 DOI: 10.19601/j.cnki.issn1943 - 9903.2024.08.003

Analysis of Regional Difference of Agricultural Land Productivity in Heilongjiang Province

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Abstract The sustenance of humanity is contingent upon the production of food. The foundation of this production is agriculture, which in turn is dependent upon the cultivation of the land. As a fundamental element of agricultural advancement, the rational development and utilization of land play a pivotal role in the process of rural revitalization. Agricultural land productivity serves as a principal indicator of the efficacy of land utilization and the extent of agricultural advancement. Nevertheless, there is a paucity of research examining the productivity of agricultural land, particularly a lack of specialized research on large agricultural provinces. In light of the aforementioned considerations, this paper presents a comprehensive examination of agricultural land productivity and its regional variations in Heilongjiang Province in 2022, with the aid of pertinent statistical data. The findings of the analysis indicate that among the prefecture-level cities, Daqing and Suihua exhibit the highest levels of agricultural land productivity. Additionally, Zhaodong City, Zhaozhou, Qinggang, Wangkui, and Lanxi counties exhibit high levels of agricultural land productivity within their respective prefecture-level cities. There are notable disparities in agricultural land productivity across various regions, including Yichun, Heihe, Harbin, Daqing, Hegang, and Suihua. In contrast, other regions demonstrate a more balanced spatial distribution. In order to facilitate the prosperous development of the agricultural industry in Heilongjiang Province, it is essential to optimize the spatial planning of the land, to investigate the potential for agricultural development in each region, to establish effective collaboration between resources and industries, and to create a development synergy that will collectively advance rural revitalization.

Key words Agricultural land, Productivity, Regional difference, Heilongjiang Province

1 Introduction

Once the granaries are full, the populace adheres to the established norms of conduct. When there is sufficient food and clothing, the people are able to discern right from wrong. Agriculture is the foundation of human society, providing sustenance, clothing, and the means for survival. It is the cornerstone of social stability and harmony. China has historically accorded significant attention to matters pertaining to agriculture, rural areas and farmers, collectively known as the "three rural issues". The No. 1 central document, issued on February 3, 2024, entitled *Opinions of the CPC Central Committee and The State Council on Learning and Applying the Experience of the Thousand Village Demonstration and Ten Thousand Village Renovation Project to Promote the Comprehensive Revitalization of Rural Areas*[1], proposed that the goal of building an agricultural power should be anchored to ensure national food security and to prevent the further exacerbation of large-scale poverty. The objective is to enhance the quality of rural industry, construction, and governance, thereby contributing to comprehensive rural revitalization. Land is an indispensable foundation for agricultural production. The rational utilization of agricultural land can enhance the configuration of rural industries, stimulate the revitalization of rural industries, and expedite the realization of agricultural and rural modernization. As a consequence of economic and social development, the relationship between people and land is becoming increasingly complex. This has led to the emergence of a phenomenon whereby construction land is encroaching upon agricultural land, which is highly detrimental to the sustainable development of land resources. It is therefore of great significance to raise the productivity level of agricultural land in the region in order to ensure the stability of the region's rice production, to facilitate the modernization of agriculture and rural areas, and to promote the comprehensive revitalization of the countryside. The Heilongjiang Province is a major grain and agricultural production center in China. As of 2023, it has consistently ranked first in China in grain production for 14 consecutive years. The current research focus on agricultural land is primarily concerned with the impact of land transfer on farmers' income[2], the evaluation of land efficiency[3], the intensive utilization of agricultural land[4], and other related topics. However, there is a paucity of studies on the productivity of agricultural land[5]. This study employs statistical data to provide an overall analysis of the difference of agricultural land productivity in Heilongjiang Province. The objective is to offer insights and references for the formulation of agricultural land development and utilization plans that align with local conditions, the advancement of modern large-scale agriculture, and the revitalization of northeastern China.

