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Impact of "Non-Grain" in Cultivated Land on Agricultural Development Resilience: A Case Study from the Major Grain-Producing Area of Northeast China

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Abstract: Previous studies focused on the status and driving factors of non-grain cultivated land (NGCL), but lacked research on the impact mechanism of NGCL on sustainable agricultural development from the perspective of farmers' household livelihoods and agricultural production factor allocation. Therefore, the concept of resilience was introduced. According to official statistics of China from 2010 to 2021, such as the local statistical yearbooks, the impact of NGCL on agricultural development resilience (ADR) in the main grain-producing area of Northeast China was explored based on the threshold effect model and the spatial lag model. The results indicate that: (1) the overall level of NGCI in the study area from 2011 to 2020 show an upward followed by a downward trend; (2) the size of agricultural labor force and average area per labor constrain the impact of NGCI on ADR, and the change can be characterized by negative to positive, increasing and then decreasing respectively, and the former is more constrained than the latter; (3) a negative effect of the NGCI trend on ADR exists without spatial spillover effect. The expansion of food production exacerbates the risk of factor mismatch, which is accentuated by the governance environment that pursues food production excessively. Establishing the NFP governance standards should consider the transformation of farmers' livelihoods and the optimization of production factor allocation. Constructing a resilient risk management mechanism, promoting moderate scale operation and optimizing agricultural labor scale are specific paths for improving the governance mechanisms of NGCI. This study provides a theoretical reference for the development of policies and governance strategies for NGCI in underdeveloped areas.

Keywords: cultivated land use; governance; development resilience of agriculture; food security; major grain-producing area of Northeast China

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1. Introduction

Since 2018, affected by blockades and interdiction of commerce caused by the Sino-U.S. trade friction, the COVID-19 pandemic, and the Russia-Ukraine war, the uncertainty of geopolitical tensions is increasing. The food supply system and its stability are also not optimistic [1,2]. According to the "Global Report on Food Crises-2022" released by the Global Network to Address Food Crises (GNAFC), more than 193 million people in 53 countries or territories are at risk of food insecurity or worse in 2021. This figure hits a notably new historical high, and the international cooperation mechanisms and the global food supply chain are being somewhat disrupted [3]. As a large agricultural country, the human–land conflict has been running through China's agricultural development history and constituted the fundamental constraint of its agricultural modernization [4]. As far as grain production is concerned, the protection and utilization of cultivated land are rationally important bases for food security and agricultural modernization [5]. However, the phenomenon of non-grain cultivation driven by interests has become increasingly serious in China in recent years. The non-grain in cultivated land (NGCL) has changed the mode of land use and the factor allocation of agricultural production, resulting in enormous hidden losses in grain productivity that exceed those caused by farmland conversion explicitly [6,7]. NGCL has threatened the national food security, social stability and sustainable development of agricultural systems. Additionally, the process of NGCL reflects the practical problems of intensified human–land conflict, single functions, lower benefits, and rigid systems in agricultural space [8]. Therefore, to promote rational use of agricultural space, the influence mechanism of NGCL on the sustainable development of agriculture should also be explored. Clarifying the internal logic of NGCL governance is also important to promote high-quality development of agricultural space and ensure food security.

A key principle of Chinese national food security is food self-sufficiency based on domestic grain production, which requires adjusting governance to local conditions and coordinating food security and production factors [9,10]. Moreover, the bottom-line mind and protection priority idea emphasized in territorial spatial planning coincide with the food security idea of China—that is, staying above the red line of 120 million hectares of total farmland [11,12]. In reality, a strict agricultural land use control requirement of China's territorial spatial planning has provided institutional constraints for strengthening the control of general cultivated land and permanent basic farmland [13]. Meanwhile, a "production-living-ecology space" concept and scientific layout have contributed to the high-quality development of agricultural space in territorial spatial planning [14]. Therefore, starting from the unified governance of all factors advocated by the territorial spatial planning, the concepts of agricultural development resilience (ADR) are endowed in this research. Further, ADR refers to the ability to maintain existing characteristics and key functional structures for adaptation, risk response, and internal recovery while digesting and absorbing external disturbances [15,16]. This concept of resilience was learned from many fields. For example, in the field of engineering the system resilience is the ability to recover after resisting the external system influence [17]. The resilience system refers to a system whose structure, function, and service are destroyed and damaged by influence in the field of ecology [18]; the resilience is based on the skills of tracking learning, using, and managing changes in the field of social ecology [19].

Analysis of NGCL's impact on ADR is intertwined with its impact on cultivated land use mode and production factor allocation. Existing studies have focused on the classification of NGCL types [20], spatial characteristics [21], driving mechanism [22], and its impact on cultivated land protection [15], food production [23], and food security [21,24]. For example, the relationship between NGCL and the changes in production factors and the price market of agricultural products was investigated using the different performances of NGCL in agricultural production practice. Some studies have argued that the higher relative price of labor causes the "non-grain" of planting structure [25]. The lease stability in land transfer lease period dimension and lease instability in market dimension induces the "non-grain" planting behavior of farmland transfer to households [26]. The farmland transfer price increases the probability and ratio of "non-grain" planting [27], and the farmers with small scale transfer are more inclined to "non-grain" planting structure [28]. The agricultural land transfer area and "non-grain" planting ratio forms into an inverted "U" relationship [29]. In addition, beyond the reason of lower benefit to growing grain, NGCL is also closely related to the level of factors and allocation in farmers' grain production [30]. Factors such as the fragmentation of cultivated land [31], farmers' labor endowment [30], social capital and so on are all driving factors of "non-grain" production expansion. Additionally, different types of NGCL have different effects on the quantity, quality, and ecological environment of cultivated land in addition to destroying the plow layer [28,29,32]. There has also been discussion of the impact of NGCL on farmland flow loss and negative externalities [33], and the interaction theory and analytical frameworks have also been referenced [32,34].

From the existing research, there is no consensus on the criteria for NGCL governance. Although high-resolution remote sensing is helpful for identifying the current situation of NGCL [35], no logic and basis is in place for the governance of NGCL problems and seasonal planting structure adjustment around large cities. Chinese territorial spatial planning should promote the high-quality development of agricultural space, not only should land quantity and factor allocation be considered, but also the effects of factor space flow, agricultural production structure, management mode, and regional industrial structure [36]. Under the changes in labor flow and market environment, the relevant studies have focused more on the relationship between NGCL and production factor allocation in micro farm households [25,30]. However, NGCL has not been examined from the perspective of the allocation of production factors systemically. It is not conducive to clear the intensity and direction of "non-grain" governance. Thus, clarifying the systematic relationship between NGCL and the factor allocation of agricultural production in micro-household and macro-industry is particularly meaningful. Exploring the response mechanism of NGCL to agricultural sustainable development based on allocation of production factors in this research is also important.

