pressure in Guangxi.


**Fig. 1 The change trend of cultivated land pressure index in Guangxi during 1980 – 2014**

**4.1.2** Analysis on spatial difference of cultivated land pressure (2005 – 2014). By measuring pressure index value of cultivated land in 14 prefecture-level cities of Guangxi during 2005 – 2014 (Table 3), it was found that pressure value of cultivated land in 14 prefecture-level cities had a big difference to some extent. Due to smaller change fluctuation of cultivated land pressure level in each prefecture city, mean pressure value of cultivated land in 14 prefecture-level cities during 2005 – 2014 was taken as its mean level of cultivated land pressure, and arrangement sequence of cultivated land pressure was Chongzuo City < Baise City < Laibin City < Liuzhou City < Fangchenggang City < Nanning City < Hechi City < Guigang City < Beihai City < Hezhou City < Qinzhou City < Yulin City < Wuzhou City < Guilin City. Spatial distribution chart of average cultivated land pressure index in Guangxi during 2005 – 2014 was shown as Fig. 2, and the color from shallow to deep respectively represented level one to seven. Among them, the cities that average cultivated land pressure level was smaller than average level in Guangxi at the same period were Chongzuo City, Baise City, Laibin City, Liuzhou City, Fangchenggang City, Nanning City, Hechi City and Guigang City, and mean pressure of cultivated land in the 8 cities was smaller than 1. According to natural endowment and feature of social economic development, Guangxi was divided into five economic zones: north Guangxi, central Guangxi, west Guangxi, east Guangxi and south Guangxi. The sequence of cultivated land pressure value in the five economic zones was west Guangxi < central Guangxi < south Guangxi < east Guangxi < north Guangxi. (i) In south Guangxi economic zone, using the advantage of geographical position, port economy and modern industry were vigorously developed, in which cultivated land pressure indexes of Nanning and Fangchenggang were both lower than 1 in recent years, while cultivated land pressure value of Beihai in recent years fluctuated around 1, and cultivated land pressure index of Qinzhou City in recent years was all higher than 1, with mean cultivated land pressure value of 1.008. (ii) Central Guangxi economic zone was dominated by industry, and pressure level of cultivated land was relatively lower. Liuzhou and Laibin had very close change trend of cultivated land pressure value, and average pressure value in latter 5 years slightly decreased than that in prior 5 years, and mean of cultivated land pressure in 10 years was 0.805. (iii) North Guangxi economic zone indicated Guilin City, which was dominated by tourism, with higher terrain, worse agricultural production condition, larger visitors flowrate and larger cultivated land pressure. It was the region with the maximum cultivated land pressure, which was 1.532. (iv) East Guangxi economic zone was main region of agriculture development in Guangxi. Yulin and Wuzhou had lower terrain and large population density, and mean of cultivated land pressure was 1.201, which was always at larger pressure grade. (v) Due to disadvantage of geographical position, west Guangxi economic zone became the area with relatively lagging agriculture and economy development in Guangxi, higher terrain, and smaller population density, and mean of cultivated land pressure was 0.786, with smaller pressure characterization.