Received: March 8, 2024 Accepted: July 12, 2024

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2 Overview of the study area

The Heilongjiang Province is situated in the northeast of

China, with the Inner Mongolia Autonomous Region located to its west, Jilin Province to its south, and the Ussuri and Heilongjiang Rivers to its east and north. It is situated in close proximity to Russia, with the Heilongjiang River forming a natural border between them. The province is situated at the center of Northeast Asia, enjoying considerable geographic and locational advantages. The region's geomorphology is distinguished by a topographical configuration comprising "five mountains, one water, one grass, and three fields". This pattern is reflected in a general elevation gradient, with the highest points located in the northwest, north, and southeast, and the lowest points situated in the northeast and southwest. The Heilongjiang Province is endowed with a wealth of land resources, with the majority of arable land concentrated in the Songnen Plain and the Sanjiang Plain. Forested land is predominantly distributed in the Daxing'anling, Xiaoxing'anling, and the mountainous regions in the southeastern portion of the province. Pasture land is primarily situated in the western region of the Songnen Plain. The Heilongjiang Province boasts a plethora of original ecological resources, including expansive plains, verdant forests, wetlands, big ice and snow, and snow-capped mountains. These resources serve as a vital barrier for the ecological security of the northern part of China. At the present time, 136 distinct mineral resource types (including subspecies) have been identified, of which 61 have been subjected to exploitation.

3 Research methods and data sources

3.1 Research methods

3.1.1 Calculation method of agricultural land productivity. The agricultural land productivity can be understood as a reflection of the overall output level and degree of utilization of land dedicated to agricultural, forestry, animal husbandry, and fishery activities. This is typically measured by the ratio of the total output value of these sectors (or the output value of the primary industry in the GDP) to the total area of agricultural land, which encompasses arable land, forest land, garden land, pasture land, water surface, and other types of agricultural land[6-7]. The calculation formula is as follows:

$$ALP = \frac{GOVA}{ALA} \tag{1}$$

where ALP represents the agricultural land productivity; $GOVA$ signifies the gross value of agricultural, forestry, animal husbandry, and fishery output; and ALA denotes the agricultural land area.

3.1.2 Calculation of the coefficient of variation. The coefficient of variation is a statistical measure used to quantify the dispersion of a set of data[8]. It can be employed to assess the degree of regional variation and homogeneity of a research object.

$$CV = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - \overline{P})^2}}{\overline{P}} \tag{2}$$

where CV denotes the coefficient of variation of agricultural land productivity; P_i signifies the agricultural land productivity of the county (city) i of a given prefecture; $\overline{P}$ represents the mean value of the productivity of a certain type of land in all counties (cities) under the jurisdiction of a given prefecture; n denotes the number of counties (cities) studied. A greater CV value indicates a more pronounced spatial discrepancy in the research indicator.

3.2 Data sources The data regarding the gross output value of agriculture, forestry, animal husbandry, and fishery, as well as the gross domestic product (GDP) of Heilongjiang Province and its prefectural cities, districts, and counties (districts), were obtained from the *Heilongjiang Statistical Yearbook*[9]. The data regarding the total area of all land types were obtained from the aforementioned yearbook and the 2023 Land Use Change Survey of Heilongjiang Province. This paper is limited in scope to the 12 prefecture-level cities and their subordinate counties (cities) in Heilongjiang Province, with the Daxing'anling region excluded.

4 Analysis of regional differences in agricultural land productivity

4.1 Analysis of agricultural land productivity In accordance with the established formula for measuring agricultural land productivity, this study evaluated the agricultural land productivity of Heilongjiang Province and its constituent prefecture-level cities (Table 1). Additionally, the study assessed the agricultural land productivity of urban and county (city) areas within each prefecture-level city (Fig. 1).

The Heilongjiang Province is endowed with a rich reserve of black soil, with a cultivated area of 10 million ha, representing 56.1% of the total area of typical black soil in the Northeast China region. This region is the primary production area for a significant proportion of China's agricultural output. The regional disparities in agricultural land productivity are attributable to a confluence of factors, including disparate industrial development emphases, varying location conditions, and disparate economic development levels. As illustrated in Table 1, the productivity of agricultural land in Daqing and Suihua exceeds 30 000 yuan/ha, whereas the productivity of agricultural land in Harbin, Qiqihar, and Jiamusi falls within the range of 20 000 to 30 000 yuan/ha, which represents the second range. The agricultural land productivity of Jixi, Hegang, Shuangyashan, Qitaihe, and Mudanjiang ranges from 10 000 to 20 000 yuan/ha, which is in the third range. In contrast, Heihe and Yichun have the lowest agricultural land productivity, which is less than 10 000 yuan/ha, and rank in the fourth range. The Daqing region is distinguished by its relatively flat terrain and the concentration of agricultural land, which has facilitated the advancement of agricultural and animal husbandry practices. Suihua is linked to Daqing and situated within the primary black soil region of Heilongjiang Province, characterized by elevated natural land fertility and robust agricultural infrastructure. This area is the primary grain production hub in Heilongjiang Province, with agricultural land productivity significantly exceeding the provincial average, ranking within the highest range. Harbin is situated in the eastern portion of the Songnen Plain. The distribution of agricultural land is concentrated and continuous,