Strictly preventing the "non-grain" trends of cultivated land in major grain-producing areas is very important to ensure national food security [20]. In the main grain-producing areas of Northeast China, agricultural production structure renewal, scale management, land circulation, and agricultural mechanization are relatively higher, but the rural young and middle-aged labor force is lacking; population growth is slow. The situation of cultivated land protection has been very serious. Based on this background, the micro-household livelihood and macro-allocation of agricultural production factors have overlapped in space. The problem of "non-grain" governance has become urgent. In terms of the realistic conditions of abundant cultivated land resources and complex rural social problems in the area above, the specific goals of this study were to: (1) analyze the level of NGCL in the study area from 2011 to 2020, as well as its spatial and temporal characteristics; (2) evaluate the ADR in line with combining the agricultural production practice, and explore the impact of NGCL level on ADR; (3) analyze the impact of the change trend of NGCL on ADR and its policy implications. The research results will not only provide reference for clarifying the standards of NGCL governance and improving the mechanism of NGCL governance, but also help to promote the transformation of rural households livelihoods, and improve their ability and efficiency to cope with changes in the external environment.

2. Theoretical Analysis Framework

The improvement of agricultural production efficiency, green development, and sustainability of economic development are the key points of agricultural development system [37]. In food production, the improvement of agricultural production efficiency is the basis for increasing farmers' income and ensuring food supply. Agriculture green development reflects the allocation level of agricultural production factors. Agricultural pollution reduction and land fertility maintenance are conducive to the sustainable development of agriculture. Arable land and its social security function, which facilitates the agricultural infrastructure input and the agricultural machinery promotion, contributing to the sustainable development of the agricultural economy [15,38]. The ADR, as the expression of agricultural supply and sustainable development level, connects the factor allocation of macro agricultural production with the micro farmers' cultivated land use behavior.

In agricultural spatial factor allocation, the external environment of agricultural development system includes the policy system and regional industrial structure. They restrain the ability and level of agricultural development system to resist external interference. Additionally, when human capital scale and quality interact with agricultural development system, they are not only subject to the scale stress of agricultural development system but also restrict the changes in ADR. Social capital is the crucial connection between household livelihood and agricultural spatial factor. In this way, grain demand and supply determine the agricultural development space of the main grain-producing areas, which represents the allocation of factors in terms of farmer and industry. Grain demand and supply determine the agricultural development space of the main grain-producing areas, which forms a space system represented by the allocation of factors in terms of farmer and industry (Figure 1).

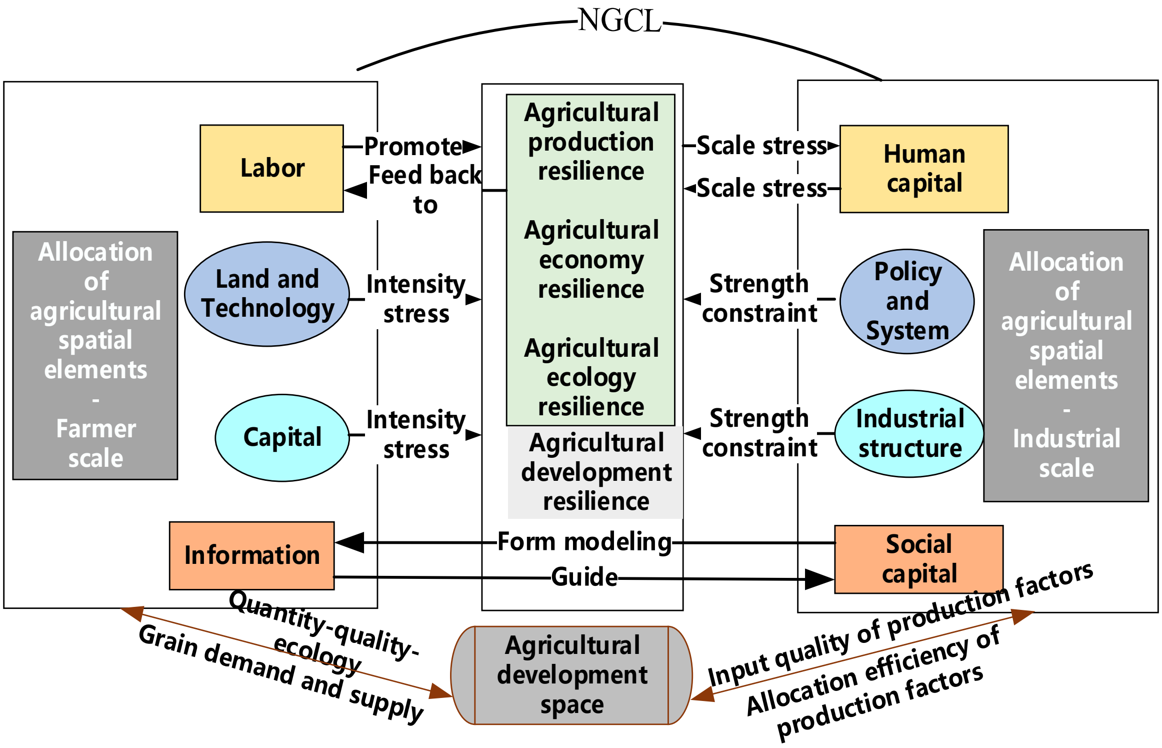

Figure 1. NGCL and its interactive relationship with ADR based on the allocation of agricultural spatial factors.

On the farm household scale, NGCL results from reallocating production factors such as land, labor, information, and family capital. A farmer's long-term income is determined by the free flow of production factors among region and the optimal allocation of it within the household [39]. According to Schultz's rational smallholder theory extended by Popkin, small farmers make decisions according to their own preferences and values [40]. Farmers' decision making in planting behavior is uncertain due to the heterogeneity of their families in different family life cycles, genetic relationships, and changes in rural social structures. The factor input of cash crops is quite different from that of grain planting. The former faces extra input of labor, technology, and capital, whereas vegetable greenhouses and short-term cash crops can avoid the adverse effects of climate factors and natural disasters on crop planting income [13]. In reality, the comparative income of growing grain is low, and the land transfer market is imperfect. In a short time, improving farmers' family welfare by increasing grain income and promoting land transfer is extremely difficult due to the limited technological advances and relatively fixed channels of information dissemination. Labor and land are the main production factors in household decision making. Therefore, labor mobility and the change in cultivated land use mode have become important considerations for farmers' NGCL behavior.

On the industrial scale in the macro policy system, "grain-oriented" is the main orientation of agricultural policy [22]. Differences exist in the implementation effect of different policies: the minimum purchase price of rice has strengthened the behavior of large rice growers toward grain [41]. Agricultural support and protection subsidies have significantly expanded the grain planting area of large-scale farmers, with no effect on their planting structure [42]. In underdeveloped areas, land transfer is one of the paths to increase agricultural income [43]. The transfer of farmland has released a certain amount of surplus rural labor force, which flows more to the urban and non-agricultural sectors and enriches the employment channels and rates of rural labor force. In regard to the adjustment of agricultural production structure and the moderate scale management of farmland, the expansion of farmland transfer scale somewhat improves the efficiency of cultivated land use [44]. However, the expansion of land operation scale is often accompanied by higher land rent, as well as natural and market risks of agricultural production, which may not advance high-quality agricultural development. Technical factors, such as agricultural mechanization degree and agricultural industrialization level, have a positive “co-group effect” on the positive influence of food production [38]. In reality, the government support often in underdeveloped areas for agriculture is limited and agricultural technology diffusion is relatively lagging behind. In addition, the traditionally advantageous industries occupy the core position in such areas. The new industries develop slowly, social capital is adequate, and agricultural employers’ mismatch problems exist where factors of production are not allocated rationally.

