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Temporal and Spatial Variation of Agricultural and Pastoral Production in the Eastern Section of the Agro-Pastoral Transitional Zone in Northern China

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Abstract: The agro-pastoral transitional zone in northern China is an important agricultural and pastoral production base. This study focuses on the eastern section of the agro-pastoral transitional zone in northern China. Combined with spatio-temporal analysis, stepwise regression, and gray relation analysis, we analyzed the average annual growth rate, spatio-temporal changes, and influencing factors of agricultural and pastoral production in the study area during 2000–2020. The results show that, in the past 20 years, the agricultural and pastoral production of the 50 municipal districts and counties has significantly changed, among which the agricultural production of 38 municipal districts and counties has shown an extremely significant increase. Generally, the growth rate of agricultural production is higher than that of pastoral production. Agricultural and pastoral production in the study area is influenced by socio-economic and land use/cover factors, with an average correlation degree of 0.79 and 0.88, respectively. Climate change affects agricultural production in agricultural counties, with a correlation degree of 0.85. The results of this research provide valuable insights into understanding the long-term temporal and spatial changes in agricultural and pastoral production and help to develop sound agriculture and pastoral management practices in the eastern section of the agro-pastoral transitional zone in Northern China.

Keywords: multi-scale; agro-pastoral management; spatio-temporal change; gray relation analysis; land use/cover change

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1. Introduction

Food security is one of the three major security issues in the world [1]. The main issues of food security include a severe imbalance in food supply, high food prices, and a continuous increase in the number of hungry people. In 2022, 258 million people in 58 countries and regions suffered from severe hunger [2,3]. Food is the most basic necessity of human life, and food production directly affects a country's economic and social development and people's living standards.

The world is a highly interconnected network [4]. The connection between socio-economic, environmental, and technological systems transfers risks from one system or sector to another, creating new risks or exacerbating existing ones [5,6]. Climate change has become a threat to human society and exacerbates food security issues [7]. The Global Food Crisis Report 2023 points out that due to economic shocks, the geopolitical environment, climate change, and extreme weather events, the global food crisis and severe food insecurity will escalate [8,9]. The National Assessment Report on Climate Change in China emphasizes that in the past century, the average surface temperature in China has significantly increased, with human activities causing a 1 °C increase in surface temperature compared to the pre-industrial period, threatening the normal supply of agricultural products.

Studies have shown climate and land use change as the primary factors affecting crop production and productivity [10,11]. Climate change greatly affects plant growth and production under abiotic stress, which typically experiences various stresses such as drought, high temperature, and low temperature [12]. Wheat is the world's staple food crop. With a temperature increase of 2 °C, it is expected that wheat production will experience a reasonable decrease, and related research predicts that wheat production will decrease by 6% [13]. In addition, climate change not only directly affects crop production but also affects crops by changing the driving factors of compound heat–moisture stresses [14]. However, changes in land use/cover can mitigate or amplify climate change-induced surface hydrothermal stresses [15–18]. Therefore, quantifying the dynamics of land use change is crucial for addressing global social challenges, including food security and climate change. In just 60 years, from 1960 to 2019, land use change has affected nearly one-third of the world's land area [19], which has directly affected agricultural and pastoral distribution and production.

The agro-pastoral transitional zone in northern China is an important zone for agricultural production and an important area for protecting China's food security. It serves as a crucial transition area between traditional pastoral and agricultural ecosystems, functioning as a valuable environmental safety buffer [20,21]. It represents the transition zone from the semi-humid agricultural region to the arid and semi-arid pastoral region. It serves as a primary supplier of pastoral products for eastern agricultural regions and a source of feed for western pastoral regions [22]. Simultaneously, it consistently provides agricultural products to the local area. However, over the past few decades, because of the influence of climate change and human activities, such as overgrazing and overcultivation, the northern agro-pastoral transitional zone has become one of the eight extremely vulnerable ecosystems in China [23,24]. Since 2000, under the influence of global climate aridification and China's aggressive ecological restoration projects, like the 'Grain for Green' program, the spatial and temporal patterns of land use/cover have undergone substantial changes [25,26]. Under the continuous impact of climate change, it is important to rationally plan the distribution of agricultural and pastoral industry in the northern agricultural and pastoral transition zone and guide orderly human activities to maintain the supply of local agricultural and pastoral products. Therefore, understanding the mechanisms of how climate change and human activities influenced the temporal and spatial changes in agricultural and pastoral production would promote the regionally sustainable provision of production. Though there have been numerous studies on the agricultural and pastoral production in the northern agro-pastoral transitional zone, most of them have focused on simulating and predicting production and optimizing land use/cover. Exploring the impact of changes in climate and land use on the spatial–temporal patterns of agricultural and pastoral production would aid in formulating adaptive policies for optimizing agricultural and pastoral resources in response to climate change.

