Evaluation of Land Production Potential in Changsha City

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Abstract. In the post-epidemic era, with rapid economic development, food reserves and food security have become an important basis for maintaining social stability and development. Land productive potential represents the organic matter content that the land can provide under the influence of natural factors in a certain period of time. The higher the productive potential of the land, the higher the utilizable value of the land. Therefore, the improvement of land utilization rate can be achieved by increasing the productive potential of land. In this paper, the land production potential of Changsha City in Hunan Province in 2021 is calculated by calculating the photosynthetic production potential, light and temperature production potential, climate production potential, land production potential and social production potential. The methods of improving land productive potential are discussed by analyzing the factors affecting land productive potential. According to the calculation, the land production potential of Changsha in 2021 is 16,615.76kg/hm^2, and the grain output of the city in the same year is 6,893.94 kg/hm^2. Therefore, the actual grain production of Changsha city has great space for improvement. According to the analysis, the productive potential of land can be improved by improving the utilization rate of light energy, the effective coefficient of water and the effective coefficient of irrigation. Therefore, as far as Changsha City is concerned, reducing soil water evaporation, selecting suitable sowing methods and irrigation methods according to different soils and developing green agriculture are effective measures to improve land production potential.

Keywords: Land potential productivity; Grain output; Soil; Land use.

1. Introduction

In the era of rapid economic development, food reserve and food security have become the social issues that every country is focusing on. During the 13th Five-Year Plan period, China further improved its national food security system and proposed to create a comprehensive food security guarantee mechanism in the Strategic Plan for Rural Revitalization (2018-2022) [1]. At present, the total area of cultivated land in the country remains stable, and grain production is also increasing with demand. However, the reserve resources of cultivated land are still insufficient, and the quality of cultivated land is gradually declining. These problems pose a number of threats to food stocks and food security. The impact of COVID-19 is still being felt around the world, so the issue of food reserves and food security has become an important basis for maintaining social stability and ensuring the normal supply of the national markets. China as a big country of grain production, there is a serious contradiction between more people and less land. With the development of the urbanization, the urban area continues to expand, and the population is gradually transferred from the countryside to the city. Fewer and fewer people are staying in the countryside to farm, and most of them are the elderly and children. Furthermore, pollution from urban development has greatly affected the land quality. The nutrients in the soil are gradually reduced and the area of wasteland is gradually increased. Therefore, it is necessary to accurately understand the current level of land production potential. This ensures maximum utilization of limited cultivated land and avoids idling or waste of land. In addition, the best sowing and watering methods can be developed according to the productive potential of the land. Select suitable food crops according to different soils and improve related cultivation facilities. It is also possible to find ways to improve soil quality by analyzing the factors that affect the productive potential of the land, so as to increase actual food production.

Land production potential refers to the maximum biomass yield that land can provide under certain management level, light, heat, water, soil and other conditions, which is determined by the limitations of natural factors. At present, the methods of calculating land productivity potential can be summarized into three categories: trend extrapolation method, empirical formula method and mechanism method [2]. The results of the trend extrapolation method indicate the actual production potential of the calculated year. The empirical formula method is mainly used to calculate the climatic production potential. The mechanism principle can study the production potential of each level according to the research needs. This paper uses the mechanism method, which is the basic method for calculating the production potential. Compared with the other two methods, this method takes into account the conditions of light, temperature, water and soil more accurately, and calculates the production potential according to the gradual decay of the energy conversion process. The maximum productive capacity of land can be obtained by calculating the regional productive potential of land. In the calculation process, some factors affecting the land production potential can be further studied, such as the maximum utilization rate of light energy and the coefficient of irrigation efficiency. People can develop more rational and efficient production methods to improve the level of these factors. In turn, the productive potential of the land can be raised to its maximum level, and actual food production can be increased.

