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Assessment and Comparison of Agricultural Technology Development under Different Farmland Management Modes: A Case Study of Grain Production, China

Hui Luo [1], Zhaomin Hu [2,3], Xiuping Hao [4,*], Nawab Khan [5] and Xiaojie Liu [2,*]

[1] School of Economics and Management (School of Co-Operatives), Qingdao Agricultural University, Qingdao 266109, China
[2] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[3] University of Chinese Academy of Sciences, Beijing 100049, China
[4] School of Water Resources, North China University of Water Resources and Electric Power, Zhengzhou 450045, China
[5] College of Management, Sichuan Agricultural University, Chengdu 611100, China
* Correspondence: haoxiuping@ncwu.edu.cn (X.H.); liuxj@igsnrr.ac.cn (X.L.)

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Abstract: Agricultural technological change plays a crucial role in food security and agricultural development. In the case of considering economic risks and technical risk tolerance, farmers will use different technologies to match production factors to achieve the optimal production state. Therefore, under different farmland management modes, farms show different characteristics of technological progress. This paper attempts to compare and analyze agricultural technology development under different farmland management modes: the unified management mode of collective organizations (UMCO) and the decentralized management mode of contracted families (DMCF). The Stochastic Frontier Analysis (SFA) of the translog average production function was applied to the 24 farms of the Hulunbuir Agricultural Reclamation Group, of which 11 farms in the western part of the Greater Khingan Mountains (Western Farms) were managed by the DMCF, and the other 13 farms in the eastern part of the Greater Khingan Mountains (Eastern Farms) were managed by the UMCO. The results are as follows: (1) without considering the resource allocation efficiency, from 2000 to 2019, the generalized technological progress rate (TFPG) of the 13 Eastern Farms (7.65%) was higher than that of the Western Farms (2.25%). (2) The returns to scale (SRC) of the Western Farms was higher than that of the Eastern Farms. (3) The technological efficiency change rate (TEC) and the technical progress (TP) of the Eastern Farms is higher than that of the Western Farms. It is recommended that farms strengthen the construction of their infrastructure and service systems, resist natural disasters, reduce the disaster's impact on technological progress, give full play to the overall planning advantages of the collective organizations, improve the product allocation efficiency factors, and create connotative profit points.

Keywords: land management modes; SFA; technological progress rate; Hulunbuir Farm Reclamation Group

1. Introduction

The advancement of agricultural technology plays a fundamental role in food production and food security and it is also a necessary prerequisite for promoting sustainable agricultural development [1,2]. The modernization of agricultural technology has greatly changed the mode of agricultural management, increased agricultural production, improved the comprehensive production capacity, promoted overall economic growth, reduced poverty, and improved the livelihoods of farmers in developing countries [3–6].

Agricultural technological progress is a unique trend and is the law of agricultural technology change, under specific natural environments and economic and social conditions. As one of the important external environmental constraints, the allocation and management mode of agricultural land provides the basic organizational and institutional framework for science and technology progress. Simultaneously, according to the resource allocation theory, the rational allocation and the management of land resources play an important role in making full use of the potential value of land and improving its utilization efficiency.

In developing countries, low and middle-income families, living on small-scale farmland, are the main workforce to promote the country's agricultural development. However, with urbanization and agricultural technological advancement, more and more farmlands have gradually been transferred from many small-scale farmers to agricultural enterprises or large growers. Did the land transfer improve the technical efficiency? How did the transfer impact the agricultural production and the farmers' income? A lot of research from many counties have been carried out to explore these questions raised by the different farmland management modes, according to their agricultural resource endowments and land management policies. Some researchers believed that the family-based smallholder production and management mode could easily stimulate the positivity of farmers, and it was believed that it is the best way for short and medium-term agricultural development in developing countries, and a lot of human and financial investments have been made to maintain this production mode [7]. It is because the family-based management mode could push the farms to make use of production technology more efficiently and positively. Meanwhile, with the large-scale agricultural production mode, the machinery and technology were adopted extensively, which would lead to unemployment and a restriction of development in rural areas, as well as bringing employment pressure to the city [8]. On the contrary, some ideas were that the family-based management mode hindered the integration of public resources and increased farm costs, due to the inability to achieve returns to scale, while large-scale production can effectively improve the efficiency of resource allocation [9]. Furthermore, the agricultural technology input, often based on a certain scale of farmland management, can significantly improve the production efficiency while replacing the labor input, and promoting the total factor productivity(TFP)and land productivity growth [10], and then improve the bargaining power of the agricultural product suppliers in the market, and finally increase the income of agricultural producers.

The impact of the transition from the family-based management mode to the enterprise-based large-scale management mode from different perspectives has been studied [11–14]. Taking Ethiopia as an example, the study found that if resources, such as land, were distributed freely among counties, the total factor productivity of agriculture would increase significantly, by 32% [15]. However, the misallocation or the inefficiency of land resources is prevalent in underdeveloped countries, due to unclear land property rights, asymmetric market information, and institutional constraints [16–19]. From the perspective of social welfare, it would reduce the surplus income of farmers (by about 33%, on average) and increase the economic surplus of urban consumers (by an average increase of about 51%) to transform the small farmers' management mode into an intensive mode. Since the increase in the surplus for urban consumers would be greater than the loss of surplus for farmers, the average total social welfare increases [20,21].

In China, with the change of agricultural land property right system, two modes of land management modes have been formed. One is the decentralized management of contracted families (DMCF), such as most small-scale farmers, large-scale farmers, household farms, etc. The other is the unified management of collective organizations (UMCO), such as collective operations, enterprise operations, cooperative operations, etc. The different farmland management modes have a joint impact on the allocation of other agricultural production resources and the efficiency of the corresponding agricultural production technology, such as farmland managers, will adopt different technologies to match the labor and capital resources, in order to achieve the optimal production state.