The ADR can be further divided into agricultural production resilience, economic resilience, and ecological resilience. Agricultural production resilience refers to the resilience of agricultural production system to withstand risks, which is mainly affected by the level of technology and agricultural infrastructure. In the context of limited progress in agricultural production technology, the comparative returns of grain production are lower and the risk of grain price is higher under the fluctuation of factor prices. Moreover, farmers’ production has a large efficiency loss, especially the distortion of production factor allocation [45]. Farm household labor allocation drives agricultural production resilience, and agricultural human capital constrains agricultural production systems and influences farm household labor allocation decisions through the agricultural production system. Meanwhile, the change in social capital, information transmission and social network affects the allocation behavior of household production factors [46]. Farmland use changes are caused by “non-grain” behavior, which results in the disturbance of agricultural production systems. It also acts on the scale and quantity structure of agricultural human capital while regulating the resilience and resistance of agricultural production system to resist external risks. Agricultural economic resilience refers to the ability of farmers or agriculture to cope with economic shock risks. NGCL in urban suburbs or economically developed areas facilitates the extension of agricultural industry chains and increases in “value added” of agriculture [34]. In the process of “non-grain” production, the accumulation of human capital block the inter-generational transmission of household poverty in a short time, while somewhat alleviating the livelihood problems of farmers in relatively poor areas [47]. However, when spontaneous land use behavior lacks productivity and normative characteristics, the adaptability and recovery of agricultural economic systems are affected. Different policy contents and intensities integrate agricultural economic development and interact with farm household land use levels, household capital inputs, and the adoption of agricultural technologies in the agricultural economic system. Agricultural ecological resilience represents the ability of agricultural development systems to withstand changes in the natural environment. Planting cash crops increases agriculture’s resilience and elasticity to climate change, but cultivated land has its priority in serving food production. Farmers’ spontaneous adjustment in planting structure may lead to soil acidification or salinization differently, and the different irrigation and drainage facilities also affect the cultivated land system. Because of this, some studies have concluded that in major grain-producing regions, the arable land has increased and its ownership has become more stable, but the agricultural production remains low [48]. This suggests that the structure of cropping or agro-industrial imposes constraints on the agroecosystem together with the capital inputs of farm household.

3. Materials and Methods

3.1. Study Area

Heilongjiang, Jilin, and Liaoning provinces, as important grain-producing areas in Northeast China, are located in the middle and high latitudes (118°53′ E–135°05′ E, 38°43′ N–53°33′ N). The flat terrain has fertile black land, unique natural location advantages, and the monsoon climate of medium latitudes. Three provinces in Northeast China are important grain production bases, with the highest per capita grain commodity rate (See Figure 2). It has 29.90 million ha of arable land and 143.28 million tons of grain production, accounting for 20.87% of the country's total in 2022. They are the best places in China to operate at a moderate scale. In 2016, the area of cultivated land transfer reached 6.93 million hm^2, accounting for 21.70% of the total. The number of farmers with a family operation scale of 13.33 hm^2 or more accounted for 37.20% of the proportion in China [49]. However, the urbanization rate of resident population in the area exceeds 60%. With a small increase in labor force and a continuous decline in flow rate, regional economic development has been sluggish in recent years, and the volatility of cash crop sown areas has increased. Three provinces in Northeast China are the typical areas with abundant cultivated land resources, regional poverty, insufficient labor quality, and a high level of land transfer and large-scale operation. clarifying the direction and intensity of NGCL governance in these areas is of great significance to protect cultivated land and ensure national food security.

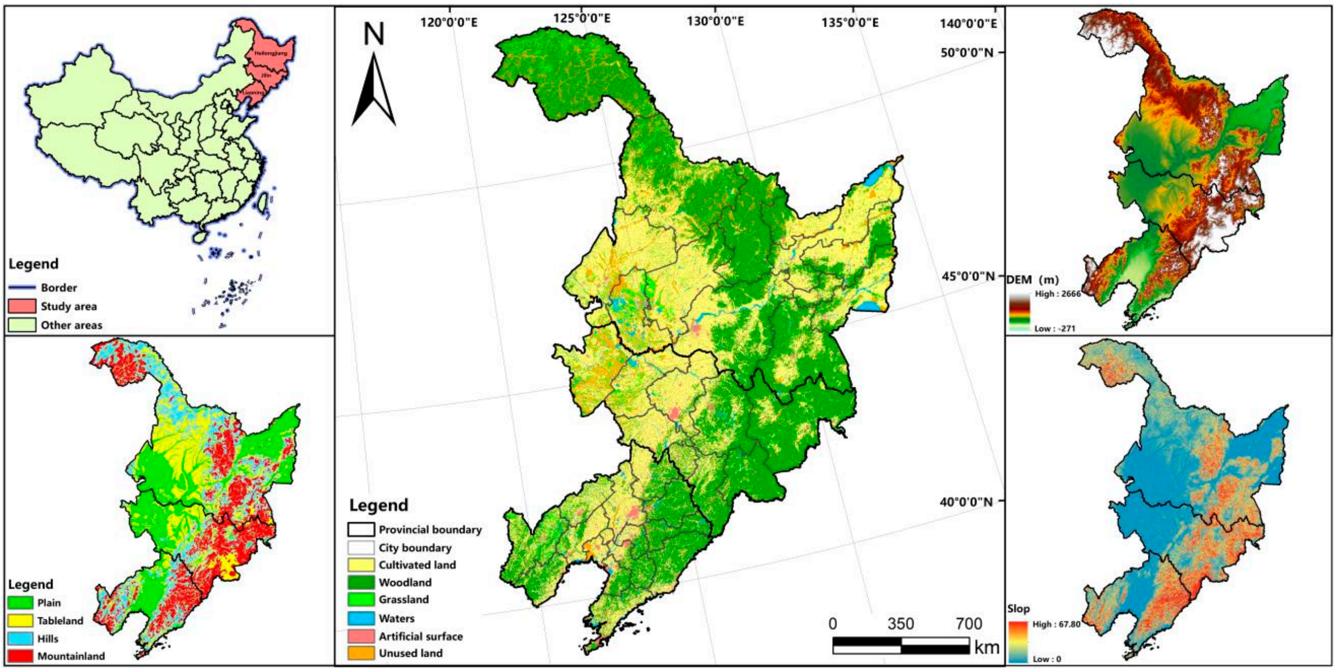

Figure 2. Location of the study area. Source: Figure 2 is drawn by ArcGIS 10.2, the topographic data, geomorphological data, and land use data involved in the map are from the National Earth System Science Data Center of China.