2. Method

2.1. Photosynthetic Production Potential

Photosynthetic potential refers to the maximum dry matter yield of high-efficiency plant varieties with ideal population structure when the CO_2 content in the air is normal and the temperature, moisture, soil, fertility, agricultural technology and management measures are at their best in unit time and unit area [3]. Computational formula:

$$r_Q = \frac{10^5}{C} \cdot A \cdot F \cdot Q \quad (1)$$

In the formula, r_Q stands for the photosynthetic potential productivity (kg/hm^2). A stands for economic coefficient. The economic coefficient of most cereal crops is between 0.3 and 0.5. F stands for the maximum utilization of light energy. The maximum theoretical value is 15.68, depending on geographical location. C stands for calorific value of dry matter (kcal/g). Most averages are 4.25. Q stands for the total solar radiation (kcal/cm^2).

2.2. Light and Temperature Production Potential

Light and temperature production potential refers to the crop yield determined by the two factors of light and temperature when water, soil fertility and agricultural technical measures are in the best state, which can be used as an approximate indicator of the upper yield limit of field crops. It is to make temperature correction on the basis of photosynthetic production potential [3]. Computational formula:

$$r_T = r_Q \cdot f(T) \quad (2)$$

In the formula, r_T stands for potential production of light and temperature (kg/hm^2). f(T) stands for temperature effective coefficient, f(T)=n/365, n is the number of frost-free days. Frost-free period refers to the period of time between the last frost and the first frost in a year. No frost appears during this period. The growing period of crops is closely related to the frost-free period. The longer the frost-free period, the longer the growing season.

2.3. Climate Production Potential

Climate productivity potential refers to the amount of organic matter produced by crops making full use of natural climate resources (light and moderate precipitation) when the soil and crop population structure in the system are in the optimal state [3]. Computational formula:

$$r_W = r_T \cdot f(W) \tag{3}$$

In the formula, r_W stands for climate productive potential (kg/hm^2). f(W) stands for moisture effective coefficient. The calculation of water effective coefficient f (W) is shown in Table 1. In the formula, ET stands for the annual precipitation. ET0 stands for possible annual evaporation.

Table 1. The calculation of water effective coefficient.

Water effective coefficient	Computational formula	Application condition
f(W)	ET/ET0	ET≤ET0
	1-[(ET - ET0)/3ET0]	ET0<ET<4ET0
	0	ET≥4ET0

2.4. Land Production Potential

Land production potential refers to the organic matter that crops can produce by making full use of natural climate resources and land fertility when the crop population structure and other management factors in the system are in the optimal state. The calculation requires a land correction of the climate productive potential [3]. Computational formula:

$$r_S = r_W \cdot f(S) \tag{4}$$

In the formula, rs stands for the potential of land production (kg/hm^2). f(S) stands for the soil availability coefficient. The value range (0-0.9) is mainly determined by slope conditions.

$$f(S) = \sum P_i \cdot A_i = \sum \frac{B_i \cdot A_i}{C} \tag{5}$$

In the formula, P_i stands for the ratio of each soil type to total soil. A_i stands for the suitability of each soil type to crops. B_i stands for suitability of each soil type for crops. C stands for total soil area. The formula for calculating the suitability of soil to crops is shown in Table 2. (g is the ground slope in the calculation formula). When g≤7°, the land is the best arable land. When g ≥25°, the land cannot be used for cultivation.

Table 2. The formula for calculating the suitability of soil to crops.

Suitability of soil to crops	Computational formula	Application condition
A_i	1	g≤7°
	1-2.5°sin(g-7)	7°<g<25°
	0	g≥25°

2.5. Social Production Potential

Social productive potential refers to the indirectly existing productive forces with the possibility of creating use value [3]. Computational formula:

$$r_M = r_S \cdot f(M) \tag{6}$$

In the formula, r_M stands for social production potential. f (M) stands for the effective coefficient of irrigation. That is the ratio of the effective irrigated area to the total cultivated area.