It means that under different farmland management modes, the influence of agricultural production factors on agricultural technology progress present different conditions, and thus the progress shows different directions and characteristics. In this paper, we thought that the differences mainly came from two aspects. (1) The varied technological progress rate with different land scales was proven in many investigations. Some ideas are that larger farms have a higher rate of technological progress, while smaller farms have a significant negative effect on technological progress. The main reason is that farmers with large farms are more willing to invest the time and money to learn and adopt new knowledge and technologies [2]. (2) Different technical efficiency and total factor productivity (TFP) with different production and management modes. Research in this field is still relatively sparse, and most of the literature discussing farmland management and technological progress is from the perspective of land scale or a single farmland management type [22–26], but the rare studies focus on the resource input structure and the technological progress of the different farmland management modes (e.g., DMCF and UMCO), to establish the better management mode. In developing countries, e.g., China, the land transfer system is gradually improving, and a variety of land management modes have been formed in the process of transfer. The comparative study of the agricultural technological development under the different management modes, will help to explore the reasons for the inadequacy of their modes, and to improve the quality and efficiency of agriculture by soft power, on the condition of an unchanged technological level.

Considering the basic consistency of production time and space, the factor inputs, and the agricultural technology required for an effective comparative analysis, this paper selected the Hulunbuir Farming Reclamation Group Co. Ltd, as the research subject to conduct a verification discussion on China's farmland management mode, which has two farmland management of DMCF and UMCO and acquires a large number of data through field research. Based on the stochastic frontier analysis (SFA) model and the generalized technological progress rate model, this paper implements a comparative analysis of the input and output of grain production factors and investigates the differences in the agricultural technological progress under the two farmland management modes. The results are expected to provide the policy implications for the optimized allocation of the farmland resources and the modern agricultural technology implementations, which also provide a reference for the agricultural technology development in other countries.

2. Conceptual Framework of the Study

2.1. China's Farmland System Reform

Over the past 70 years, China's rural land system has gone through four stages: private ownership, collective ownership, separation of two rights (ownership and contract rights), and separation of three rights (ownership, contract rights and management rights). In the early days of the People's Republic of China, the economic strategy was dominated by the priority to develop heavy industry and a fast pace of development [27,28]. During the process of national industrialization, China established the "People's Commune" production mode with a large-scale, high-public-ownership, and formed an industrialization system within nearly 20 years. However, the traditional large collective production mode, such as the People's Commune, bred the opportunistic behavior of idle work, and decreased the labor performance and productivity [29]. Until the late 1970s and early 1980s, China tried to establish a household contract responsibility system, based on the collective land ownership. According to this land policy, the collective land was contracted to individual farmers to form a decentralized agricultural land management mode which would improve the agricultural productivity and solve the difficulties of peasants' livelihoods, effectively. The biggest advantage of the decentralized household contract management mode is that the separation of farmland ownership and the contracted management rights encouraged farmers to build an implementation mechanism of independent production and self-supervision, which effectively increased the output of agricultural labor production [30,31]. However, the decentralized management of agricultural land is not conducive to developing a more socialized, large-scale, and intensified agricultural production, and the lower ability of individual farmers to resist natural disasters and market risk, make it difficult to obtain large-scale benefits. Meanwhile, the decentralization of land by the population or labor force was seriously refined, and this wasn't favorable to mechanized farming. It was proven, that in the early days of China's reform, the use of tractors plummeted, while the use of livestock increased sharply, which hindered the development of agricultural modernization [32]. It means that in the two-layer management system, as the basis of the household contract management, and the coexisting collective unified management, during this period, there was enthusiasm for decentralization towards a household contract management system, while the unification function of the collective organizations weakened. To address the shortcomings of the decentralized family management mode and to meet the needs of the national industrialization and urbanization developments, China launched another major innovation reform in the rural areas, with the separation of the three rights (ownership, contract rights, and management rights) of farmland [33]. In 2013, the Central Government of CPC called for the orderly transfer of the farmland's contract right, encouraging the household contracted farmland transfer to large-scale family farms, farmers' cooperatives and large growers, and to develop various forms of moderate-scale farmland management. In 2015, the three rights concerning the separation of farmland were required to be clearly expressed in the form of a law. In 2016, the three rights concerning agricultural land (the ownership, contract rights, and management rights) were formally separated with the publication of the Opinions on Improving the Separation of Rural Land Ownership, Contract Rights and Management Rights and then the diversified agricultural management modes, such as the family management, collective management, cooperative operation, and enterprise management were formed. In 2018 and 2019, the three-rights separation system of agricultural land was established by the law instead of by policy, which provided a legal guarantee for farmland to enter the market.

2.2. Agricultural Land Management Mode

Now, there are two main agricultural land management modes in China One is the household contract decentralized management (DMCF), such as the vast number of small farmers, large farmers, household farms, etc. This type of farmland is mainly managed by contracted households, and the scale of land depends on whether farmers choose to transfer their land to achieve a moderate scale of concentrated management. The advantages of this mode are that it can effectively enhance the families' labor positivity, flexibly allocate agricultural production resources, and improve the technological efficiency and land productivity. However, the farming decisions under the household contract management mode are affected by the farmer's characteristics, experiences, and risk tolerance. For example, the education status of farmers would greatly affect the choice of technology and other resource allocations. It was found that the amount of fertilizer used by farmers in China showed the obvious characteristics of early empirical fixed behavior habits [34,35]. African farmers, who are risk-averse, are more likely to adopt drought tolerance technologies, because it helps reduce their production risks [36,37].

The other mode of agricultural land management, is the collective organization management mode (UMCO), e.g., collective management, enterprise management, etc. In this mode, the collective organization has the land's contract rights and the management rights. The farmers can earn their labor remuneration as an employee, and the land is relatively large in scale. Compared with the traditional collective management mode, the advantage of this current mode is that the decision-making power belongs to the collective or the enterprise. Each farm or cooperative can allocate capital goods to obtain a maximized profit, and also establish a salary performance system. It not only ensures the scale and intensification of the production but also avoids the decreasing labor productivity caused by the inconsistency between farmers' efforts and their remuneration. Compared with the decentralized household management mode, the unified management mode of a collective organization can effectively separate the household living expenses and agricultural production costs, stabilize the agricultural production costs and promote the efficiency of scale production.