which provides more favorable conditions for the advancement of agriculture, forestry, and animal husbandry. As the capital city of the province, it serves as a conduit for the inflow of labor, resources, and other factors. Qiqihar, with its elevated soil organic matter content, serves as a primary agricultural production center in Heilongjiang Province and a nationally significant commercial grain production hub. Jiamusi City is situated within the hinterland of the Sanjiang Plain, with a significant proportion of land dedicated to agriculture, predominantly arable and forested areas, and a plentiful supply of water resources. The city is traversed by three principal water systems: the Heilongjiang, Ussuri, and Songhua Rivers. Additionally, there is a notable alignment between the availability of water and soil resources. Consequently, these three areas exhibit above-average agricultural land productivity and are classified within the second range. The cities of Jixi, Hegang, Shuangyashan, and Qitaihe are notable for their abundance of coal resources. However, these cities also exhibit lower agricultural productivity than the provincial average, with lower agricultural land area and lower gross output value in agriculture, forestry, animal husbandry, and fishery. This is accompanied by a relatively more advantageous development of the coal industry. Consequently, the overall productivity of agricultural land in these cities is lower, ranking in the third range. Mudanjiang is situated in the hinterland of Zhangguangcailing and Laoyeling. Its terrain is characterized by hilly terraces and mountains, which contribute to the area's third-ranked agricultural land. However, the gross value of agricultural, forestry, animal husbandry and fishery production is relatively low, resulting in a third-range productivity of agricultural land. Heihe is the most extensive city in terms of agricultural land area. However, the output value of agricultural, forestry, livestock, and fishery is below the provincial average, resulting in a productivity of agricultural land in the area that is less than 10 000 yuan/ha. Yichun, situated in the northeastern region of Heilongjiang Province, is renowned as the "forest capital of China". The majority of the region's agricultural land is forested, yet the total output value of agriculture, forestry, animal husbandry, and fishery is relatively low, resulting in a low ranking for agricultural land productivity.

A comparative analysis of municipal districts and counties (cities) of prefecture-level cities in Heilongjiang Province reveals that only the urban agricultural land productivity of Harbin, Jiamusi, and Heihe exceeds that of the counties (cities) under their jurisdiction. Furthermore, the ranking of the urban agricultural land productivity of the three cities is as follows: Harbin > Jiamusi > Heihe. The productivity of agricultural land under the jurisdiction of the remaining prefectural-level cities is less than that of the counties (cities).

Table 1 Agricultural land productivity in Heilongjiang Province and prefecture-level cities

Region	Total output value of agriculture, forestry, animal husbandry and fishery//10^5 yuan	Agricultural land area//ha	Agricultural land productivity//10^5 yuan/ha	Coefficient of variation
Heilongjiang Province	67 182 358.00	42 819 548	1.57	0.44
Harbin City	12 592 497.00	4 896 968	2.57	0.49
Qiqihar City	8 055 053.00	3 624 953	2.22	0.11
Jixi City	3 677 419.31	1 917 879	1.92	0.16
Hegang City	2 048 351.48	1 339 911	1.53	0.45
Shuangyashan City	3 661 100.00	2 043 048	1.79	0.28
Daqing City	5 337 041.00	1 673 039	3.19	0.44
Yichun City	2 172 981.83	3 160 268	0.69	0.60
Jiamusi City	6 855 461.35	2 910 018	2.36	0.31
Qitaihe City	843 673.00	583 653	1.45	0.30
Mudanjiang City	4 224 212.24	3 734 089	1.13	0.36
Heihe City	5 233 835.49	5 988 075	0.87	0.55
Suihua City	11 277 410.92	3 181 779	3.54	0.45
Mean	5 498 253.05	2 921 140	1.94	0.38