3. Result

3.1. Introduction of Study Area

Changsha is located in the northeast of Hunan Province. In 2021, the city's land area is 11,816 square kilometers, of which the urban area is 2,150.9 square kilometers and the built-up area is 572.0 square kilometers [4]. Changsha has a subtropical monsoon climate with four distinct seasons and a mild climate. In 2021, the city's permanent population is 10.2393 million. The urban population is 8,515,300, and the rural population is 1,172.40 million. According to the yearbook, the sown area of crops in Changsha in 2021 is 575,650 hectares. The sown area of food crops was 313,380 hectares, and the grain output was 2,160,423 tons [5]. Therefore, the grain yield per hectare of cultivated land is 6,893.94 kg/hm^2.

3.2. Calculation Results of Land Productive Potential

In 2021, the total sunshine hours of Changsha City is 1,501 hours, and the annual solar radiation of the city is about 4,300MJ/m^2, which is about 102.63kcal/cm^2 after unit conversion. The economic coefficient varies with plant species, varieties, natural conditions and cultivation practices. The main crop in Changsha is rice, and the average economic coefficient is 0.47. The average maximum utilization of light energy is 2.5%. The photosynthetic potential calculated according to formula (1) is 28,374.18kg/hm^2.

The length of frost-free period is related to geographical location and temperature change. According to the survey, the number of frost-free days in 2021 in Changsha is about 279 days. The calculated temperature effective coefficient is 0.76. By substituting the formula (2), the potential production of light and temperature is 21,564.38kg/hm^2.

Rainfall in Changsha is abundant, mainly from February to August. In 2021, the annual precipitation of Changsha City is 1,390.8mm, and the annual possible evaporation is 1,194.9mm. Because the annual precipitation is greater than the annual possible evaporation and less than four times the annual possible evaporation, the calculated water effective coefficient f(W) is about 0.945. The calculated climatic production potential according to formula (3) is 20,378.34kg/hm^2.

According to the main data of the third land survey, the cultivated land area of Changsha city is 202,402.68 hectares. Among them, 168,306.95 hectares of cultivated land with a slope of 2°-7° (including 7°). 32,907.26 hectares of cultivated land with slope of 7°-25° (including 25°). 1,188.47 hectares of cultivated land with a slope of more than 25° [6]. The calculated effective coefficient of soil according to formula (5) is 0.937, and the potential of land production is 19,098.58kg/hm^2.

According to the yearbook of Changsha City, the total area of cultivated land in 2021 is 271,970 hectares, and the effective irrigated area is 236,450 hectares. The calculated effective coefficient of irrigation f (M) is 0.87. The calculated social productive potential is 16,615.76kg/hm^2.

4. Discussion

4.1. Present Situation of Land Use

With the development of economy, the urbanization rate of Changsha is getting higher and higher. The reserve resources of cultivated land in Changsha city are few, and most of the central urban areas do not have the conditions to supplement cultivated land. The cultivated land of Changsha is mainly distributed in Ningxiang City, Liuyang City and Changsha County, accounting for 82.41% of the cultivated land area of the city [6]. In 2021, the grain sown area of Changsha is 313,400 hectares, an increase of 0.2% over the previous year. Among them, 286,500 hectares are sown with rice, an increase of 0.1%. The area sown with vegetables reached 163,600 hectares, up 3.2% the planted area of oil is 57,500 hectares, down 3.7% [7]. The total grain output was 2,160,423 tons that is 6,893.94 kilograms per hectare of cultivated land, an increase of 2% over the previous year. The main food crop is rice, with a output of 2,015,342 tons. The construction land area of Changsha City center has

exceeded the construction land scale realized by the overall planning, but the limited land resources restrict the development of economy and society. How to coordinate the relationship between socioeconomic development and cultivated land protection has become an important issue in land use planning.