This paper selected the eastern part of the agro-pastoral transition zone in Northern China as the study area, where large-scale ecological restoration has been carried out. Based on the statistical data, we analyzed the spatial–temporal patterns and trends of agricultural and pastoral production at the county level from 2000 to 2020. Then, the impact and contribution of socio-economic factors, meteorological factors, and land use/cover factors on the changes in the agricultural and pastoral production were analyzed.

2. Research Location

The study area is located between 115°–125° E and 40°–49° N, and the altitude ranges from −152–2229 m (Figure 1), covering an approximate area of 352,400 square kilometers. The region starts from the western foot of the Greater Hinggan Mountains and the northern edge of the Songnen Grassland in the north and enters the Bashang Grassland on the eastern edge of the Mongolian Plateau through the western part of the Songnen Grassland and the Horqin Sandy Land [27]. It mainly belongs to a temperate continental climate [28]. The total annual active accumulated temperature (≥10 °C) is 2900–3200 °C, and the annual precipitation is between 350–500 mm. The growing season has abundant precipitation, accounting for more than 80% of the total annual precipitation. Climatic conditions are favorable for the growth of crops and forage grass. The region connects China's two major food production systems (agriculture and pastoral) with enormous production potential [29]. Per person, agricultural production is higher than the national average level [30]. The pastoral industry has formed an industrial network from cattle and sheep breeding to forage grass planting. The study area encompasses 50 counties and municipal districts across five provinces/autonomous regions of Heilongjiang, Jilin, Liaoning, Hebei, and Inner Mongolia, among which there are 28 agricultural counties, 4 pastoral counties, and 18 semi-pastoral counties [31] (Table 1).

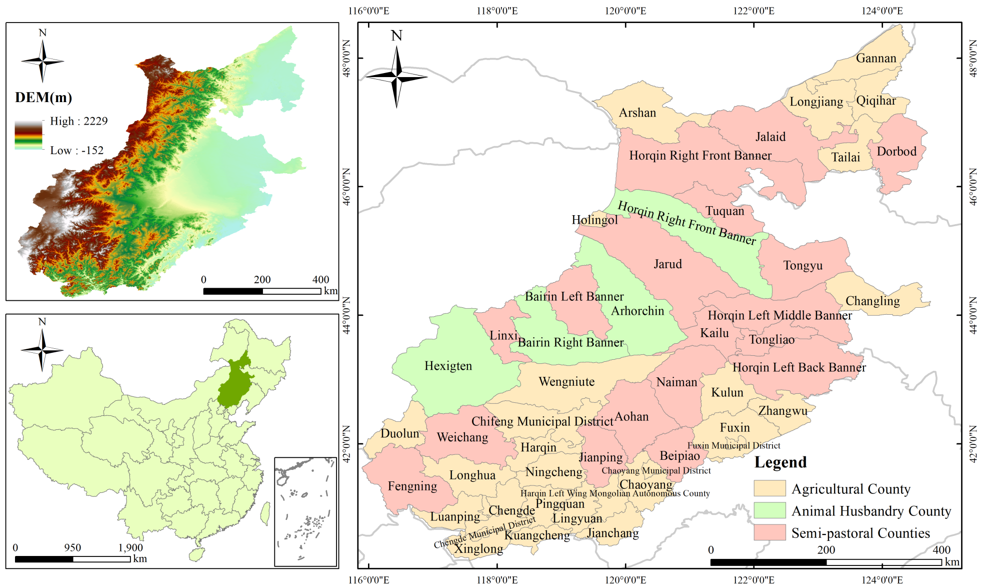

Figure 1. Location of the eastern section of the northern agricultural–pastoral transitional zone and distribution map of agricultural and pastoral counties.

Table 1. The counties in the eastern section of the northern agricultural–pastoral transitional zone.