The farmland manager in the DMCF mode, regardless of the scale of the farmland, is the traditional household farmer. The farming income is not only the source of the household living expenses, but also a source of farming input. According to Maslow's hierarchy of needs, the farmers' income usually pays for a family's living, prior to the agricultural production input, or subsidize the household living and farming costs with a concurrent business, which will undoubtedly hurt the agricultural production and the adoption of new technologies. It was found that the relationship between farmers' concurrent businesses and the adoption of technology, in China displays an inverted U-shape. That is, the concurrent business doesn't favor the adoption of new technologies [38,39]. However, the farmland manager in the UMCO mode, mainly adopts the modern enterprise management method, often counts the agricultural output by the cost accounting method and pays out the labor remuneration in the form of a "wage". Without the limitation of the household factors, the farm can build its infrastructure or purchase advanced machinery, equipment, and production goods, to satisfy the farming demands, and effectively increase the returns to scale. Meanwhile, the organized agricultural production also helps to resist natural and market risks and tends to be more stable. Although it is better for the UMCO mode to mobilize the enthusiasm of the labor, than it is for the traditional large collective mode, as the quality of the management depends more on the decision-making ability and the production organization capacity of the managers. In addition, the large-scale single agricultural production is more vulnerable to the impact of the external market environments, climate conditions, and pests and diseases, which can lead to considerable losses if poorly managed.

2.3. Agricultural Technology Progress

In addition to the external conditions, such as the climatic conditions and institutional policies, food production is mainly affected by production factors and agricultural technologies (Figure 1). Production factors are divided into explicit input factors, including natural resources (such as land and freshwater), labor, physical capital input (such as seeds, fertilizers, and technology), etc., as well as the implicit input factors that are difficult to directly quantify. The process of grain input and output includes management, human capital, institutional arrangements, etc. According to the scope of the technical investigation, the technologies are divided into the narrow technology and the broad technology. Food production technology is narrowly defined as the technology embodied in food production factors, that can improve material or labor productivity, including soil fertility improvement technology, modern mechanical technology, chemical technology, breeding technology, and pest control technology. It is also called pure technology, cutting-edge technology, or hard technology. Technology, in a broad sense, includes not only technology in the narrow sense, but also the experience, skills, knowledge, means, and organization accumulated in the process of food production, such as advanced agricultural management methods and concepts, the development of new farming management disciplines, and various agricultural management systems. Innovation, the improvement of technical services, is also known as an economic management technology.

As far as agricultural production is concerned, agricultural technology progress is the evolution and reform process that breaks through the original production constraints in order to achieve a new goal in agriculture. Whether it is the evolution of the existing agricultural technology (or technology system) or the creation of a new technology (or technology system), as long as it can be closer to the new goal (e.g., improving the yield and agricultural products' quality, saving scarce resources and energy, increasing farmers' incomes, reducing labor intensity, improving the ecological environment, etc.), it is known as agricultural technological progress. Specifically, there are three aspects of the generalized technological progress. First, technological progress, in a narrow sense, refers to the progress in which agricultural, scientific, and technological achievements are put into agricultural production in the form of material production factors, and the production possibility frontier is moved outward, mainly in the form of improving the quality and enhancing the function of the factors. The second is the change in the efficiency of the resource allocations and the change in the returns to scale. The change in the resource allocation efficiency represents the input-output level of the total resources, which can be improved through the optimal allocation of the resource input amount in different regions and varieties. The change in the returns to scale is observed if the output is increased by the equivalent multiple of the increasing resource inputs. Third, the changes in the technical efficiency refer to the proportion of the actual grain output affected by external factors (such as climatic conditions, short-term agricultural policies, etc.) or factors of the food producers (such as educational level, economic strength, employment demand, etc.) is lower than the maximum possible output or frontier output, that is, the contribution of the effective application of the existing technologies to the current output. The changes in the technical efficiency reflect the changes in the actual output close to the optimal production frontier [40]. These indicators are also known as the generalized technological progress rate or the growth rate of total factor productivity (short for TFP growth rate or TFPG).

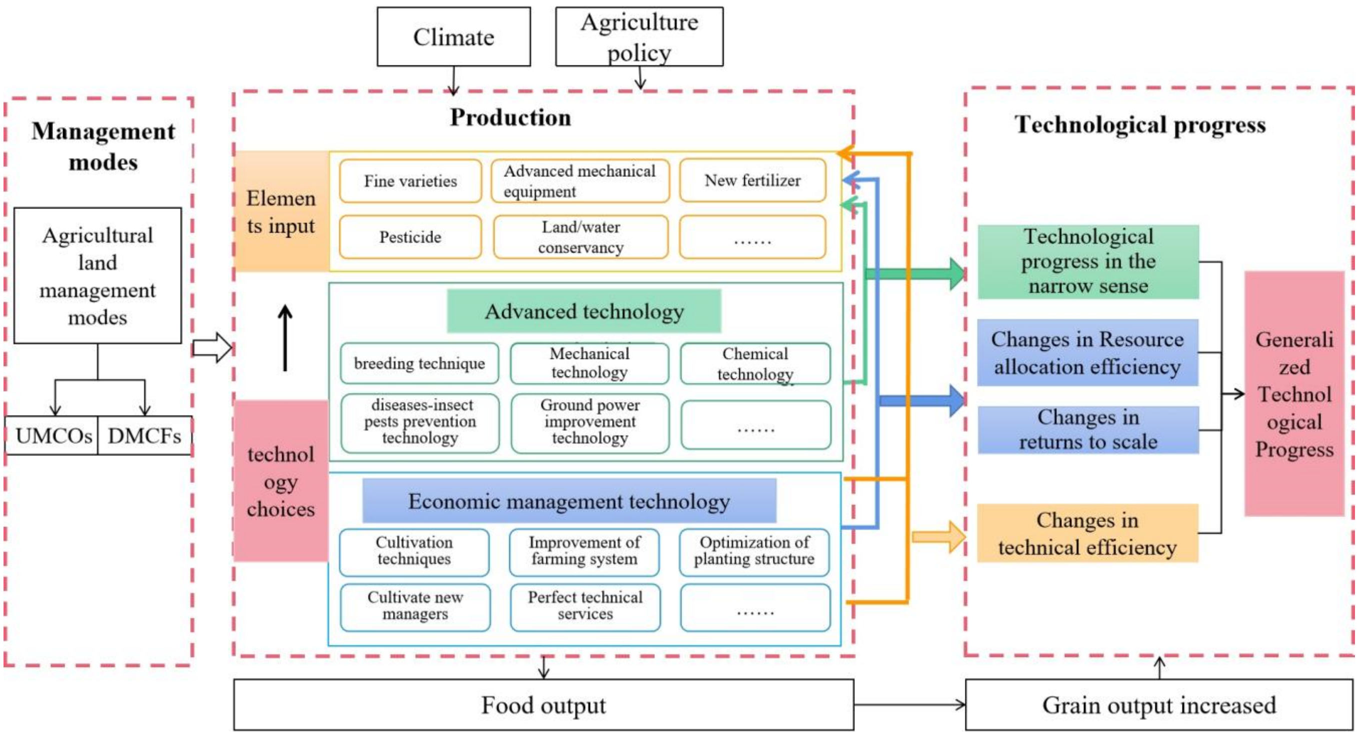

Figure 1. The relationship between the grain production, production factors, and agricultural technology.