3.2. Data Source

This study involves data from the CEIC Economic Database and Prospective Database, Statistical Yearbooks of Heilongjiang, Liaoning, and Jilin provinces and their prefecture-level cities of China from 2010 to 2021, Statistical Yearbooks, Economic and Social Statistical Yearbooks, Statistical Communiqué of National Economic and Social Development of 35 prefectural-level cities in the study area (excluding the Da Hinggan Ling Prefecture and the state farm), as well as local government departments. The economic data had been processed for eliminating of inflation. The agricultural output value has been replaced by the output value of the primary industry when considering the availability of data.

Individual missing values were supplemented by random forest algorithm [50]; a total of 8% of missing values were compensated. Relying on the algorithm's good classification accuracy, the multiple decision trees were constructed to fill the missing values. The randomness and uncertainty of filling data were clarified, and the real distribution of unknown data were reflected. Therefore, the accuracy and reliability of filling values were ensured [51,52].

3.3. Methods

According to the theoretical framework, the process of NGCL affecting ADR is constrained by labor force, cultivated land production scale and other factors; the influence may show a nonlinear relationship. In econometrics, the threshold effect models are often used to study nonlinear patterns in panel data [53]. It not only realizes the purpose of grasping the operation mechanism of the network macroscopically, but also concretely helps investigate microscopic conditions of the nodes. The panel threshold model explores the relationship between dependent and independent variables more precisely than the linear model, which is particularly important for informing policy makers. Therefore, the threshold panel model was established in this study.

In addition, considering the lag of agricultural spatial production factor flow and farmers' planting behavior, exploring the impact of development trend of NGCL on the ADR has better significance. The spatial econometric models represented by the spatial durbin model, the spatial error model, and the spatial lag model have greater advantages for preventing the endogeneity of spatial spillover effects and examining the spatial spillover direction of the impact effect. They can also provide reference for improving the spatial synergistic governance mechanism of arable land use. The spatial error model established is the result of statistical test selection.

3.3.1. Panel Threshold Model

The panel threshold model explains the phenomenon that when one parameter reaches a specific value, it causes another parameter to undergo a sudden shift to other forms of development. The critical value that causes the shift is called the threshold value. One or more threshold levels can be generated in the threshold effects model, thus classifying the data into two or more regimes depending on the threshold level [54]. Significant differences exist in the changes in ADR caused by NGCL in different threshold values. The development of the panel threshold model consists of three steps: hypothesis, estimation, and test. Firstly, the null hypothesis that there is no threshold is: Ho: both coefficients are the same, while constructing the LM statistic. According to Hansen's [53], the calculation formula of the model is as follows.

$$\ln res_{it} = \beta_0 + \beta_{11} \ln rngc_{it} d(q \le \lambda_i) + \beta_{12} \ln rngc_{it} \times d(q > \lambda_i) + \sum_{k=2}^{4} Z_{kit}\beta_k + \varepsilon_{it} \quad (1)$$

where, res_{it} and $rngc_{it}$ are the ADR and NGCL level of the ith city in the tth year, respectively. q and λ_i are the threshold variable and threshold value. The relationship between q and λ_i is the variable of elasticity coefficient of NGCL level affecting the change of ADR. $d()$ is the indicator function, ε represents the error disturbance term, Z_{kit} is a set of control variables, and β_1 and β_k are estimated coefficients of explanatory variables.

Generally speaking, apart from the external factors of the economic system, the labor force quality and the agricultural operation scale are the most significant variables affecting the allocation of production factors in theory. The effect of policy intervention and the role of market in resource allocation are beneficial tools to improve the mismatch in production factors. Thus, in this study, cultivated land per labor force, NGCL level, proportion of agricultural laborers (refers to the proportion of agricultural employees in the total population), and agricultural machinery per capita were selected as alternative threshold variables. Among them, the cultivated land area per agricultural practitioner reflects the agricultural production level and the actual situation of agricultural production [54]. The proportion of agricultural employees represents the scale of regional agricultural labor force, and it somewhat reflects the level of regional agricultural labor force. Thus, the three variables above represent the quality of agricultural production factors. Furthermore, an alternative threshold variable was selected for analysis to express the threshold characteristics of the direct impact of the NGCL level on ADR.

To eliminate individual fixed effects in panel data, the software Stata 17 is used, and hypothesized threshold variables are estimated. The variables passing the significance test are further analyzed based on a bootstrap method. The principle of this method is to obtain a self-sampling sample by simulating a sequence of dependent variables that meet the standard distribution, followed by a simulated LM statistic. The simulation process is repeated 1000 times, and the p-value in the statistical test is obtained when the LM statistic generated by the simulation is greater than the proportion of the given number of times to the total number of simulations, resulting in a meaningful threshold variable [55]. In addition, the exact number of thresholds needs to be confirmed separately. After the first threshold is estimated, the second threshold is then searched for. After two thresholds are determined, a third threshold is found, in the same way as before, until the null hypothesis cannot be rejected. The parameters of each variable in model are also estimated by ordinary least squares (OLS) and so on, combining with robustness tests.

3.3.2. Spatial Lag Model

NGCL variation has disturbance effect on agricultural development system, and regional agricultural development often has spatial correlation and dependence. Therefore, the estimation results that ignore spatial spillover effect inevitably have result bias [56]. Owing to the influence of farmers' planting experience and production inertia, while investigating the factor flow, it is necessary to analyze the possible spatial spillover characteristics of the impact of NGCL on ADR from the perspective of change trend. Therefore, based on the consideration of the lag and path dependence characteristics of ADR, a spatial lag model was established with the spatial spillover of ADR based on the statistical test selection.

$$\begin{aligned} \ln res_{it} &= \beta_0 + \rho \sum_{j=1}^{n} W_{ij} \ln res_{it} + \beta_1 \ln rngc_{it} + \sum_{k=2}^{4} Z_{kit}\beta_k + \mu_{\mathrm{i}} + \varepsilon_{it} \\ & i = 1,2,\ldots,N,\ \mathrm{t} = 1,2,\ldots T \\ \ln res_{it} &= \beta_0 + \beta_{11} \ln rngc_{it} d(q \leq \lambda_i) + \beta_{12} \ln rngc_{it} \times d(q > \lambda_i) + \sum_{k=2}^{4} Z_{kit}\beta_k + \varepsilon_{it} \end{aligned} \quad (2)$$

where, β_0 is the intercept term, ρ is the estimation coefficient of spatial lag term of ADR, $W_{ij} \ln res_{it}$ is the corresponding spatial interaction effect, μ_{i} is the individual fixed effect, ε_{it} is the time fixed effect, the other variables are the same as Equation (1).

The application of the spatial lag model generally consists of the following four steps [57]:

(1) Defining the adjacency relations and establishing the weight matrix. The geographical distance affects the sharing and rational allocation of agricultural technology and knowledge resources. Thus, the geographic weighting matrix was established before estimating the model parameters [58]. The geographical distance weight matrix was chosen as follows.

$$W_{ij} = 1/d_{ij}, (i \neq j), W_{ij} = 0, (i = j) \quad (3)$$

where, d_{ij} is the surface distance of the study area calculated by longitude and latitude position;

(2) Testing the spatial autocorrelation of variables (based on the GeoDa V1.20);

(3) Performing ordinary linear regression to detect residual autocorrelation;

(4) Running the spatial regression model by using on the software Stata 17.