In 2022, at the request of the government, Changsha began to prepare special plans for cultivated land protection. The special plan puts forward the goal of future farmland protection and clarifies the task of permanent basic farmland protection. There are some important changes in this plan compared with previous plans for cultivated land protection. From the past development and construction planning transition to protection planning. From quantity and quality management in the past to comprehensive farmland use control [8]. Countermeasures to ensure food security and production of characteristic agricultural products are put forward from two aspects of cultivated land quality and ecological construction. It provides reference for improving the production conditions and quality of urban agricultural land and optimizing the structure and layout of urban cultivated land.

4.2. Improved Method

It can be seen from the calculation results that according to the data of 2021, the land production potential of Changsha is 16,615.76kg/hm^2, but the grain output per hectare of cultivated land in Changsha in 2021 is 6,893.94 kg/hm^2. Therefore, the land production potential of Changsha city is large, and the upper limit of land production potential can be reached by increasing the main factors affecting the production potential, so that the actual grain output can be increased.

Firstly, the water evaporation from the soil surface can be reduced by adding soil organic mulch, such as straw and wood chips. The precipitation in Changsha is abundant, but evaporation is also large. It is necessary to grasp the favorable climatic conditions and choose the best planting time and cultivation method from the actual situation. Selecting suitable seeds according to different soils and improve the level of agricultural mechanization, so as to achieve scientific planting and efficient production.

Secondly, in order to reach the upper limit of land production potential, the construction of high-standard farmland should be strengthened. It is necessary to solve the problems of soil improvement and farmland irrigation facilities and promote the construction of efficient water-saving irrigation systems. The utilization rate of low soil and slope farmland should be increased, and the main treatment of saline-alkali land should be changed to select saline-alkali tolerant crops adapted to saline-alkali land [9]. In addition, it is necessary to strengthen the construction of water conservancy infrastructure and improve the utilization rate of irrigation water. Irrigation facilities in semi-arid areas should be improved to develop efficient and water-saving agriculture. Besides, scientific methods of fertilization and killing pests should be promoted. It is useful to increase the application of organic fertilizers and control the number of fertilizers and pesticides. These can effectively prevent the deterioration of soil quality and land utilization problems. The techniques of regenerative rice cultivation and field water and fertilizer management should be popularized in areas where conditions permit and promote the application of emerging agricultural technologies to increase food production.

Finally, green agriculture should be developed to improve soil efficiency [10]. The integration of water and fertilizer and the improvement of the recycling and treatment system of agricultural waste need to be advocated. Excessive reclamation and land use should be prevented to ensure soil organic content. The government should formulate development plans according to the actual situation and formulate preferential policies for enterprises related to green agricultural development. In this way, soil pollution can be reduced, and ecological environment can be improved.

5. Conclusion

Through the analysis and calculation results, the land production potential of Changsha city is relatively high. Although the actual grain output is above the average level in China, there is still

much space for improvement. The light energy resources of Changsha city are not very rich, so the limited light energy resources can be utilized to the maximum extent by improving the utilization rate of light energy. It is necessary to hold the best natural conditions for scientific and efficient crop cultivation. Changsha has abundant precipitation and long frost-free period, but the soil evaporation is large. Land mulching can be rationally used to improve the ability of soil heat preservation and moisture retention to ensure soil moisture in farmland. In addition, sowing should be adapted to local conditions, and suitable food crops should be selected according to different soil types. Irrigation systems should also be improved to maximize the use of limited water resources. It is necessary to develop efficient and water-saving agriculture and mechanized agriculture, which can make maximum use of limited arable land. It is important to ensure the basic farmland area and the cultivation area of main crops. Permanent basic farmland should be used mainly for the development of food production, especially for major food crops such as rice, wheat and maize. The government should promote the development of green agriculture and encourage scientific planting to prevent soil pollution and waste of resources. The results of this study are helpful to understand the land production potential of the study area and help reach the upper limit of land production potential, so as to increase the actual grain yield. Due to the limitation of data, there are idealization factors in the calculation results. The accurate data can only be obtained after surveying the actual situation of the cultivated land. After the calculation results are combined with the actual situation, more perfect methods can be developed to improve the land production potential, and the actual food production can be increased.

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