Province	County
Heilongjiang Province	Longjiang, Tailai, Gannan, Qiqihar municipal District, Dorbod Mongolian Autonomous County
Inner Mongolia Province	Wengniute, Harqin, Ningcheng, Chifeng municipal district, Kulun, Holingol, Arshan, Dolun, *Arhorchin*, *Bairin right banner*, *Hexigten*, *Horqin Right Middle Banner*, Bairin left banner, Linxi, Aohan, Horqin Left Middle Banner, Horqin Left Back Banner, Kailu, Naiman, Jarud, Tongliao Municipal District, Horqin Right Front Banner, Jalaid, Tuquan
Hebei Province	Chengde, Xinglong, Pingquan, Luanping, Longhua, Kuancheng Manchu Autonomous County, Chengde municipal District, Fengning Manchu Autonomous County, Weichang Manchu and Mongolian Autonomous County
Jilin Province	Changling, Tongyu
Liaoning Province	Fuxin Mongolian Autonomous County, Changwu, Fuxin Municipal District, Chaoyang, Harqin Left Wing Mongolian Autonomous County, Lingyuan, Chaoyang Municipal District, Jianchang, Jianping, Beipiao

Note: the agricultural counties are underlined, the pastoral counties are italicized, the semi-pastoral counties constitute the rest.

3. Materials and Methods

3.1. Data Sources

The research data include the social-economic data, the meteorological data, and the land use/cover data from 2000 to 2020 (Table 2). Among them, the land use data from 2000 represent the land use situation from 2000 to 2003, the data from 2005 represent the situation from 2004 to 2007, the data from 2010 represent the situation from 2008 to 2012, the data from 2015 represent the situation from 2013 to 2017, and the data from 2020 represent the situation from 2018 to 2020. Thus, the land use/cover data could match the time scales of the meteorological and socio-economic data. Rice and wheat production (unit: ton) were selected as representative of agricultural production, given their significance as the primary staple foods in China. According to the data available in the statistical yearbooks of each municipal district and county, pastoral production focused on the total production of three meat types, including cattle, sheep, and pigs (unit: ton). Daily climate data, including temperature and precipitation, were collected from 22 meteorological stations within and around the study area. We used the inverse distance weighting (IDW) interpolation method to obtain spatial distribution maps for each meteorological element. Annual interstitial data were derived by calculating the average temperature and the total precipitation based on the daily data. Regional statistical methods were applied to obtain the annual average precipitation and temperature for each municipal district, banner, and county within the study area from 2000 to 2020.

Table 2. Research data in the study.

Data Type	Index	Data Source	Data Specifications
Socio-economic data	Agricultural and pastoral production Primary industry Secondary industry Population	CNKI (China National Knowledge Infrastructure) China Economic and Social Big Data	County-scale statistical data from 2000 to 2020
Meteorological data	Annual average temperature Annual average precipitation	National Meteorological Science Data Sharing Service Platform—China Ground Climate Daily Data Set (V3.0) (http://data.cma.cn/ (accessed on 15 February 2023))	Daily Meteorological Station data from 2000 to 2020
Remote sensing data	Land use/cover type	Chinese Academy of Sciences Resource and Environmental Science Data Center (http://www.resdc.cn/ (accessd on 20 February 2023))	For the years 2000, 2005, 2010, 2015, and 2020, with a spatial resolution of 1 km.

3.2. Research Methods

3.2.1. Trend Analysis Method

We used the Theil Sen Medium (Sen) slope estimation and Mann Kendall (MK) trend analysis methods to analyze the change trends of agricultural and pastoral production in the study area from 2000 to 2020. Sen was used to determine the annual change magnitude of agricultural and pastoral production over time. A positive slope indicates an increasing trend in agricultural and pastoral production, while a negative slope indicates a decreasing trend. The MK results were used to determine whether an indicator exhibited a significant monotonic increasing or decreasing trend [32]. The absolute values of Z were greater than 1.65, 1.96, and 2.58, indicating that the trend passed the significance tests with reliability of 90%, 95%, and 99% with a significance level of ($\alpha = 0.05$).

3.2.2. Analysis of Influencing Factors

The analysis of influencing factors on agricultural and pastoral production adopts stepwise regression analysis and gray relation analysis methods. Stepwise regression is a more complex regression analysis method that constructs the optimal regression model by gradually selecting independent variables. In stepwise regression, independent variables are added or removed from the model one by one to maximize its explanatory and predictive power. It helps to eliminate multicollinearity, reduce redundant variables, and improve model stability. Gray relation analysis is a statistical technique that is mainly used to analyze the degree of correlation between parent factors and sub-factors within a system. This analysis helps determine the primary and secondary factors influencing development and changes in the system, providing a quantitative comparative analysis method for the dynamic development trends of the system. Combining the two methods, we can eliminate factors that have no significant impact on agricultural and pastoral production and conduct relation analysis on significant factors to identify the main and secondary factors that affect agricultural and pastoral production (Figure 2).