**Table 3 Cultivated land pressure indexes of 14 cities**

| Area | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | City | Area |
| Guangxi | | 0.963 | 0.965 | 0.994 | 1.013 | 1.023 | 0.986 | 0.937 | 0.986 | 0.953 | 0.957 | 0.977 | |
| South Guangxi | Nanning | 0.856 | 0.883 | 0.912 | 0.925 | 0.950 | 0.908 | 0.918 | 0.929 | 0.942 | 0.948 | 0.917 | 1.008 |
| | Chongzuo | 0.591 | 0.606 | 0.655 | 0.650 | 0.611 | 0.602 | 0.625 | 0.645 | 0.659 | 0.670 | 0.631 | |
| | Beihai | 1.022 | 1.033 | 1.069 | 1.085 | 1.006 | 0.975 | 0.994 | 0.999 | 1.008 | 1.017 | 1.020 | |
| | Qinzhou | 1.172 | 1.241 | 1.275 | 1.312 | 1.215 | 1.162 | 1.173 | 1.183 | 1.214 | 1.238 | 1.218 | |
| | Fangchenggang | 0.825 | 0.862 | 0.897 | 0.882 | 0.878 | 0.846 | 0.855 | 0.888 | 0.908 | 0.930 | 0.877 | |
| Central Guangxi | Liuzhou | 0.835 | 0.860 | 0.873 | 0.883 | 0.759 | 0.752 | 0.767 | 0.778 | 0.791 | 0.797 | 0.809 | 0.805 |
| | Laibin | 0.864 | 0.911 | 0.935 | 0.935 | 0.724 | 0.702 | 0.712 | 0.729 | 0.751 | 0.751 | 0.801 | |
| North Guangxi | Guilin | 1.664 | 1.761 | 1.814 | 1.828 | 1.345 | 1.333 | 1.355 | 1.376 | 1.411 | 1.438 | 1.532 | 1.532 |
| East Guangxi | Wuzhou | 1.406 | 1.500 | 1.536 | 1.541 | 1.343 | 1.331 | 1.358 | 1.396 | 1.416 | 1.438 | 1.426 | 1.201 |
| | Hezhou | 1.221 | 1.008 | 1.078 | 1.278 | 0.843 | 0.970 | 0.987 | 1.004 | 1.005 | 1.029 | 1.042 | |
| | Yulin | 1.379 | 1.417 | 1.447 | 1.464 | 1.367 | 1.322 | 1.339 | 1.362 | 1.385 | 1.399 | 1.387 | |
| | Guigang | 0.953 | 1.006 | 1.033 | 1.062 | 0.898 | 0.876 | 0.888 | 0.905 | 0.931 | 0.951 | 0.950 | |
| West Guangxi | Baise | 0.840 | 0.880 | 0.881 | 0.875 | 0.758 | 0.737 | 0.734 | 0.751 | 0.765 | 0.773 | 0.799 | 0.786 |
| | Hechi | 1.010 | 1.056 | 1.049 | 1.033 | 0.847 | 0.838 | 0.840 | 0.849 | 0.890 | 0.890 | 0.930 | |

**4.1.3** Analysis on pressure level of cultivated land in typical cities. Nanning is located in the south of Guangxi, and is the first big city of Guangxi and center city of Beibu Gulf Economic Zone. From 2005 to 2014, pressure level of cultivated land overall showed an increasing trend, and pressure index of cultivated land rose from 0.856 in 2005 to 0.948 in 2014, with increase amplitude of 10.2%. Main causes of cultivated land pressure index increasing were as below. In recent years, urbanization and industrialization processes of Nanning in recent years were impelled fast, and the area of urban district continuously expanded, and coverage of road and railway increased. In Nanning City, total population number was 6.4885 million in 2005 and increased to 7.2443 million in 2014, with increase rate of 11.6%. Cultivated land area in 2014 was 6854.5 $m^2$, which accounted for 10.56% of total administrative area. During 2005 – 2014, grain yield per unit area in Nanning City was promoted to 22.9%. Population continuously increased, making that cultivated land pressure increased. Due to continuous improvement of grain yield per unit area, it slowed down increasing velocity of cultivated land pressure to a certain degree. Guilin was the region with the maximum pressure index of cultivated land in Guangxi, and its pressure status of cultivated land during 2005 – 2014 was all $K > 1$, while pressure value of