4.2 Analysis of regional difference in agricultural land productivity Among the counties (cities) under the jurisdiction of Harbin, Bayan County and Wuchang City have the highest agricultural land productivity, which exceeds 30 000 yuan/ha. Fangzheng County and Binxian County have the next highest productivity, with values between 20 000 and 30 000 yuan/ha. The agricultural land productivity of Yilan County, Mulan County, Tonghe County, Yanshou County, and Shangzhi City is found to be the lowest among the counties (cities) in Harbin, with a value between 10 000 and 20 000 yuan/ha. The discrepancies in agricultural land productivity among the counties (cities) under the jurisdiction of Qiqihar are relatively minor. Longjiang, Yi'an, Gannan, Fuyu, Keshan, Kedong, and Baiquan counties exhibit relatively elevated agricultural land productivity, exceeding 20 000 yuan/ha. Conversely, Tailai County and Nehe City demonstrate comparatively diminished agricultural land productivity, ranging between 10 000 and 20 000 yuan/ha. In comparison to other counties (cities) under the jurisdiction of Jixi City, Mishan City exhibits a relatively high level of agricultural land productivity, with an average of 20 500 yuan/ha. Jidong County and Hulin City demonstrate a comparable level of agricultural land productivity, with an average of 19 500 yuan/ha. The productivity of agricultural land in Luobei County of Hegang