3.3.3. Variable Explanation and Description

1. Dependent variable: ADR. Based on existing research and theoretical analysis [21,54,59], an indicator system, including agricultural production resilience, economic resilience, and ecological resilience, was established as Table 1.

Table 1. The indicators system of ADR.

Object Level	System Level	Weights	Indicators	Calculation Method	Weights
ADR	Agricultural production resilience	0.3070	Proportion of effective irrigation area	Effective irrigation area/cultivated land area	0.1910
			Total power of agricultural machinery per area	Total power of agricultural machinery/Sown area	0.1278
			Fixed-asset investment per agricultural labor	Fixed-asset investment/Number of agricultural labor	0.6812
	Agricultural ecological resilience	0.2117	Pure amount of chemical fertilizers applied per area	Pure amount of chemical fertilizers/Sown area	0.3171
			Amount of pesticides applied per area	Amount of pesticides applied/Sown area	0.2392
			Agricultural water consumption per area	Agricultural water consumption/Sown area	0.4437
	Agricultural economic resilience	0.4813	Total agricultural output value per agricultural labor	Total agricultural output value/Number of agricultural labor	0.2877
			Total agricultural output value per area	Total agricultural output value/Sown area	0.1447
			Output value of fixed-asset per area	Output value of fixed-asset/Sown area	0.5676

The effective irrigation area, total power of agricultural machinery, and fixed-asset investment reflect the role of agricultural infrastructure and the production factors' quality in improving the agricultural production resilience. The pesticide and fertilizer inputs and agricultural water use reflect the efficiency of water resources use and the effects of chemical inputs on agricultural ecological environment. The total agricultural output value per farmer, total agricultural output value per cultivated land area, output value of fixed-asset per cultivated land area are to deal with agricultural finance and other risks and agricultural economic development efficiency measurement.

2. Explanatory variable: NGCL. In the threshold effect model, from the perspective of planting system, data availability, and allocation of agricultural production factors in the study area, the rate of "non-grain" of cropland ($rngc_1$) was taken as the explanatory variable and the "non-agricultural crop sown area/crop sown area" was used to characterize the NGCL level. In the spatial lag model, according to the influence of farmers' planting inertia, planting experience, and rural social network relationship, the NGCL trend was taken as the explanatory variable; the change rate of NGCL was adopted to measure it.

$$rngc_2 = \left| \frac{S_{nt}}{S_t} - \frac{S_{nt-1}}{S_{t-1}} \right| \quad (4)$$

where, S_{nt} and S_{nt-1} are the sown area of crops in year tth and year $(t-1)$th, respectively, and S_t and S_{t-1} are the non-grain crops (cereals, tubers, etc.) sown area in year tth and year $(t-1)$th, respectively.

3. Control variables: to promote the robustness of the estimation result, the industrial structure *is*, local general public budget expenditure lg*pbe*, and grain output *gp* were selected as control variables in the models referring to existing studies [54,60]. The industrial structure refers to the structure of regional tertiary industries, which is represented by the proportion of the added value of the primary industry to the gross regional product. All other variables except the ratio were treated with logarithms.

4. Sample overview: the 35-prefecture-level cities in the study area formed a sample of 350. The mean and standard deviation of relevant indicators for samples are shown in Table 2.

Table 2. Sample indicators overview.

Sample Indicators	Mean	Standard Deviation
ADR	237.1336	152.2365
NGCL level	0.1172	0.0087
NGCL trend	1.1912	1.6277
Grain output (tons)	3,522,923.3260	3,468,554
Local general public budget expenditure (million Yuan)	2,978,139	2,371,077
Industrial structure	0.1823	0.1238

4. Results

To analyze the impact of NGCL on ADR, the level of NGCL was calculated in the study area from 2011 to 2020, as well as the impact mechanism of NGCL on ADR from two aspects: the impact of NGCL level on ADR and the spatial effect of NGCL trend on ADR.

4.1. Level of NGCL in Study Area during 2011–2020

In time sequence changes, the NGCL level in the three provinces of Northeast China showes an upward followed by a downward trend during 2011–2020. In terms of temporal–spatial differences, the NGCL level of Liaoning Province is the highest, followed by Jilin and Heilongjiang provinces (see Figure 3).

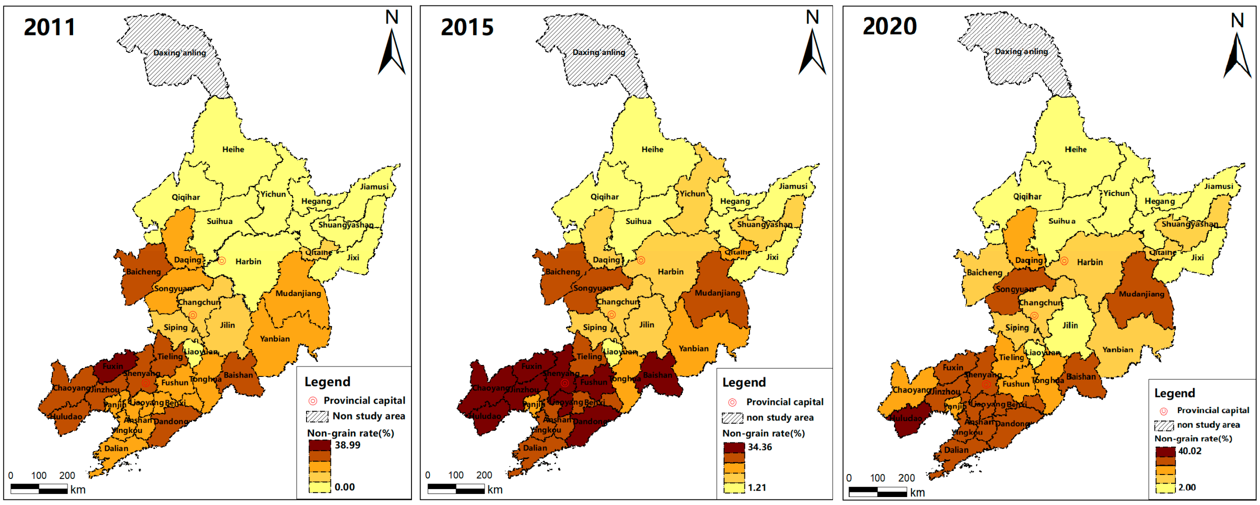

Figure 3. The level of NGCL in the study area in 2011, 2015, and 2020.

The level of NGCL is relatively high in cities, surrounding areas, and coastal areas, such as Dalian City, Huludao City, and Shenyang City, due to the quality and location of cultivated land. The labor cost is higher in developed areas, and the problem of large-scale migration of rural labor force is more common. In land factor endowment, the quality of cultivated land in Sanjiang Plain and Songnen Plain is better and the scale management level is higher, which inhibited the expansion of NGCL production.