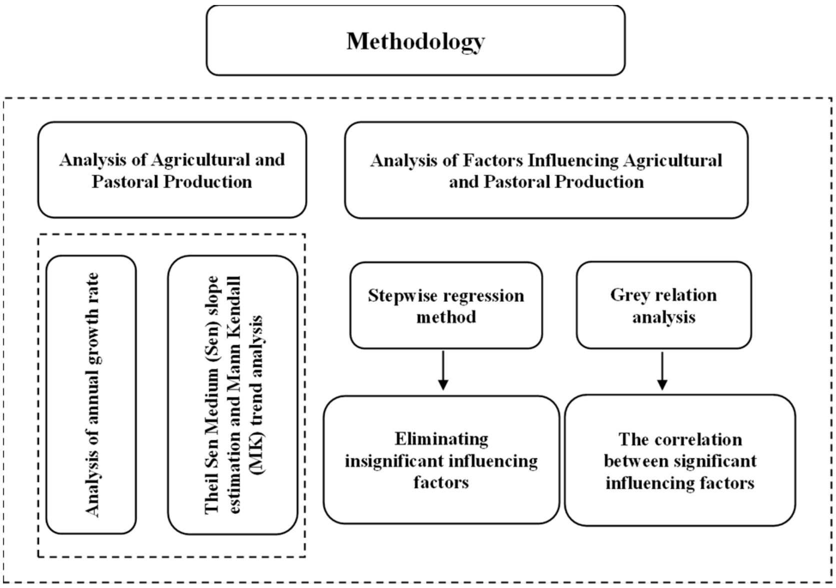

Figure 2. Methodology flowchart.

Stepwise Regression Method

We adopted the stepwise regression method to analyze the influence of climate factors and land use/cover factors on agricultural and pastoral production in three types of countries, including agricultural counties, pastoral counties, and semi-pastoral counties. There are 9 independent variables of socio-economic factors, meteorological factors, and land use/cover factors. Socio-economic factors covered primary industry, secondary industry, and population; meteorological factors included annual temperature and precipitation; the land use/cover factors included cropland area, forest area, grassland area, and urban and rural land areas. The forward stepwise regression method was used in the study, starting with a minimal set of independent variables, gradually adding one variable at one operation. At each step, non-significant variables were removed from the regression model until no variables could be introduced.

Specific steps are as follows:

Step 1: Establish a univariate regression model for each of the independent variables $X1, X2, \ldots, Xp$, with the dependent variable Y. p is the number of the independent variables.

$$Y = \beta_0 + \beta_i X_i + \in, i = 1, \ldots, p. \quad (1)$$

Calculate the F test statistic of the regression coefficient of variable Xi, denoted as ${F_1}^{(1)}$, $\ldots$, ${F_p}^{(1)}$, and determine the maximum ${F_{i1}}^{(1)}$ as follows:

$$F_{i1}^{(1)} = max\{F_1^{(1)}, \ldots, F_p^{(1)}\}. \quad (2)$$

At the given significance level, the corresponding critical value is denoted as $F^{(1)}$. If $F_{i1}^{(1)} \geq F^{(1)}$, then introduce X_{i1} into the regression model, and denote I_1 as the set of selected variables.

Step 2: Establish bivariate regression models between the dependent variable Y and subsets of independent variables $\{X_{i1}, X_1\}$, …, $\{X_{i1}, X_{i1-1}\}$, $\{X_{i1}, X_{i1+1}\}$, …, $\{X_{i1}, X_p\}$ for a total of $p - 1$ models. Calculate the F-test statistic for the regression coefficients of variables and denote it as $F_k(2)(k \in I_1)$. Select the maximum among them and denote it as I2.

$$F_{i2}^{(1)} = max\{F_1^{(2)}, \ldots F_{i-1}^{(2)}, F_{i+1}^{(2)}, \ldots, F_p^{(2)}\}. \quad (3)$$

At the given significance level $(\alpha = 0.05)$, the corresponding critical value is denoted as $F^{(2)}$. If $F_{i2}^{(1)} \geq F^{(2)}$, introduce variable X_{i2} into the regression model. Otherwise, terminate the process of variable introduction. Repeat this procedure, selecting one variable in one operation from the remaining variables not yet introduced into the regression model until no variables pass the test for introduction.

Gray Relation Analysis

In this study, agricultural and pastoral production is taken as the reference sequence (Y) in agricultural counties, pastoral counties, and semi-pastoral counties. The comparative sequences included primary industry, secondary industry, population, annual average temperature, annual average precipitation, cropland area, forest area, grassland area, and urban and rural land area.

The specific steps are as follows:

Step 1: Select the reference sequence $Y = (y1, y2, y3, \ldots, ym)^T$; compare sequences $X_{nm} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}$.

where: n is the number of years and m is the number of elements.