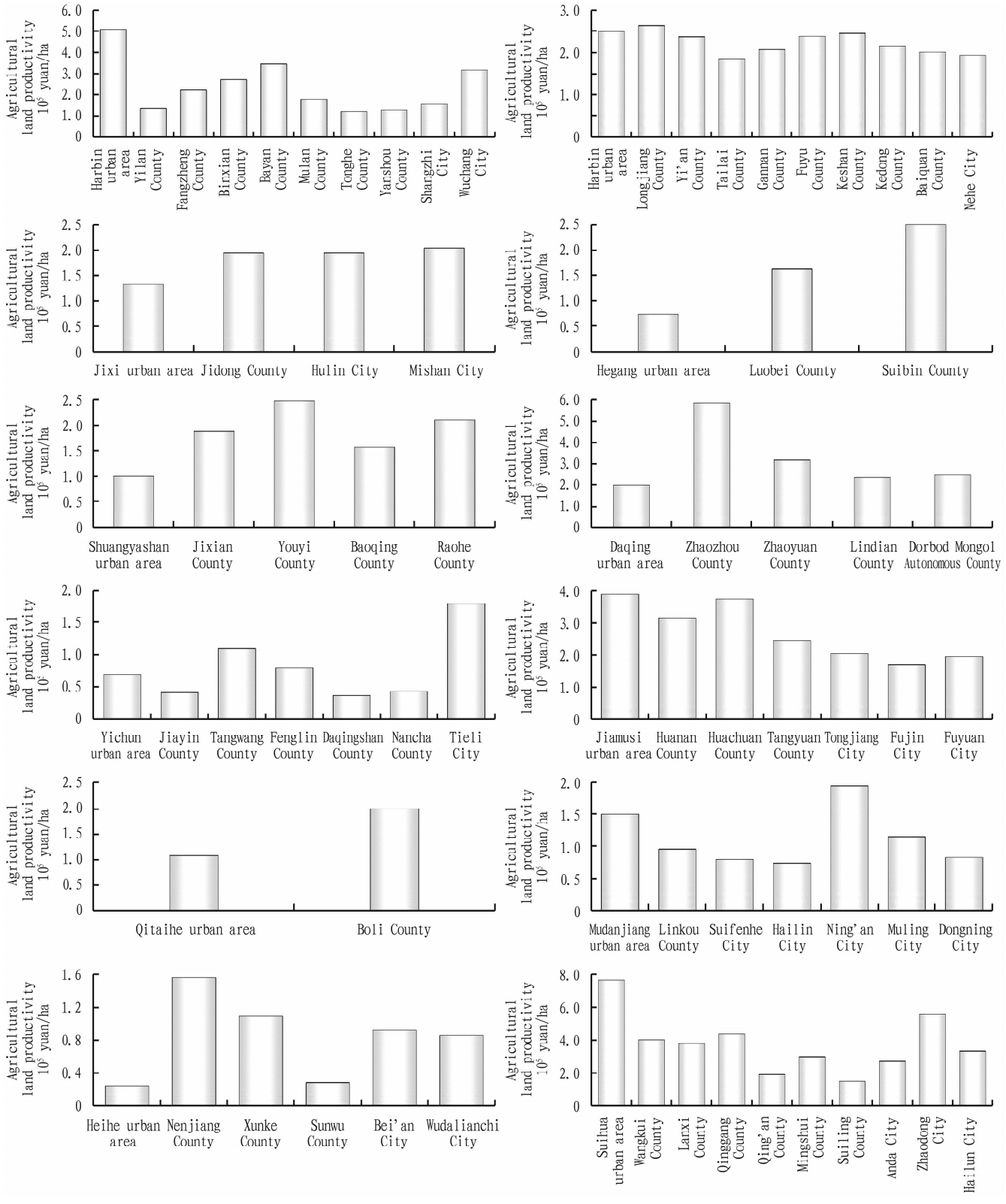

Fig. 1 Agricultural land productivity of prefecture-level cities, counties (cities) in Heilongjiang Province

City is relatively low, at 16 200 yuan/ha, whereas that of Suibin County is comparatively high, at 25 000 yuan/ha. The agricultural land productivity in Youyi and Raohe counties in Shuangyashan City is relatively low, with a value between 10 000 and 20 000 yuan/ha. In contrast, Jixian and Baoqing counties exhibit relatively high agricultural land productivity, with a value above

20 000 yuan/ha. It is evident that there are notable disparities in agricultural land productivity across the counties under the purview of Daqing City. Zhaozhou County exhibits the highest agricultural land productivity, reaching 58 600 yuan/ha. This is followed by Zhaoyuan County, which demonstrates a relatively high agricultural land productivity of 31 800 yuan/ha. Lindian and Dorbod Mongol Autonomous County also exhibit considerable agricultural land productivity, ranging from 20 000 to 30 000 yuan/ha. The agricultural productivity is low in all counties (cities) under the jurisdiction of Yichun City. Only Tangwang County and Tieli City have the agricultural land productivity exceeding 10 000 yuan/ha, while Jiayin, Fenglin, Daqingshan, and Nancha counties have the agricultural land productivity below 10 000 yuan/ha. The agricultural land productivity of Jiamusi City's Huainan and Huachuan counties is notably high, with values ranging between 30 000 and 40 000 yuan/ha. Tangyuan County and Tongjiang City's agricultural land productivity falls within the second range, with values between 20 000 and 30 000 yuan/ha. Conversely, the agricultural land productivity of Fujin and Fuyuan cities is comparatively low, with values between 10 000 and 20 000 yuan/ha, placing them within the third range. Boli County is the sole county in Qitaihe City with the agricultural land productivity reaching 20 100 yuan/ha. The productivity of agricultural land in the counties (cities) under the jurisdiction of Mudanjiang City is, on the whole, relatively low. The productivity of agricultural land in Ning'an and Muling cities is between 10 000 and 20 000 yuan/ha, whereas the remaining counties (cities) have productivity levels below 10 000 yuan/ha. The overall agricultural land productivity of counties (cities) under Suihua City is high, with notable regional disparities. Zhaodong City exhibits the highest agricultural land productivity at 55 500 yuan/ha, followed by Wangkui and Qinggang counties, which have the second highest agricultural land productivity at 40 000 – 50 000 yuan/ha. The agricultural land productivity of Lanxi County and Hailun City is between 30 000 and 40 000 yuan/ha, while that of Anda City is between 20 000 and 30 000 yuan/ha. Qing'an and Suiling counties have a productivity of between 20 000 and 30 000 yuan/ha.

With regard to the coefficient of variation, the regions of Yichun and Heihe exhibit the highest coefficient of variation of agricultural land productivity, which ranges from 0.5 to 0.6. This suggests that the regional disparities in agricultural land productivity are most pronounced in these two locations. The coefficient of variation for agricultural land productivity in the cities of Harbin, Daqing, Hegang, and Suihua is between 0.4 and 0.5, which is within the second range. The coefficients of variation of agricultural land productivity in the aforementioned six prefectures are all greater than or equal to the average coefficient of variation for agricultural land productivity in Heilongjiang Province. This indicates that there is greater regional disparity in agricultural land productivity in these locations. The coefficient of variation of agricultural land productivity in the three cities of Jiamusi, Qitaihe, and Mudanjiang ranges from 0.3 to 0.4, which is situated within the third range. The coefficient of variation of agricultural land productivity in Shuangyashan is 0.28, which is situated within the fourth range. The coefficient of variation of agricultural land productivity in Qiqihar and Jixi is less than 0.2, which is indicative of a relatively low level of variability. This suggests that the spatial distribution of agricultural land productivity in Jiamusi, Qitaihe, Mudanjiang, Shuangyashan, Qiqihar, and Jixi is more balanced.