The expanding population of the world requires a rapid increase in food production, thus stimulating the demand for technological innovations in agriculture, to increase the quantity of food to feed a growing population. As can be seen, the progress of agricultural technology is an important factor affecting farmers' welfare, agricultural productivity, and the economy of the food sector. The impact of the agricultural technology on grain production is reflected in the agricultural productivity and the production relations through the activities of the agricultural operators. This is mainly because agriculture is a risky industry. Food production can be greatly affected by the changes in the external conditions, such as weather shocks, unexpected pest and disease damage, and agricultural policies [41]. Different agricultural operators have a different sensitivity and tolerance to risks, which can directly affect their input to the production factors and the adoption of technology. Moreover, the benefits derived from the adoption of new technology can be equally uncertain, depending on the operators' different production management experiences, geographical environment, and climate conditions.

A large number of practices show that the management mode of farmland will have joint effects on the allocation of other agricultural production factors and the corresponding agricultural production technology, that is, farmland operators will adopt different production technologies to match the production factors, in order to achieve the optimal production state, based on their ability to bear economic and technical risks. Therefore, under different agricultural land management modes, the farmers will tend to adopt different technologies, due to the different decision-making environments, thus showing the different characteristics of technological progress.

3. Model and Data Source

3.1. Basic Model

3.1.1. Production Function Model

In the literature, the stochastic frontier analysis (SFA) [42,43] and the data envelopment analysis (DEA) [44–47] are widely used to measure the rate of the technological progress. The DEA is a linear planning model, which does not require assumptions about the form of the production frontier function, but this method does not have the stochastic terms to control the uncertainties in the production process. In addition, it cannot measure the output elasticity coefficient. Therefore, the SFA, proposed by Battese and Coelli [48], which consists of a production function and a first-order condition for maximizing the output, is chosen to study the agricultural productivity in this paper. In that, the traditional Cobb–Douglas production function has some defects, in theory, and cannot represent the biased technology and the changing elasticity trend. However, the translog function conforms to the setting of the economic theory and can set the virtual and proxy variables, according to the theoretical and practical needs, which can make more accurate economic explanations. So, in this paper, the SFA with the translog function was finally selected. The models are assumed as follows:

$$y_{it} = f(x_{it}, t; \beta) exp(v_{it} - u_{it}) \tag{1}$$

$$lny_{it} = lnf(x_{it}, t; \beta) + (v_{it} - u_{it}) \tag{2}$$

Equation (2) is the logarithm form of Equation (1).

In the two formulas, subscript i represents the ith production unit, e.g., ith farm; the subscript t represents the tth calculated period, e.g., the tth year; y_{it} represents the grain output; $f(\cdot)$ represents the output frontiers function; x represents the input; β represents all of the coefficients to be determined; v_{it} represents the uncontrollable random errors $v_{it} \sim N(0, \sigma_v^2)$, $\mathrm{u_{it}}$ represents the inefficient production technology, independent of v_{it}, $\mu_{it} \sim i.i.d.N^+\left(m_{it}, \sigma_\mu^2\right)$.

$$\begin{aligned} \ln Y_{it} = \beta_0 &+ \beta_1 \ln L_{it} + \beta_2 \ln F_{it} + \beta_3 \ln M_{it} + \beta_4 \ln S_{it} + \frac{1}{2}\beta_5 (\ln L_{it})^2 + \frac{1}{2}\beta_6 (\ln F_{it})^2 \\ &+ \frac{1}{2}\beta_7 (\ln M_{it})^2 + \frac{1}{2}\beta_8 (\ln S_{it})^2 + \beta_9 \ln L_{it} \ln F_{it} + \beta_{10} \ln L_{it} \ln M_{it} \\ &+ \beta_{11} \ln L_{it} \ln S_{it} + \beta_{12} \ln F_{it} \ln M_{it} + \beta_{13} \ln F_{it} \ln S_{it} + \beta_{14} \ln S_{it} \ln M_{it} + \beta_{15} t \\ &+ \frac{1}{2}\beta_{16} t^2 + \beta_{17} t \ln L_{it} + \beta_{18} t \ln F_{it} + \beta_{19} t \ln M_{it} + \beta_{20} t \ln S_{it} + \beta_{21} DIS_{it} \\ &+ (v_{it} - u_{it}) \end{aligned} \tag{3}$$

where:

Y_{it} is the grain output (yuan/ha) of the ith farm in tth year;

Lit, Fit, Mit, Sit represent the employees' number (person/ha), fertilizer discount (kg/ha), mechanical power (watt/ha), and seed input (kg/ha) of the ith farm in tth year, respectively;

DIS_{it} represents the disaster rate, here, $DIS_{it} = A_a / A_S$; Aa, As is the affected area, and the sowing area of the farmland;

β represents 22 parameters to be estimated;

V_{it} represents the random error. $v_{it} \sim N(0, \sigma_v^2)$;

μ_{it} represents a non-negative random variable reflecting the loss of the technological efficiencies in the ith farm.

Assuming $\mu_{it} \sim i.i.d.N^+\left(m_{it}, \sigma_\mu^2\right)$.

The deviation between the real output and the output frontier of the production unit is regarded as the efficiency loss or inefficiency. Considering the influence of the natural factors, the farm economy, and the reform of the reclamation group on the technological efficiency, the non-time-varying fixed effect model is adopted in this technological efficiency loss model. The model is as follows:

$$m_{it} = d_0 + d_1 G_{it} + d_2 AR_{it} + d_3 T \quad (4)$$

Equation (4), G_{it} represents the virtual variable of the reclamation group reform, it is 0 from 2000 to 2011 and 1 from 2012 to 2019; AR_{it} represents the actual per-capital income of the employees calculated at constant prices in 2000, reflecting the economic situation of each farm; T is the time trend variable, reflecting the trend change of the technological efficiency loss affected by other factors.