Step 2: Dimensionless processing of variables. Common methods include the initial value method, mean value method, etc. The initial value method is used here.

$$f(x(k)) = \frac{x(k)}{x(1)} = y(k), x(1) \neq 0. \quad (4)$$

Step 3: Calculate the difference sequence of the minimum and maximum.

$$Minimum\ difference : a = \min_i \min_j \mid x_0(k) - x_i(k) \mid, \quad (5)$$

$$Maximum\ difference : b = \max_i \max_j \mid x_0(k) - x_i(k) \mid. \quad (6)$$

Step 4: Calculate the degree of association

$$Z_{k,j} = \xi_j(k) = \frac{a + \rho b}{\mid x_{kj} - y_j + \rho b \mid}. \quad (7)$$

Step 5: Calculate the degree of correlation.

4. Results

4.1. Annual Growth Rate of Agricultural and Pastoral Production

On the whole, the average annual growth rate (>35%) of agricultural production was higher in the south and northeast of the study area, including Kuancheng Manchu Autonomous County, Jianchang, Chaoyang, and Gannan. The average annual growth rate of agricultural production in the northern, western, and southern parts of the study area was between 15% and 35%, including 18 municipal districts and counties, such as Fuxin Mongolian Autonomous County, Pingquan, and Luanping. The other 26 municipal districts and counties had an average annual growth rate from 0% to 15%, among which Kailu, Chengde Municipal District, and Xinglong had the lowest annual growth rate (Figure 3a). In the past 20 years, except for Fengning Manchu Autonomous County, Chengde Municipal District, and Pingquan, pastoral production showed negative growth, but in all other districts and counties, it showed an increasing trend. Among them, six municipal districts and counties, including Horqin Right Front Banner, Tongliao Municipal District, and Beipiao, had the highest average annual growth rate (>15%), and most of the municipal districts and counties had an average annual growth rate between 5% and 10%, mainly distributed in the northeast of the study area (Figure 3b).

By comparing the average annual growth rate of agricultural and pastoral production, it was found that the average annual growth rate of pastoral production was higher than that of agricultural production in Horqin Right Front Banner, Holingol, Kailu, Tongliao Municipal District, and Ningcheng, while the other municipal districts and counties showed the opposite pattern (Figure 3c).

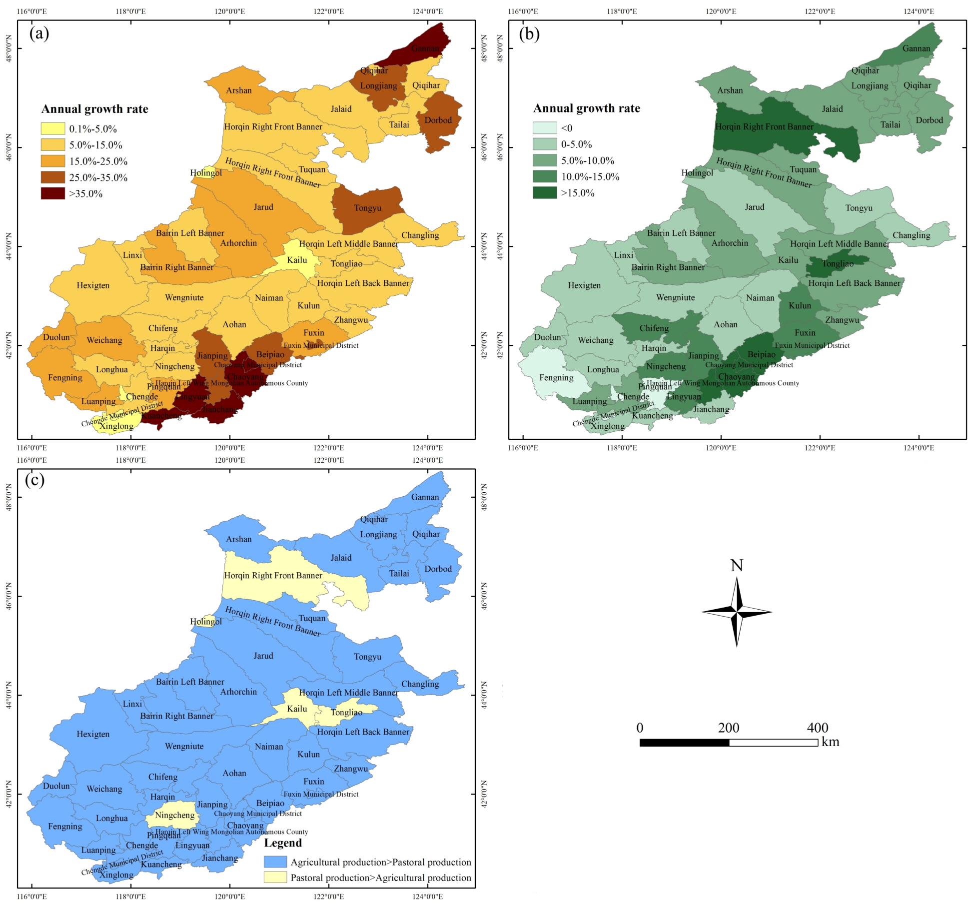

Figure 3. Annual change rates of agricultural production (**a**) and pastoral production (**b**), and comparison chart (**c**) in the study area during 2000–2020.