5 Conclusions

In light of the aforementioned measurements and analysis, the following fundamental conclusions can be drawn:

(i) A comparative analysis of agricultural land productivity at the prefecture level reveals that Daqing and Suihua exhibit the highest productivity, followed by Harbin, Qiqihar, and Jiamusi. Jixi, Hegang, Shuangyashan, Qitaihe, and Mudanjiang demonstrate the third highest productivity, while Heihe and Yichun exhibit the lowest. Among the counties (cities) under the jurisdiction of all prefecture-level cities, the top five are Zhaodong City, Zhaozhou, Qinggang, Wangkui, and Lanxi counties.

(ii) A regional analysis reveals that Yichun and Heihe exhibit the highest coefficients of variation in agricultural land productivity, followed by Harbin, Daqing, Hegang, and Suihua. The agricultural land productivity of these six cities is greater than or equal to the average value of the coefficient of variation of agricultural land productivity in Heilongjiang Province, indicating a more pronounced regional disparity in their agricultural land productivity. The coefficients of variation of agricultural land productivity in Jiamusi, Qitaihe, Mudanjiang, Shuangyashan, Qiqihar, and Jixi are less than the mean value of the coefficients of variation for the entire province. Furthermore, the spatial distribution of agricultural land productivity is more balanced in these six cities.

(iii) The extent of agricultural land in some regions is considerable, yet the productivity of these lands is relatively low. For instance, Heihe City boasts the largest area of agricultural land, yet its agricultural productivity is the second lowest, and there is a discrepancy between the resources available and the pace of industrial development, which is incongruent with the country's rural revitalization strategy. It is thus imperative to reinforce the spatial planning of land in Heilongjiang Province, develop and utilize land resources in accordance with local conditions, and achieve the coordinated development of "land" and "industry" with the objective of "industrial prosperity", thereby facilitating the revitalization of the northeast.

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the number of species in the farmland ecosystem, but also in the increase in species diversity and ecological complexity[9]. The increase in biodiversity means that the stability and resistance of farmland ecosystem have been enhanced, and it can better cope with the disturbance and change of external environment. In addition, the use of biological prevention and control technology has a positive impact on soil quality. By reducing the use of chemical pesticides, beneficial microorganisms in the soil are protected, soil structure is improved, and soil fertility is enhanced. These changes are not only beneficial to the growth of crops, but also lay a solid foundation for the long-term development of farmland ecosystem.

In summary, the use of biological prevention and control technology has played an important role in maintaining ecological balance and biodiversity, and reducing the pollution and destruction of chemical pesticides to the environment. The application of this technology not only improves the biodiversity index of farmland, but also significantly improves the soil quality, which provides a new idea and way for the sustainable development of agriculture.

5 Conclusions and prospects

5.1 Conclusions In conclusion, biological prevention and control technology of crop plant diseases and insect pests has significant advantages in economic cost, which can reduce direct and indirect costs and improve economic, ecological and social benefits. Therefore, it is recommended that agricultural producers should actively adopt biological prevention and control technology, strengthen technical training and promotion, and enhance the effect of prevention and control and market competitiveness. In addition, government and various circles of society should also increase their support for biological prevention and control technology and jointly promote the green development and construction of ecological civilization of agriculture.

5.2 Prospects With the continuous improvement in people's awareness of food safety and ecological environmental protection, biological prevention and control technology will play a more important role in agricultural production in the future. In the future, it is recommended to strengthen the research and development and innovation of biological prevention and control technology, and promote the transformation and application of technological achievements. Besides, it is necessary to strengthen technical training and guidance for farmers and improve their application ability and level. In addition, it is also necessary to strengthen the exchange and cooperation with international advanced technology, introduce and absorb international advanced technology achievements, and improve the overall level of biological prevention and control technology in China. It is believed that with the joint efforts of all parties, biological control technology will make greater contributions to the realization of the strategic goals of green agricultural development and rural revitalization.

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