Defined $\gamma = \sigma_u^2/\left(\sigma_u^2 + \sigma_v^2\right)$, $0 \le \gamma \le 1$.

γ reflects the relative importance of the technological efficiency to the actual output. the bigger the γ, the stronger the impact of the technological efficiency factor; the smaller the γ, the stronger the effect of the random error factors.

The production function model is tested in the following four aspects:

(1) H0: γ = 0, if the original hypothesis is not rejected, it is not necessary to use the stochastic frontier model analysis; if the original assumption is rejected, it is reasonable to set the model as the stochastic frontier.
(2) H0: $\beta_5 = \beta_6 = \beta_7 = \ldots \ldots = \beta_{19} = \beta_{20} = 0$, if the original hypothesis is rejected, the transcendental logarithmic production function should be adopted; conversely, use the C-D function.
(3) H0: $\beta_{15} = \beta_{16} = \beta_{17} = \beta_{18} = \beta_{19} = \beta_{20} = 0$, if the original hypothesis is rejected, there is technological progress.
(4) H0: $\beta_{17} = \beta_{18} = \beta_{19} = \beta_{20} = 0$, if the original hypothesis is rejected, the Hicks technology is non-neutral, that is, the technological progress is related to the factor input.

The generalized likelihood ratio (LR) tests are used for the above four tests, and the statistics are LR= -2 ($L_0 - L_1$), L_0, and L_1, representing the logarithmic likelihood function values of the original hypothesis and the alternative hypothesis, respectively. The LR statistic follows a mixed chi-squared distribution, where the chi-squared test limit is five, $\chi^2_{1-0.05}(5) = 10.37$. If the LR statistic is greater than 10.37, the original hypothesis is rejected at a 5% significance; otherwise, the original hypothesis is not rejected.

3.1.2. Decomposition of the Generalized Technology Progress Rate (TFPG)

Referring to the literature [2,49], this paper decomposes the generalized technological progress rate (TFPG) into four parts: the narrow sense of the technological progress rate (TP), the change rate of the returns to scale (SRC), the change rate of the resource allocation efficiency (AEC) and the change rate of the technological efficiency (TEC), namely:

$$\text{TFPG} = \text{TP} + \text{SRC} + \text{AEC} + \text{TEC} \quad (5)$$

The technology progress rate, in the narrow sense (TP)

$$TP = \frac{\partial \ln Y_{it}}{\partial t} = \beta_{15} + \beta_{16} t + \beta_{17} \ln L_{it} + \beta_{18} \ln F_{it} + \beta_{19} \ln M_{it} + \beta_{20} \ln S_{it} \quad (6)$$

In Equation (6), the narrow technology progress rate TP includes two parts: the neutral technology progress rate (TP_n) and the bias technology progress rate (TP_b). Equation (5) $\beta_{15} + \beta_{16} t$ represents the neutral rate of the technological progress (TP_n), it changes over time, which does not affect the proportional relationship among the economic variables in the function, and it is mainly a fundamental, technological change, to make the production technology frontier improve overall; $\beta_{17} \ln L_{it} + \beta_{18} \ln F_{it} + \beta_{19} \ln M_{it} + \beta_{20} \ln S_{it}$ represents the bias technological progress rate (TP_b) of the individual input elements.

The change rate of scale return income (SRC)

$$\text{SRC} = (\varepsilon - 1) \sum_{\text{j}} \frac{\varepsilon_j d \ln X_j}{\varepsilon \cdot dt} \tag{7}$$

where, Xj successively represents labor (Lit), chemical fertilizer (Fit), machinery (Mit), and seeds (Sit); subscript j is the resource element number, j = 1, 2, 3, 4 successively represents labor, fertilizer, agricultural machinery, and seeds; εj represents the output elasticity of the jth resource elements, $\varepsilon = \sum \varepsilon_j$. If $\varepsilon = 1$, indicates that the returns to scale (RS) remain unchanged, namely RS = 0; if $\varepsilon > 1$, indicates the RS is increasing; if $\varepsilon < 1$, it means the RS is diminishing.

The change rate of the resource allocation efficiency (AEC)

$$\text{AEC} = (\frac{\varepsilon_j}{\varepsilon} - \text{Z}_j) \cdot \frac{d \ln X_j}{dt} \tag{8}$$

where, $Z_j = c_j / \sum c_j$, c_j (j = 1, 2, 3, 4) represents the marginal cost of the jth resource element. When the production factor configuration is the most optimal. $\varepsilon_j / \varepsilon = \text{Z}_j$ is technological efficiency change rate (TEC)

$$TEC_{it} = \frac{\partial TE}{\partial t} \tag{9}$$

$$TE_{it} = \frac{\text{Y}_{it}}{\text{Y}^*_{it}} = \frac{\text{Y}_{it}}{f(x_{it}, \beta) \exp(v_{it})} = \exp(-u_{it}) \tag{10}$$

where, TE is the technological efficiency; Y^*_{it} represents the random boundary of the grain output, it is also the grain output when the efficiency loss is $\mu_{it} = 0$.