Specifically, the higher level of NGCL in the study area in 2011 is in coastal areas or areas with convenient transportation such as around large cities. Agricultural products can be more easily marketed and transported because of better accessibility, enabling farmers to grow higher-yielding cash crops. In particular, Fuxin City in Liaoning Province, as an important transportation node city in Northeast China, has reached a level of 38% for NGCL. Before 2015, a demand-side agricultural management mode focused on quantity, total volume and short-term goals was implemented in China. The NGCL was further deepened in 2015 owing to inadequate grain cultivation subsidies, low subsidy standards and insufficient infrastructure inputs such as farmland water conservation. After 2015, agricultural supply-side reforms focused on efficiency, structure, and quality of factor inputs. The structure of grain cultivation subsidies was optimized, and the land transfer and moderate scale agricultural operations were strongly promoted, which stimulated grain crop cultivation in plains.

4.2. Impact of NGCL Level on ADR

Combined with the Hausman test (Statistic = 188.91, Prob > chi2 = 0.0000), the fixed effect model was selected. The software Stata17 was used to test the significance of a single threshold, double threshold, and triple threshold of four alternative threshold variables (Table 3).

Table 3. Detection results of alternative threshold variables.

Variables	Single Threshold		Double Threshold		Triple Threshold	
	LR_F	LR_P	LR_F	LR_P	LR_F	LR_P
Cultivated land per labor force ($clplf$)	49.15	0.0000	4.01	0.8600	3.31	0.8667
Rate of non-grain of cropland ($rngc_1$)	4.23	0.963	4.84	0.8900	6.09	0.7833
Proportion of agricultural laborers (pal)	18.58	0.0300	20.33	0.0500	6.30	0.5500
Agricultural machinery per capita ($ampc$)	10.86	0.3467	7.35	0.4867	8.12	0.6167
N	350		350		350	

The results in Table 3 showed that the variables of $clplf$ and pal passed the single threshold test of 5%, whereas the threshold test results of $rngc_1$ and $ampc$ were insignificant. Therefore, the $clplf$ and pal were selected as the threshold variables. OLS was used to estimate the regression model parameters with different threshold variables (Table 4). OLS is a mathematical optimization technique; its principle is choosing a set of parameters of a linear function of the explanatory variables, and minimizing the sum of squared residuals between the dependent variable (the predicted variable) and the predictor variable observed in a given data set. This method easily facilitates determining the parameters to be estimated and minimizing the sum of squared residuals for all observations.

Meanwhile, the time-space dual fixed effect Model (1) was established, and Model (2) without control variables and Model (3) with control variables were also built (Table 4). The regression result of Model (1) showed that NGCL has a positive and significant effect on ADR, which was higher than the results of other models. The regression results of Models (2) and (3) showed that the impact of NGCL on ADR was further increased after adding control variables with basically similar threshold characteristics. It indicated that the regression result of Model (3) was basically robust.

Table 4. Model robustness test and threshold effect estimation results.

Variables	Model (1)	Model (2)		Mode (3)	
	Fixed Effect	*pal* (λ_0 = 0.0980)	*clplf* (λ_0 = 2.0340)	*pal* (λ_0 = 0.0707; λ_1 = 0.0980)	*clplf* (λ_0 = 2.0340)
$\ln rngc_1(q \leq \lambda_0)$	-	−0.0094	0.6353 **	−0.1618 **	0.4623 *
$\ln rngc_1(\lambda_0 \prec q \leq \lambda_1)$	-	-	−0.1651	0.0302	−0.2304
$\ln rngc_1(q > \lambda_1)$	-	0.1037 ***	-	0.0742 **	-
$\ln rngc_1$	0.1602 *	-	-	-	-
$\ln lgpbe$	−0.0847 *	-	-	−0.0742 *	−0.0792 *
$\ln gp$	−0.1217 *	-	-	−0.0725	−0.1661 **
is	−0.4977 *	-	-	−0.5137 *	−0.5037 *
cons	8.5337 ***	-	-	7.6871 ***	8.8637 ***
R^2	0.3506	0.3335	0.3258	0.4130	0.4830

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Furthermore, the regression results showed that in the study area, NGCL had no negative influence on ADR from 2011 to 2020. According to the study, the NGCL in Northeast China may have been driven by changes in planting trends and changes in residents' diets, which somewhat encouraged rational allocations of agricultural production factors. As far as the threshold regression results, due to the scale of regional agricultural labor force, a threshold effect occurred on the impact of NGCL on ADR. The influence of NGCL on ADR had a significant negative effect when it was less than 7.07%. When the proportion was higher than 7.07% and less than 9.80%, the effects had a positive recessive cumulative effect, when the proportion was greater than 9.8%, the influence had a dominant accelerating effect. The regression result with $clplf$ as the threshold variable showed that the occurrence of NGCL had a significant positive effect on ADR, when the $clplf$ was less than 2.034 ha. Meanwhile, the $clplf$ was larger than a certain scale, the effect showed an invisible negative accumulation feature. According to the estimated results of the control variables, the local general public budget expenditure, grain output, and industrial structure all had negative effects on ADR (Table 4).

4.3. Impact of NGCL Trends on ADR

Prior to the establishment of the spatial panel model, the moran index was used to analyze the spatial effect of ADR. The software GeoDa V1.20 was used to calculate the spatial auto-correlation index. The analysis results showed that in the study area, the spatial auto-correlation index of ADR from 2011 to 2020 was between −1 and 1; all of them passed the significance test of 5% (Table 5), indicating a spatial correlation of ADR.

Table 5. Moran Index of ADR 2011–2020.

Time	Moran's I	*p*-Value	Time	Moran's I	*p*-Value
2011	−0.049	0.0199	2016	−0.045	0.0425
2012	−0.049	0.0201	2017	−0.048	0.0252
2013	−0.049	0.0196	2018	−0.048	0.0198
2014	−0.048	0.0340	2019	−0.048	0.0193
2015	−0.051	0.0144	2020	−0.047	0.0235

Combined with LM test (F = 19.95, p-Value > F = 0.0000) and spatial auto-correlation analysis, the spatial panel model was selected. Based on the Hausman test (Statistic = 14.61, p = 0.0122), individual fixed effect test (F = 178.35, Prob > F = 0.0000), and time fixed effect test (Statistic = 1271.99, Prob > F = 0.0000), the spatial durbin model with both time and space fixed was established. The spatial lag model (SLM) was established according to the LR test based on software Stata17. To avoid the endogenous problems, the model parameters were estimated by the maximum likelihood method. Table 6 shows the estimation results of SLM and the analysis results of spatial spillover effect.

Table 6. SLM estimation results and spatial effect analysis.

SLM Estimation Results				Spatial Effect Analysis			
Variables	Estimation Coefficient	SE	p	Variables	Direct Effect	Indirect Effect	Total Effect
$\ln rngc_2$	−0.0440	0.0200	0.028	$\ln rngc_2$	−0.0442 **	−0.0442	−0.0884 *
$\ln lgpbe$	0.2823	0.0485	0.000	$\ln lgpbe$	0.2865 ***	0.2878 *	0.5743 **
is	0.4162	0.2235	0.063	is	0.4219 *	0.4130	0.8349 *
$\ln gp$	−0.0243	0.0501	0.628	$\ln gp$	−0.0242	−0.0239	−0.0501
ρ	0.4766	0.1163	0.000	R^2		0.3677	
$LogL$		315.7757		N		350	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SLM estimation results showed that the spatial effect of ADR was 0.4766. The influence of the NGCL trend on ADR was negative and significant at the 5% level without spillover effect, and the overall effect was negative and significant at the 10% level. The effects of $lgpbe$ and is on ADR were positive and significant, but only the spillover effect and total effect of $lgpbe$ were positive and significant.