4.2. Temporal and Spatial Variation Characteristics of Agricultural and Pastoral Production

Sen–MK trend analysis showed that the changing trend of agricultural production from 2000 to 2020 can be roughly divided into a significant increase ($p < 0.05$, slope > 0), no significant increase ($p > 0.05$, slope > 0), and no significant decrease ($p > 0.05$, slope < 0). In the study area, 38 municipal districts and counties showed an extremely significant increase ($Z > 2.58$) in agricultural production, accounting for 88.6% of the total area; 5 municipal districts and counties exhibited a significant increase ($1.96 < Z \leq 2.58$), accounting for 5.7% of the total area; 1 municipal district (Lingyuan) displayed a slight increase ($1.65 < Z \leq 1.96$). The areas with a non-significant increase and non-significant decrease in agricultural production were mainly distributed in the southern part of the study area. There were four municipal districts and counties with non-significant increase, namely Holingol, Pingquan, Jianchang, and Kuancheng Manchu Autonomous County, and two municipal districts and counties with non-significant decrease (Figure 4a).

The general changes in pastoral production in the 50 municipal districts and counties were similar to those in agricultural production (Figure 4). However, the spatial distribution pattern of the temporal change trend of pastoral production was different from that of agricultural production. The areas with an extremely significant increase in pastoral production were mainly distributed in the northern and southern regions of the study area, accounting for 57.96% of the total area, and the areas were distributed in Tailai, Holingol, and Changling. The areas with a slight increase were distributed in Horqin Left Middle Banner and Kulun (Figure 4b).

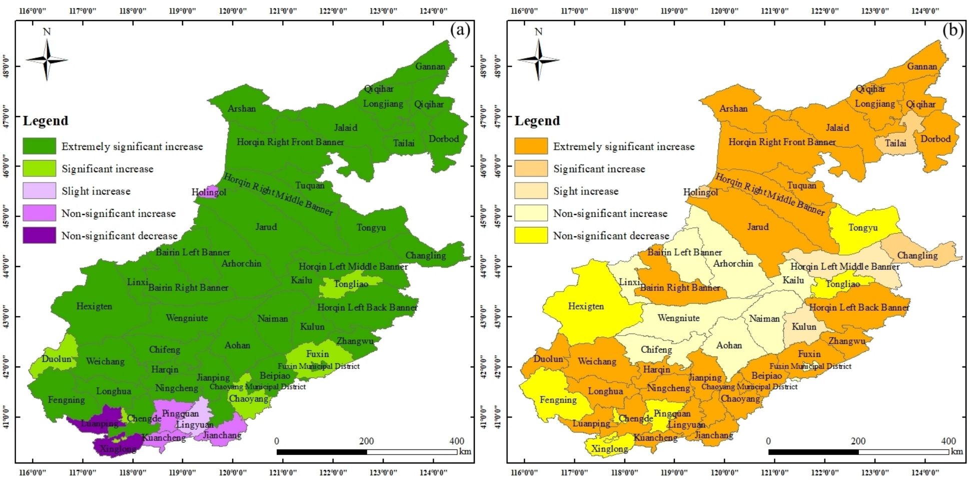

Figure 4. Spatial distribution of the temporal trends of agricultural production (**a**) and pastoral production (**b**) in the study area.

4.3. Influencing Factors of Temporal and Spatial Changes in Agricultural and Pastoral Production

We divided the 50 municipal districts and counties into agricultural counties, pastoral counties, and semi-pastoral counties to analyze the factors affecting the temporal and spatial changes in agricultural and pastoral production.

4.3.1. Qualitative Analysis Results of Influencing Factors

In agricultural counties, agricultural production was affected by the primary industry, annual average temperature, and cropland area; pastoral production was affected by primary industry, as well as urban and rural land area. In pastoral counties, the influencing factors of agricultural and pastoral production were the same, including primary industry, secondary industry, and grassland area. In semi-pastoral counties, agricultural production was affected by primary industry, secondary industry, and grassland area, and pastoral production was affected by primary industry and grassland area. Therefore, agricultural and pastoral production in the study area were mainly affected by primary industry and secondary industry concerning socio-economic factors and grassland area concerning land use/cover factors (Table 3).