3.2. Data Source and Hypothesis

In this paper, the Hulunbuir Farm Reclamation Group Company located in Inner Mongolia Autonomous Region of China was selected as a typical case to implement the investigation and research. The Hulunbuir Farm Reclamation Region was built in 1954 and managed by the central government. In 1979, Hulunbuir City was assigned to the Inner Mongolia Autonomous Region, and 24 farms and pastures in the Hulunbuir Reclamation region were divided into two administrations: the Hailar Farm Administration and the Greater Khingan Mountains Farm Administration. The Hailar Farm Administration includes 11 farms and pastures (the 1st–11th farms in Figure 2) in the west of the Greater Khingan Mountains and five farms in the east of the Greater Khingan Mountains (the 12th–16th farms in Figure 2). The Greater Khingan Mountains Farm Administration includes eight farms the east of the Greater Khingan Mountains (the 17th–24th farms in Figure 2). In 1985, with the spread of the household contract responsibility system in China, the farmland and agricultural machinery of 13 farms (the 12th–24th farms) were distributed to the reclamation workers in the way of renting. Two farmland management modes were formed in the Hulunbuir Reclamation Region: 11 farms in the west of the Greater Khingan Mountains (Western Farms) are organized and unified by unified farming, and 13 farms in the east of the Greater Khingan Mountains (Eastern Farms) are decentralized by household contracts. In 2012, the Hailar Farm Administration and the Greater Khingan Mountains Farm Administration merged into the Hulunbuir Agricultural Reclamation Group Company, and 24 farms continued the farmland management mode of the unified collective operation and the decentralized family operation. At present, the management and operation modes in Western Farms is by "Group Corporation → Professional Subsidiary → Farm → Workers", and the management and operation modes in Western Farms is by "Group Corporation → Professional Subsidiary → Farm → Family".

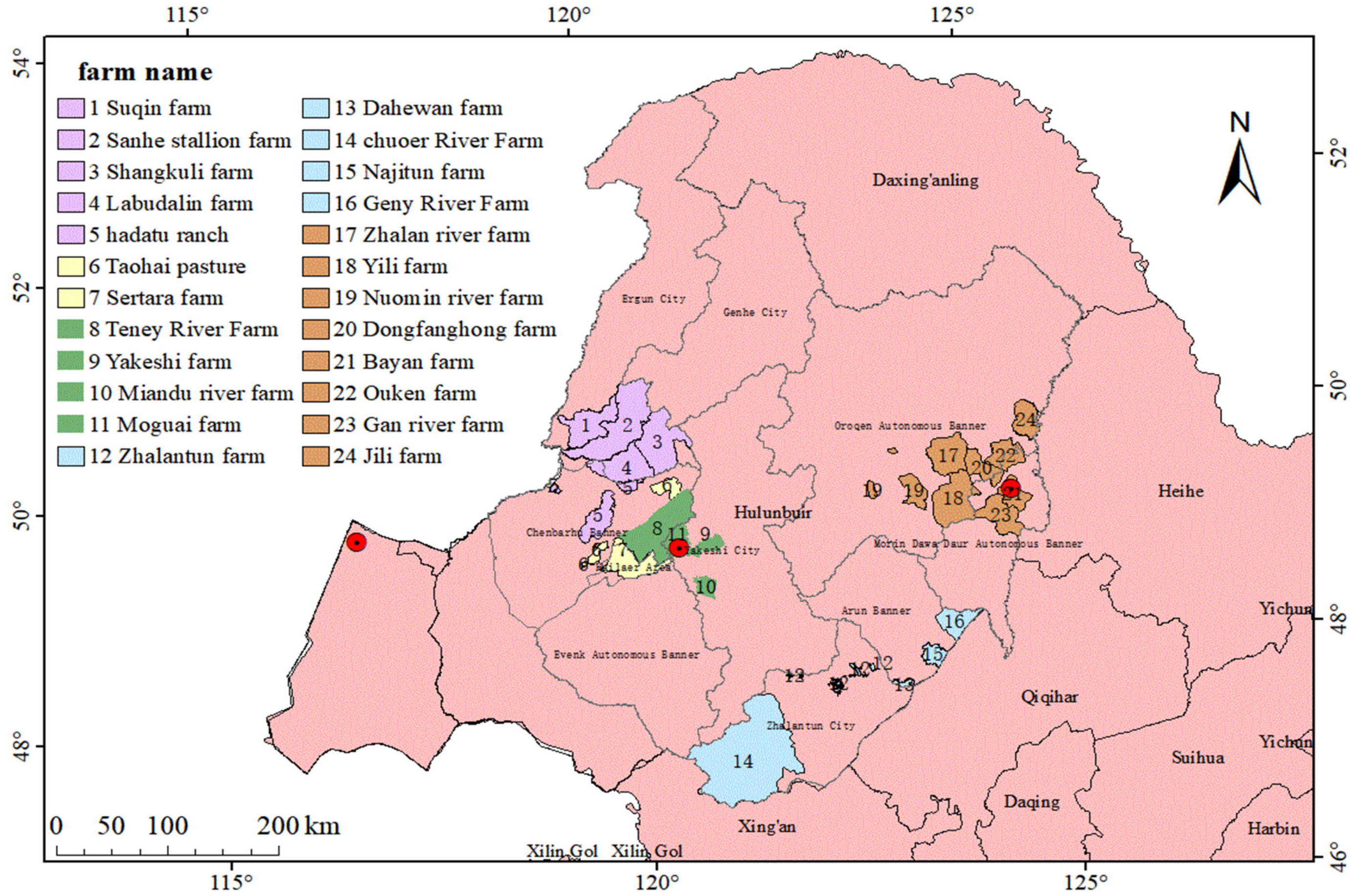

Figure 2. Location map of the 24 farms.

Now, the Hulunbuir Agricultural Reclamation Group has 400,000 ha of arable land and 670,000 ha of pasture. Table 1 by 2019, the group had more than 500,000 sets of agricultural and animal husbandry machinery and equipment, with a total power of 878,000 kw, and a comprehensive agricultural mechanization level of 99%; it has 40,300 ha of high-standard farmland, more than 60,000 ha of water-saving irrigation farmland and 323,000 ha of green farmland, to monitor; it has nearly 5000 professional and technical personnel.

Table 1. Farm management system and operation mode (2019).

Farm	Western Farms	Eastern Farms
Modes of operation	Corporate management (state farm before 2012)	Individual family management
Management structure	Group Corporation → Subsidiary→ Farm → Workers	Group Corporation →Subsidiary → Farm → Family
Land management system	Land of lease	Contracted land
Sowing area (ha)	248,097	152,227
Number of employees (person)	9802	23,650
Grain output (ton)	388,922	482,478

The Hulunbuir Farm Reclamation Group Company was selected as a typical case, mainly because of the following considerations:

(1) China's agricultural reclamation system has played a key role in ensuring the security of national food and important agricultural products, and has also undertaken the historical mission of providing a model for China's modernization;

(2) The farms owning advanced agricultural technology that can lead the technological progress of China's grain production;
(3) The farms are managed by two farmland management modes, the decentralized household contract operation, and the unified collective organization operation, and the samples sizes of the two modes are relatively equal, in order to guarantee the accuracy of the measurement;
(4) The farms in the two modes have the same external environment for grain production (including the natural environment, institutional environment, production organization, and management environment, etc.), and the consistency in the acquisition of the production factors and the agricultural technology, which can avoid the interference of the external conditions on the comparative analysis;
(5) Agricultural reclamation is better than the implementation of the double-layer management system in general rural areas as it ensures the unity of the external conditions of grain production;
(6) Consideration of the availability of the sample data and the operability of the field investigation and research.