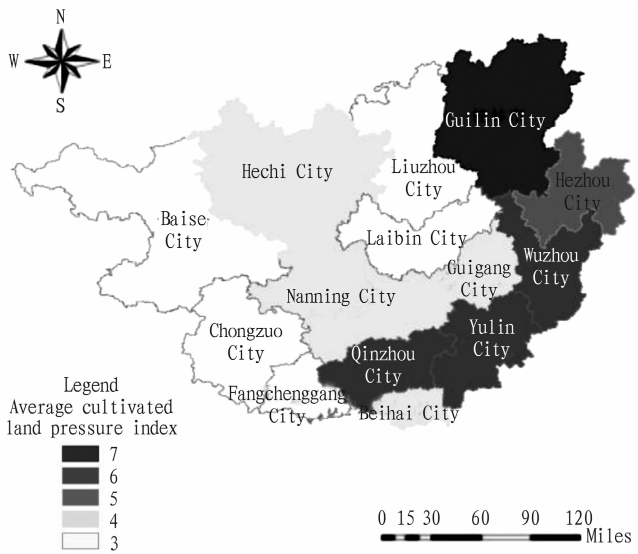


**Fig. 2 Spatial distribution of average cultivated land pressure index in Guangxi during 2005 – 2014**

cultivated land in 2007 reached 1.814, which was at level three. Characterization status of pressure was obvious cultivated land pressure. In 2014, its pressure level of cultivated land declined to 1.438. Cultivated land area of Guilin was only 3306.8 $m^2$ in 2014, and permanent population reached 4.9191 million, which was 1.4 times of Liuzhou, but total cultivated land area was smaller than Liuzhou City. Guilin had larger pressure index of cultivated land, and it was because that Guilin was key scenic city and garden city of China, and its proportion of cultivated land area to administrative area was smaller. Beihai was a typical coastal city in south Guangxi, and its pressure index of cultivated land was stable. Pressure index of cultivated land was between 1.00 and 1.10 in 7 years and between 0.95 and 1.00 in 3 years. Annual average GDP growth rate of Beihai during 2000 – 2014 maintained 17.1%, and fast economy development did not occupy large-area cultivated land but was from the implementation of a series of policies and systems protecting cultivated land by government. Yulin was one of main grain producing areas in Guangxi, and its total grain output was second only to Nanning. Mean pressure index of cultivated land in Yulin was 1.387, and it was because of large population density and less per capita arable land. In Yulin, population density was 5.53 person/ha, which was the maximum in Guangxi and was far more than average population density of Guangxi (2.33 person/ha). Due to higher land use rate and tillage level in Yulin, its yield per unit area was higher, and it was the city with the maximum grain yield per unit area in Guangxi. Land use level of Yulin was more than 16% higher than whole land use level of Guangxi. But continuous grow of population amount, impelling of non-agricultural construction, and prevalent cultivated land requisition compensation balance of cross city caused higher cultivated land pressure. Chongzuo City had the minimum cultivated land pressure in Guangxi. Its cultivated land pressure value was 0.591 in 2005 and rose to 0.670 in 2014. Cultivated land pressure level of Chongzuo in the 10 years was all lower than 0.70, and there was not larger cultivated land pressure. In the existing cultivated land of Chongzuo City, the proportion of farmland providing low or medium yield reached more than 80%. Sampling investigation of soil displayed that nutrient ratio of soil was all in middle or low level, with low cultivated land quality, and grain yield per unit area was the lowest in Guangxi.

**4.2 Analysis on driving force of Guangxi cultivated land pressure** Pressure index of cultivated land in Guangxi during 1980 – 2014 was measured, but there were complex influence factors of cultivated land pressure index. Not only were there the factors involved in the measured formula of pressure value, but also coupling relationship of certain degree may exist among each factor. Principal component analysis could decrease error redundancy among factor when analyzing driving force of cultivated land pressure[15].

**4.2.1** Factor selection. Based on prior researches, 12 factors which may have significant impact on pressure value were selected, and they were food price index($X_1$), AMPI($X_2$), urbanization rate($X_3$), ECRH($X_4$), cultivated land area per person($X_5$), disaster area($X_6$), cropping index($X_7$), irrigation index($X_8$), total population($X_9$), RPFI($X_{10}$), GDP per person($X_{11}$), and grain yield level($X_{12}$).

**4.2.2** Factor analysis. Corresponding index data of Guangxi during 1980 – 2014 were taken as the sample, and SPSS 17.0 was used to treat the related index data, thereby obtaining matrix of correlation coefficient between each factor and pressure value, and correlation coefficients between $X_1 - X_{12}$ and cultivated land pressure value were respectively 0.198, 0.117, 0.703, 0.481, 0.506, 0.648, 0.835, 0.955, 0.739, 0.452, 0.344 and 0.644. Among them, the correlation coefficient between $X_1$, $X_2$ and cultivated land pressure index was less than 0.2, with smaller correlation, which should not be considered. Principal component analysis of $X_3 - X_{12}$ was conducted, and KMO (indicated suitable degree of factor analysis, equal to or more than 0.7 showed suitable, while less than 0.6 showed not recommended) statistical amount was 0.796, illustrating that it was suitable for principal component analysis. Moreover, significance level of spherical test factor model reached 0.000, illustrating that the model was rational.