5. Discussion

5.1. Changes in the Level of NGCL

NGCL trend changes may be related to the cancellation of temporary purchase and storage price policy of maize and soybeans after 2016, and the change in the food policy of market-oriented purchase and producer subsidies in the study area. In addition, the NGCL level is relatively low in areas with higher levels of scale operations and mechanization. Naturally, this phenomenon is also related to transportation accessibility, topography, and geographic location. This finding is consistent with the study of Kong [21]. Referring to the study by Song [61], one of the other objective reasons is that the alternative crops at the high latitude area are fewer. Specifically, the Chinese government maintains that in the main grain-producing areas, the principle of using the grain-growing land to grow grain should be adhered to and grain-growing property should not be changed [62]. In underdeveloped areas, the conflict has inevitably occurred between the lower benefit of grain cropping and some realistic problems of high surplus rural labor force. Furthermore, in terms of planting operation subjects, the higher level of scale operation areas inevitably has a considerable number of family farms or large grain growers. Their behavioral decisions are not only guided by the market logic of low cost, high income, and low risk, but also depend on the practical conditions of the scale operation effect and mechanization level brought by planting. Although cash crops have a high rate of return, owing to the constraints of labor force and climate, the agricultural insurance premium is relatively low. Therefore, predicting the orientation and mechanism of planting behavior for them is difficult. Many studies have focused on the NGCL governance in the more developed regions [24,34]. However, the "non-grain" governance of areas with advantages in food production is inseparable from ensuring the bottom line of grain planting quantity, stimulating farmers' motivation for growing grain and reducing the cost and risk of production, which is consistent with Song's [33].

The changes in planting structure in Northeastern China suggests that the demand-side-oriented agricultural management mode has been somewhat ineffective in reducing NGCL. As the food consumption structure of residents continues to upgrade, the cultivation of cash crops also increases. The decline in the level of NGCL after 2015 suggests that the agricultural supply-side structural reform with direct government intervention in structural adjustment has a positive effect on preventing the further deepening of NGCL in China. The clearer policy orientation is conducive to optimizing the structure, quality, and efficiency of agricultural factor inputs [63]. Furthermore, the policies related to NGCL management should also take objective factors into account such as regional resource endowment conditions, development differences, and the characteristics of agricultural production [64]. In most studies on the governance of NGCL, the administrative management system, rural public policies, and government performance assessment system have not been systematically discussed.

5.2. Impact of Level and Trend of NGCL on ADR

ADR in the study area was not negatively affected by NGCL, which suggests that the upgrading of food consumption structure may aggravate the current "non-grain" behavior. In general, the factor inputs are quite different in cash crops and cereal crops. The former faces additional factor input, such as labor, technology and capital, whereas vegetable greenhouses and short-term cash crop planting can avoid the adverse effects of climate changes and natural disasters on crop planting returns [65]. In line with relevant studies [66], it should be affirmed that in the short term, NGCL has positive implications for farm households' livelihoods because it may resist the market risk of grain price decline and the fluctuation of production factor price, partly optimizing the household labor allocation [66]. Meanwhile, NGCL reflects the adaptive behavior of interest subjects to the factor market changes, and the correlation among the game of different subjects at different stages in the agricultural development system. Specifically, in the early stage of "non-grain" behavior, the adaptability of the subject behavior to the changing of external environment (such as capital going to the countryside) is rapidly improved [67]. It can also realize the rapid optimization of resource allocation and structure function among factors, and the improvement of potential of agricultural development system. However, the occurrence of such a behavior trend may face the interference of external policies and the feedback of land use system [68]. The spontaneous adjustment of planting behavior lacks standardized and productive characteristics in the agricultural development system, which releases the factors' resilience and leads to the decline in ADR.

There is no spatial correlation between the influence of ADR on individual farmers, suggesting that information exchange and neighborhood effects do not have a significant impact on neighboring areas. This is in line with the convergence and short-term, individual economic behavior characteristics of farmers in terms of wealth and security [63]. Their decisions are based on perceived market environment risks and policy values based on their own family development ability and family life cycle [69]. There is some adjustment and trial and error involved in the allocation of household production factors for farmers. Such blindness and behavior inertia brought disturbance and risk to the agricultural development system, which is not conducive to the improvement of ADR. Considering the previous studies on cultivation culture [70], in terms of the agricultural production practices, typical planting decision-making behavior is widespread particularly in areas with a strong agricultural organization culture [71]. Therefore, in the face of the general environment of declining income from food cultivation and the upgrading of the population's food consumption structure, it is necessary to manage the potential risks of "non-grain" behavior.

Other studies have focused on the impact of labor size shift and land transfer on NGCL or sustainable agricultural development [25,72]. However, the moderating role of labor size and land have not been mentioned in the relationship between NGCL and agricultural development. The threshold effect regression indicates that agricultural practitioner scale constrains "non-grain" production, as well as the process of household and agricultural production factor allocation. When the proportion of agricultural practitioners is low, the labor-constrained "non-grain" behavior is somewhat blind. In addition to reducing the efficiency of cultivated land use, it enables high-concentration fertilizers and pharmaceuticals to be applied, consequently destroying the ecological environment for agricultural development [72]. When the proportion exceeds a certain scale, the "non-grain behavior and labor force size shows a proportional matching relationship. "Non-grain" employment or cash crop planting optimizes the allocation of agricultural household labor force and releases the rural surplus labor force. Reasonable factors input with sufficient labor force is conducive to promoting reasonable matching, which has a positive effect on the ADR. Similar to existing studies, the agricultural production under scale operation has the characteristics of productivity and standardization. Moderate scale management balances the low labor intensity of the "non-grain" production process, which helps the rational use of chemical fertilizers and pesticides [73]. When the proportion of family farms is high in regions with superior food production, NGCL is uneconomic with the expansion of scale operation. A greater demand exists for agricultural labor and infrastructure. For a long time, the large input of agricultural fertilizers and pesticides affect the agricultural ecological environment as well as price changes in labor and other production factors. It adversely affects agriculture's sustainable development.

The negative effect of grain output on ADR may be related to the excessive emphasis placed on grain production by local governments. Due to unreasonable competition among local governments, the financial expenditure on agricultural production environment management and farmland protection has been reduced. Under the constraint of agricultural production scale, the grain output has a more significant negative effect on the ADR. The expansion of food production exacerbates the risk of factor mismatch, which is accentuated by the governance environment that pursues food production excessively. Predictably, similar to Zhang's [74], the inter-regional public sector's synergistic governance improves due to the rational flow of agricultural production factors. By improving the internal resilience and external adaptability of agricultural development system, the surrounding cities will improve agricultural production efficiency and scale effect [38]. The rational allocation of industrial structure and coordinated governance among regions have created a favorable institutional environment for balancing the production, economic, and ecological systems of agricultural development, which enhances the ability of agricultural development system to withstand external risks and ADR. The estimation results of the control variables show that grain production is not a significant factor restricting the sustainable development of agriculture, and furthermore, that the one-sided pursuit of grain yield can bring hidden risks to the agricultural development system.