To distinguish the differences between the collective organization unified management and the family decentralized management, in terms of technological progress and technological efficiency, the study divided 24 farms of the Agricultural Reclamation Group into two parts: Eastern Farms (13 farms) and Western Farms (11 farms). The author carried out a large number of field studies on the Hulunbuir Farm Reclamation Group and collected the relevant data on fertilizer, practitioners, total mechanical power, seeds, food production, and the affected area of the various farms in Eastern Farms and Western Farms, from 2000 to 2019. The statistical eigenvalues of the elements are shown in Table 2.

Table 2. Statistical characteristic values for 2000–2019.

Variable	Unit	Eastern Farms			Western Farms		
		Mean	Standard Error	Sample Capacity	Mean	Standard Error	Sample Capacity
Sown area	ha	11,439.40	6670.19	260	17,105.15	9220.94	220
Damage area	ha	6487.16	9600.19	260	12,171.04	10,858.94	220
Output of grain	Yuan/ha	4059.45	1468.57	260	4143.71	1899.08	220
Employees amount	persons/ha	0.15	0.11	260	0.18	0.35	220
Chemical fertilizer folding purity	kg/ha	129.52	55.76	260	141.91	60.36	220
Mechanical power	Watt/ha	2048.51	714.97	260	2078.71	804.08	220
Total seed input	kg/ha	94.02	56.81	260	185.44	83.96	220
Per-capita employee income	Yuan/person	359,227	210,328	260	368,023	203,855	220

Since the cultivated land of the Eastern Farms was contracted to the employees of the reclamation group, and the employees did not make detailed statistics on the input costs of factors, such as labor, fertilizer, machinery, and seeds, the valid data needed to measure the resource allocation efficiency (AEC) could not be obtained. In order to avoid any unnecessary calculation deviation, it is assumed that the grain production resource allocation of the agricultural reclamation group is in the optimal state, and the generalized technology progress rate only includes three parts: TP, SRC, and TEC.

4. Results Analysis and Discussion

4.1. Test of the Production Function Model

The rationality of the model setting of 24 farms, was tested by using the actual survey monitoring data. The results (Table 3) showed that the LR statistics of Eastern Farms and Western Farms were greater than 10.37, indicating that the original hypothesis was rejected, which means the setting of the transcendental logarithmic SFA model was reasonable. The estimated results using Frontier 4.1 software are shown in Table 4.

Table 3. Model setting identification test results.

Order Number	Null Hypothesis	Eastern Farms		Western Farms	
		Maximum Likelihood Value	LR Statistics	Maximum Likelihood Value	LR Statistics
1	$\gamma = 0$	−10.98	245.76	−87.73	111.17
2	$\beta_5 = \beta_6 = \beta_7 = \ldots \ldots = \beta_{19} = \beta_{20} = 0$	−37.19	52.41	−106.74	38.02
3	$\beta_{15} = \beta_{16} = \beta_{17} = \beta_{18} = \beta_{19} = \beta_{20} = 0$	−27.07	32.17	−99.64	23.82
4	$\beta_{17} = \beta_{18} = \beta_{19} = \beta_{20} = 0$	−19.19	16.41	−94.67	13.89

Table 4. Estimation results and significance of the SFA.

Explanatory Variable	Parameter	13 Farms in Eastern Farms(DMCF)		11 Farms in Western Farms(UMCO)	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
constant term	β_0	3.1744	4.1263	8.3361 ***	1.1916
$\ln L$	β_1	−0.0904	0.6714	2.2659 ***	0.8241
$\ln F$	β_2	1.2578	0.9670	−0.3397	0.9966
$\ln M$	β_3	0.3257	1.1922	−0.1945	0.6707
$\ln S$	β_4	1.3248	0.8870	2.0907 ***	0.7268
$(\ln L)^2$	β_5	−0.1481 *	0.0875	0.2354	0.1495
$(\ln F)^2$	β_6	0.2199	0.1702	−0.0984	0.2722
$(\ln M)^2$	β_7	−0.2482	0.2217	−0.2109	0.2222
$(\ln S)^2$	β_8	−0.1462	0.1024	0.0081	0.0308
$\ln L \ln F$	β_9	0.2618 ***	0.0816	0.0832	0.1208
$\ln L \ln M$	β_{10}	−0.1992 **	0.0892	−0.4014 ***	0.1243
$\ln L \ln S$	β_{11}	0.0611	0.0826	0.2500 ***	0.0779
$\ln F \ln M$	β_{12}	0.0417	0.1271	0.1977	0.1985
$\ln F \ln S$	β_{13}	−0.1899	0.1106	−0.1651 **	0.0684
$\ln M \ln S$	β_{14}	−0.1106	0.1469	−0.1898 *	0.1061
t	β_{15}	−0.0959	0.0749	0.2833 *	0.1505
t2	β_{16}	−0.0012	0.0014	−0.0053 **	0.0024
$t \ln L$	β_{17}	−0.0233 ***	0.0078	0.0241	0.0185
$t \ln F$	β_{18}	0.0027	0.0136	0.0417 *	0.0221
$t \ln M$	β_{19}	−0.0107	0.0115	−0.0488 **	0.0245
$t \ln S$	β_{20}	0.0199	0.0106	0.0231 ***	0.0079
DIS	β_{21}	−0.1728 ***	0.0406	−0.2889 ***	0.0729
Constant term	d_0	−0.4621	0.3276	−0.3136	0.5878
Group Reform (G)	d_1	1.9610 ***	0.5191	0.7582	0.6037
Per capita income (AR)	d_2	−0.0002 ***	0.0000	−0.0002 ***	0.0000
T	d_3	0.2369 ***	0.0465	0.0755	0.0487
σ^2		0.6307 ***	0.1493	1.1901 ***	0.3625
γ		0.9793 ***	0.0086	0.9657 ***	0.0149
Likelihood ratio (LR) one-sided test		245.76 ***		111.17 ***	
Number of observed values		260		220	
Number of sections		13		11	

Note: ***, ** and * indicate the significance levels of 1%, 5%, and 10%, respectively.