Table 3. Influencing factors of agricultural and pastoral production in the study area.

Types	Category	Influencing Factors	Goodness of Fit
Agricultural Counties	Agricultural production	Primary industry	0.974
	Pastoral production	Annual average temperature Cropland area Primary industry Urban and rural land	0.95
Pastoral Counties	Agricultural production	Primary industry	0.986
	Pastoral production	Secondary industry Grassland area Primary industry Secondary industry Grassland area	0.853
Semi-pastoral Counties	Agricultural production	Primary industry	0.982
	Pastoral production	Secondary industry Grassland area Primary industry Grassland area	0.878

4.3.2. Quantitative Analysis Results of Influencing Factors

Agricultural counties in the eastern section of the agro-pastoral transitional zone in northern China are located at a higher latitude (40° N–49° N). Correlation analysis revealed that agricultural production is most strongly influenced by annual average temperature (0.85), followed by cropland area (0.83) and primary industry (0.80). Pastoral production showed the highest correlation with urban and rural land (0.87), followed by primary industry (0.78). In pastoral counties, agricultural production had the highest correlation with primary industry (0.97), followed by grassland area (0.84) and secondary industry (0.66). Pastoral production had the highest correlation with grassland area (0.97), followed by primary industry (0.87) and secondary industry (0.64). In semi-pastoral counties, the correlation between agricultural production and primary industry (0.89) was the highest, followed by grassland area (0.83) and secondary industry (0.68). Pastoral production in semi-pastoral countries was similar to that of pastoral counties.

On the whole, agricultural production in agricultural counties is highly correlated with average annual temperature, and pastoral production is highly correlated with urban and rural land. Agricultural production in pastoral counties and semi-pastoral counties is highly correlated with primary industry, and pastoral production is highly correlated with grassland area (Table 4).

Table 4. The results of correlation degree of significant influencing factors.

Type	Category	Influencing Factor	Strength of Association	
Agricultural Counties	Agricultural production	Annual average temperature	0.85	1
		Cropland area	0.83	2
		Primary industry	0.80	3

Table 4. *Cont.*

Type	Category	Influencing Factor	Strength of Association	
	Pastoral production	Urban and rural land	0.87	1
		Primary industry	0.78	2
Pastoral Counties	Agricultural production	Primary industry	0.97	1
		Grassland area	0.84	2
		Grassland area	0.66	3
	Pastoral production	Grassland area	0.97	1
		Primary industry	0.87	2
		Grassland area	0.64	3
Semi-pastoral Counties	Agricultural production	Primary industry	0.89	1
		Grassland area	0.83	2
		Secondary industry	0.68	3
	Pastoral production	Grassland area	0.92	1
		Primary industry	0.83	2

5. Discussion

5.1. The Impact of Climate Change on Agricultural and Pastoral Production

Climate change has a significant impact on agricultural and pastoral production. From May to August 2018, several regions in Europe experienced extremely high temperatures, resulting in a 50% reduction in crop production in Central and Northern Europe and significant losses in the pastoral industry [33]. Somalia experienced three abnormally low rainy seasons from April 2016 to December 2017, leading to sustained and widespread drought, resulting in significant losses in agricultural and pastoral production [34]. However, in Russia, there has been an increase in wheat yield per hectare and wheat production area since 1980 [35], and new agricultural areas have opened up [36]. In this study, we also found that temperature has a significant impact on agricultural production in agricultural counties, with a correlation of 0.85, making it the main influencing factor of agricultural production. However, the impact of climate change on agricultural and pastoral production in pastoral and semi pastoral counties is not significant. The reason may be that pastoral and semi pastoral counties mainly rely on the pastoral industry, and the impact of climate change on the pastoral industry is relatively small. On the contrary, the impact of the pastoral industry on climate change is significant. Research has shown that pastoral production exacerbates global warming by emitting methane and nitrous oxide [37]. In high-latitude regions in China, temperature has always been more important than precipitation, especially the lowest temperature factor [38]. Therefore, changes in precipitation have no significant impact on agricultural and pastoral production in the study area.