5.3. Policy Implications

In order to guarantee food security and manage the phenomenon of NGCL scientifically and orderly, a systematic governance mechanism should be established based on economic, organizational, social, and environmental perspectives. It is not just about strict planning and regulation [75], perfecting the land transfer market [30], and raising farmers' incomes [76]. As for NGCL governance in regions with superior food production, the economic resilience, societal resilience, organization resilience and environmental resilience of stakeholders can be consolidated with unified governance of agricultural production factors.

In terms of governance strength, improving the economic resilience and environmental resilience of stakeholders should be the focus. First, towns or rural areas can attempt to innovate agricultural development income models, such as village collectives and farmers' share cooperation system, multi-deposit union, and share equalization based on regional characteristic resources [30]. By guiding industrial and commercial capital investment and village collectives' dividend cooperatives in a reasonable manner, local governments can increase value-added income of agriculturally based industries. Second, the planters of functional areas for grain production make full use of comprehensive land consolidation to promote high-quality development of agricultural space, taking full advantage of the scale effect which is consistent with Chen's [20]. Apart from improving the agricultural infrastructure system, the agricultural industry environment and regional public governance environment should be actively optimized. Promoting the economic radiation and industrial transfer of the central cities in urban agglomerations is also important, as well as promoting the coordinated governance among regions. From the perspective of multi-agent governance, it is necessary to link the differences in the ability, willingness, and system of stakeholders in different environments. Considering the premise that the agricultural labor force is not reduced on a large scale, one must link the social security system, farmland protection system, household registration system, and other systems with the stability of different types for planting entities. and moreover, their mutual transformation trend should be clarified and targeted policies and measures should be put forward accordingly.

In the direction of governance, organizational resilience and societal resilience should be strengthened for stakeholders. To make up for organizational resilience, the management responsibilities of township governments can also be clarified. If the "non-grain" area of cultivated land exceeds a certain proportion, the relevant political performance assessment of responsible subjects should be tightened. The administrative subject can learn from the mechanical application of state-owned farms in China, such as improving the level of mechanical application in "non-grain" areas to improve the efficiency of average labor farming [77]. While actively guiding and regulating the allocation of production factors of peasant households, the layout of cultivated land utilization requires further optimization. In order to maintain fertile farmland and grain supplies, service scale operations should be improved. Additionally, step-by-step technical training activities, which are rich channels for information exchange and policy support tailored to local conditions for different business entities, can also be provided. In addition, strengthening the detailed policy design in terms of the subject of grain purchase, the source of funds, the object of purchase, and so on, is also important. The major grain-producing areas can prioritize grain reserves to large-scale grain-growing subjects to promote the circulation of grain while regulating the risk of grain planting by combining cash crops. In poor rural areas with complex social problems and serious population aging. The birth policy and social security policy can be optimized to support the migration of rural labor force from poor areas to nearby areas [78]. Through agricultural economic development and structural adjustment, regional employment growth can be promoted [79]. Moreover, the large outflow of population and young and middle-aged labor force can be alleviated by stabilizing the regional labor supply in order to optimize the scale and quality of agricultural employees.

In addition, to explore the impact mechanism of NGCL on ADR, the econometric approach relies too heavily on data statistical significance. The feasibility and prediction accuracy of the model requires further improvement compared with the complexity of agricultural production practices. For example, methods to integrate the training set, correct transition fitting problems, and improve prediction accuracy are lacking, as well as combining machine learning algorithms for cross-validation and integrating econometric models for validation.

6. Conclusions

As a trend for planting structure adjustment, NGCL somewhat responds to the changes of factor market demand. However, if the original equilibrium relationship between agricultural growers, the government, and other interested parties is broken, efficiency will be lost in the new game process, affecting the efficiency and quality of the agricultural development system. The ADR reflects the quality and efficiency of farm households and the allocation of agricultural production factors. Exploring the impact of NGCL on ADR provides an effective guide to explore the impact mechanism of changes in farmland use on sustainable agricultural development. From the perspective of farmers' household livelihoods and the allocation of agricultural production factors, this research clarified the impact mechanism of NGCL on sustainable agricultural development, which is beneficial to carry out the governance standards and mechanisms of NGCL in underdeveloped regions.

This study shows that the impact of NGCL on ADR is constrained by the size of the labor force size and farm-average arable land; indeed, it is not linear. Like the areas of Northeast China, where cropland is abundant but economic development is lacking momentum, land and labor are the main considerations in farm household decision-making. Therefore, establishing the NFP governance standards should consider the transformation of farmers' livelihoods and the optimization of production factor allocation. The integration of farm household livelihood transition and production factor allocation should be the basic guideline for improving regional NFP governance standards and governance mechanisms under the existing policy system, which needs to avoid the more organizational and institutional costs associated with the complex top-down governance mode.

In terms of spatial factor mobility in agriculture, NGCL trends to have a negative impact on ADR, which is characterized by long-term instability by directly affecting the allocation of production factors in the region. Promoting moderate scale operation and optimizing agricultural labor scale can be the specific paths for improving governance mechanisms of NGCL. The impact of NGCL on the ADR is the result of the combined effect of the allocation of production factors at the agricultural and farm household scales, this trend driven by interests is not conducive to improving the ADR. Strengthening the economic resilience, societal resilience, organizational resilience, and environmental resilience of stakeholders can be meaningful. In particular, popularizing moderate scale management and optimizing the scale of agricultural labor force are macro paths to govern NGCL in areas with abundant cultivated land resources and complex rural social problems in developing countries in the future.

Moreover, the expansion of agricultural production increases the risk of production factor mismatch, which is reinforced by the governance environment where food production is over pursued. A resilient risk management mechanism should be built and the "one-size-fits-all" governance strategy of NGCL must be abandoned. In the process of NFP governance, farmers need to improve their perception and awareness of macro and micro environmental influences, such as economic, social, cultural, and policy factors behind NFP behavior. The awareness and identification methods of risk should be increased for different farmers to help their adjustment of household production factors' allocation in a timely manner.

Additionally, this paper focuses on the impact mechanism of NGCL on ADR from the perspective of "non-grain" planting structure, but the types and manifestations of NGCL are not limited to this aspect. Therefore, the main direction of further research is to explore the impact paths and specific mechanisms of NGCL on sustainable agricultural development based on the specific reasons of NGCL, including the occupation of cropland for planting trees; building houses; digging lakes; building roads and new greenhouses; building new photovoltaic power or new landscape park; turning cropland into landfill or other agricultural facilities; and so on.

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Glossary

Term	**Definition**
NGCL	Non-grain in cultivated land
ADR	Agricultural development resilience
is	Industrial structure
lgpbe	Local general public budget expenditure
gp	Grain production
clplf	Cultivated land per labor force
ampc	Agricultural machinery per capita
pal	Percentage of agricultural laborers
rngc	Rate of non-grain of cropland

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