**4.2.3** Analysis on driving factors. Seen from Table 4, cumulative contribution rate of the first principal component and the second principal component reached 87.83%, which exceeded 85% and corresponded with analysis condition of principal component. Therefore, the two factors were selected as public factors for driving force analysis of cultivated land pressure. Because that the extracted information result of the two public factors could not clearly show index information contained by public factor, the maximum variance rotation was conducted, and factor load matrix after rotation was used to analyze (Table 5). Seen from Table 5, the first principal component had larger load capacity (absolute value) on $X_3$, $X_4$, $X_5$, $X_9$, $X_{10}$, $X_{11}$ and $X_{12}$; while the second principal component had larger load capacity (absolute value) on $X_7$ and $X_8$. High correlation of the above factors was arranged, and main factors affecting pressure level of cultivated land could be generalized into social economic factors, production level factors and tillage resource factors. (i) Analysis on social economic influence factors. Seen from Table 4, variance contribution rate of the first principal component was 73.3%. It was clear that it was dominant in all influence factors. In the first principal component, load capacity of $X_4$ was the maximum, followed by $X_{11}$ and $X_{10}$, illustrating that farmer's living level had great influence on pressure level of cultivated land. The factors involved in measurement formula of cultivated land pressure index were mainly natural factors. When further exploring driving force, result showed that social factors had larger influence degree, and farmer's social living level in social factors was main influence factor. It was because that the measurement of minimum per capita cultivated land area was actually defined from the angle of grain safety, namely supply – demand problem of grain. Grain's demand composition is grain amount needed by all residents to maintain normal production and life in the region, while grain supply is the produced amount of the cultivated land's existing production ability in the region. Farmer's living level and per capita income directly affect grain's supply amount. Due to lower farming income, most of young farmers are engaged in industry or project, and only old and children are farming, thereby causing lower output level of cultivated land. (ii) Analysis on production level influence factors. $X_3$ and $X_9$ also had significant load capacity on the first principal component, illustrating that the relationship between man and land was also important influence factor of cultivated land pressure. $X_5$ and $X_{12}$ had very large influence degrees on the first principal component, illustrating that productivity level of cultivated land had very great driving effect on cultivated land pressure. (iii) Analysis on tillage resources influence factors. The second principal component mainly contained $X_7$ and $X_8$, and the two indexes were both factors representing tillage resources. Multiple-cropping index of Guangxi declined from 1.850 in 1980 to 1.460 in 2014, and it overall showed fluctuation type of declining trend. China overall belongs to water deficient country, and irrigation plays a key role in China's agricultural development. Effective irrigation condition has larger influence on agricultural production level, especially in the north with insufficient precipitation, the improvement of irrigation rate is an essential part of raising Chinese agricultural level.

**Table 4 Principal component analysis**

| Principal component | Characteristic value | Rate of contribution // % | Cumulative proportion // % |
|---|---|---|---|
| 1 | 7.330 | 73.300 | 73.300 |
| 2 | 1.453 | 14.530 | 87.830 |
| 3 | 0.700 | 6.997 | 94.826 |
| 4 | 0.200 | 2.002 | 96.829 |
| 5 | 0.142 | 1.416 | 98.245 |
| 6 | 0.077 | 0.774 | 99.019 |
| 7 | 0.059 | 0.592 | 99.610 |
| 8 | 0.031 | 0.310 | 99.920 |
| 9 | 0.005 | 0.045 | 99.965 |
| 10 | 0.003 | 0.035 | 100.000 |

**Table 5 Component matrix (after orthogonal rotation)**

| Factors | The first principle component | The second principle component |
|---|---|---|
| Urbanization rate $X_3$ | 0.827 | –0.474 |
| ECRH $X_4$ | –0.956 | 0.193 |
| Cultivated land area per person $X_5$ | –0.882 | 0.268 |
| Disaster area $X_6$ | 0.511 | –0.525 |
| Cropping index $X_7$ | –0.086 | 0.922 |
| Irrigation index $X_8$ | –0.290 | 0.938 |
| Total population $X_9$ | 0.837 | –0.528 |
| Per capita income of farmers $X_{10}$ | 0.940 | –0.197 |
| GDP per person $X_{11}$ | 0.945 | –0.078 |
| Grain yield level $X_{12}$ | 0.807 | –0.511 |

## 5 Conclusions

There were complex influence factors of cultivated land pressure level, and main influence factors obtained by principal component analysis could be generalized into social economic factors, production level factors and tillage resource factors. Driving factors mainly contained urbanization rate, ECRH, cultivated land area per person, total population, per capita income of farmers, GDP per person, grain yield level and cultivated land area per person.

## 6 Suggestions

(i) Improve farmer's income level, decline ECRH, and increase GDP per person. By making corresponding policies, the price of agricultural product could be improved rationally, thereby improving farmer's income from plantation; it should encourage farmers to sell agricultural products via less intermediate resale times to lower the middleman's profit margin. In addition, online sale system of agricultural product could be established, and the price of agricultural product should be open and transparent to decline the occurrence possibility of unsalable agricultural products and guarantee the price of agricultural product. (ii) Increase science and technology input, and improve grain yield per unit area. Government could enhance investment intensity of agricultural science, provide high-yield seed to farmers via scientific breeding and improve farmland's insect prevention ability via technology channel, thereby guaranteeing the stability and improvement of grain yield per unit area. (iii) Strictly control the number of cultivated land and guarantee per capita cultivated land area. At present, China is just at high-speed development period of urbanization. When urbanization rate is quickly improved, it should notice to protect the area and quality of cultivated land. Government should strictly control the implementation process of farmland "occupying one and supplementing one" policy, and unify quantity and quality.

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