5.2. The Impact of Land Use Change on Agricultural and Pastoral Production

The study results support the hypothesis that land use change has a significant impact on agricultural and pastoral production. The average correlation degree between land use and agricultural and pastoral production in the study area is the highest, reaching 0.88. Comparing agricultural counties, pastoral counties, and semi-pastoral counties, the significant factors of land use are different between the three regions. In agricultural counties, the affecting factors of agricultural production mainly focus on cropland area. Research has also shown that the contribution rate of cropland area to agricultural production in the main grain producing areas of northern China is over 30% [39]. Agricultural counties in the study area are mainly distributed in Heilongjiang, Jilin, and Liaoning provinces in China, and cropland area in the regions has changed significantly. For example, Heilongjiang had the largest change in cropland area from 2012 to 2015, with a peak of three times that of 1995 to 2010 [40]. Therefore, cropland area significantly affects agricultural production of agricultural counties, which is reasonable.

Since the late 1970s, China has implemented many large-scale ecological engineering projects to alleviate and repair the rapidly deteriorating ecological environment in northern China [41], including the Three-North Shelterbelt Program Plan [42], the Natural Forest Protection Project [43], and the Beijing–Tianjin Sandstorm Sources Governance. In the study region, pastoral and semi-pastoral counties are located within the Beijing–Tianjin Sandstorm Sources Governance and the Returning Grassland Project area. Additionally, the Chinese government has implemented policies, such as grazing bans and rotational grazing, in northern pastoral areas to alleviate grassland degradation [44]. After the implementation of the policy, most farmers have changed from grazing to stall feeding [45]. Thus, large areas of re-vegetation were achieved in the agro-pastoral transitional zone in northern China from 2000 to 2015 [46]. Therefore, in pastoral and semi-pastoral counties, pastoral production is mainly significantly affected by the grassland area in the study.

5.3. Planning and Implications in Agricultural and Pastoral Management

At present, China is actively addressing the negative impacts of climate and land use changes to ensure food stability and security. Researchers combined multiple modern technologies and management methods to improve traditional agricultural planting. Additionally, research groups are investigating cold- and drought-resistant crops to adapt to climate change [47–50]. In pastoral areas, grazing methods are transformed from prohibition to sustainable grazing methods, such as rotational grazing and balanced grazing. Continuously improving grazing methods are also pushed through policy incentives [51,52].

In general, agricultural and pastoral production in the eastern section of the agro-pastoral transitional zone in northern China during 2000–2020 has maintained stable growth, providing a solid guarantee for China's food security. Heilongjiang, Jilin, and Inner Mongolia have strong capabilities in the provision of agricultural and pastoral production and natural advantages in maintaining stable prices of agricultural and pastoral production [53,54].

5.4. Limitations and Prospects

This paper analyzed the spatio-temporal variation characteristics and influencing factors of agricultural and pastoral production in the eastern section of the agro-pastoral transitional zone in northern China. However, the influencing factors selected in this study are relatively simple and not comprehensive enough, and the methods used cannot express the impact pathways and impact contribution rate of the influencing factors on agricultural and pastoral production. In future research, we would fully consider the influencing factors and adopt more appropriate research methods to explore the influence mechanism on agricultural and pastoral production. Furthermore, the spatial heterogeneity of impact factors and associated mechanisms would be the direction for future research.

6. Conclusions

From 2000 to 2020, agricultural production in the eastern section of the agro-pastoral transitional zone in northern China showed an upward trend overall and the spatial variation rate weakened gradually from the northeast to the southwest and from the southeast to the northwest. The variation rate of pastoral production generally exhibited a low trend in the middle areas and a high trend in the surrounding areas. Overall, the annual growth rate of agricultural production was higher than that of pastoral production.

Generally, the factors that influence spatio-temporal variation in agricultural and pastoral production are mainly related to socio-economic factors (primary and secondary industries) and land use/coverage factors in the study area. In agricultural counties, agricultural production is influenced by primary industry, the annual average temperature, and cropland area, with the highest correlation seen concerning annual average temperature (0.85); pastoral production is influenced by primary industry and urban and rural land, with the highest correlation seen concerning urban and rural land (0.87). In pastoral counties, both agricultural and pastoral production are mainly influenced by primary industry, grassland area, and secondary industry, with the highest correlation between agricultural production and primary industry (0.97) and the highest correlation between pastoral production and grassland area (0.97). In semi-pastoral counties, agricultural production is influenced by primary industry, grassland area, and secondary industry, with the highest correlation observed in primary industry (0.8); pastoral production is influenced by grassland area and primary industry, with the highest correlation seen concerning grassland area (0.92). Our results can promote regionally rational planning of the agricultural and pastoral industry to assist regionally sustainable development.

In future research, more comprehensive influencing factors should be selected to explore the impact pathways and associated mechanisms of agricultural and pastoral production. Thus, more scientific suggestions for agricultural and pastoral management in the study area would be obtained.

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