From the estimation results, the LR unilateral test and γ statistics in the production functions in Eastern and the Western Farms are significant at the level of 1%, indicating that there is an efficiency loss in the crop production under the sample conditions, and the part of the technical inefficiency that can explain the compound disturbance term, is 97.93% and 96.57%, respectively, suggesting that the technical inefficiency of the reclamation group is mainly caused by human factors.

The primary and secondary coefficients of the time variable t of the Eastern Farms are negative, but the regression coefficients are not obvious, indicating that the neutral technological progress in the grain production in Eastern Farms has a negative impact on output, but the effect is not obvious. The primary and secondary coefficients of the time variable t of the Western Farms were significant, at 10% and 5%, respectively, and the primary coefficient was positive, and the second coefficient was negative, indicating that the positive effect of the neutral technological progress in grain production in Western Farms was obvious, but the progress rate was slowing.

The control variable disaster rate (*DIS*) was negative and statistically significant, indicating that natural disasters have a very negative impact on the food production in the reclamation group. The 11 farms in Western Farms are more affected.

From the perspective of the factors affecting the technological efficiency, the group reform (G), the average annual income of the group workers (AR), and the time trend (T) have a significant influence on the technological efficiency loss of the Eastern Farms; only the coefficient of the average annual income of the workers in Western Farms is obvious, at the 1% level, and the coefficient of both the group reform and the average annual income of the workers is less than that of the Eastern Farms, suggesting that the impact of these two indicators in Western Farms is not obvious. Among them, the per-capita income has a negative impact (−0.0002), indicating that the per-capita income promotes the technological efficiency, but its small coefficient has a weak promoting effect on the technological efficiency.

4.2. TFPG Assessment and Comparison

The TFPG, TP, SRC, and TEC values of the 11 farms and 13 farms, from 2001 to 2019, are shown in Table 5.

Table 5. Calculation results of the TFP growth rate and its decomposition.

Year	13 Farms in Eastern Farms (DMCF)						11 Farms in Western Farms (UMCO)					
	TP_n	**TP_b**	**TP**	**SRC**	**TEC**	**TFPG**	**TP_n**	**TP_b**	**TP**	**SRC**	**TEC**	**TFPG**
2000	−0.0971	0.1144	0.0173				0.278	−0.2157	0.0623			
2001	−0.0983	0.1208	0.0225	−0.099	−0.2846	−0.3611	0.2728	−0.2255	0.0473	0.0377	−0.1157	−0.0308
2002	−0.0995	0.1122	0.0127	−0.2266	0.7337	0.5198	0.2675	−0.225	0.0425	0.0302	0.1894	0.2622
2003	−0.1007	0.1123	0.0115	−0.1609	−0.2955	−0.4449	0.2623	−0.2399	0.0223	−0.0391	−0.4077	−0.4244
2004	−0.102	0.1237	0.0217	0.0179	0.6223	0.6618	0.257	−0.2236	0.0334	0.0603	0.3235	0.4173
2005	−0.1032	0.1286	0.0254	−0.325	0.2772	−0.0224	0.2517	−0.2194	0.0324	0.0183	0.2158	0.2665
2006	−0.1044	0.1264	0.0219	−0.086	0.1101	0.046	0.2465	−0.229	0.0175	−0.0515	−0.0466	−0.0805
2007	−0.1056	0.1288	0.0231	−0.0431	0.001	−0.019	0.2412	−0.217	0.0243	−0.0202	0.0219	0.0260
2008	−0.1069	0.1195	0.0126	−0.0443	−0.0114	−0.0431	0.236	−0.218	0.0179	−0.0082	0.0817	0.0914
2009	−0.1081	0.1289	0.0208	−0.1406	0.0225	−0.0974	0.2307	−0.2104	0.0203	0.0581	0.0170	0.0954
2010	−0.1093	0.1344	0.0251	0.1586	−0.1294	0.0543	0.2255	−0.2028	0.0227	−0.0411	0.0338	0.0154
2011	−0.1105	0.1347	0.0241	0.6145	0.1157	0.7543	0.2202	−0.2203	−0.0001	−0.0133	−0.0126	−0.0260
2012	−0.1118	0.1355	0.0237	−0.2447	0.1393	−0.0817	0.215	−0.2273	−0.0124	0.0731	0.0573	0.1180
2013	−0.113	0.1341	0.0211	−0.0123	−0.033	−0.0242	0.2097	−0.2265	−0.0168	0.3246	0.0470	0.3548
2014	−0.1142	0.1375	0.0233	0.1755	0.1233	0.3221	0.2044	−0.2211	−0.0167	−0.5748	0.0399	−0.5515
2015	−0.1154	0.1368	0.0214	−0.2996	−0.2525	−0.5307	0.1992	−0.2119	−0.0127	−0.0147	−0.0566	−0.0840
2016	−0.1167	0.1364	0.0197	−0.1142	0.0539	−0.0406	0.1939	−0.2147	−0.0208	0.0162	−0.2580	−0.2626
2017	−0.1179	0.1363	0.0184	−0.0134	0.2186	0.2236	0.1887	−0.2178	−0.0291	−0.0217	0.3427	0.2918
2018	−0.1191	0.1334	0.0143	0.2317	0.1724	0.4183	0.1834	−0.2227	−0.0393	0.0097	−0.0500	−0.0797
2019	−0.1203	0.1353	0.0149	0.1121	−0.0093	0.1177	0.1782	−0.2292	−0.051	0.0488	0.0304	0.0281
Average	−0.1087	0.1285	0.0198	−0.0263	0.0829	0.0765	0.2281	−0.2209	0.0072	−0.0057	0.0239	0.0225

4.2.1. The Varied Main Driving Force of the TP Change under the Two Modes

As shown in Figures 3 and 4, the annual average TP in Eastern Farms (1.98%) is higher than that in Western Farms (0.72%). In the Eastern Farms, the TP_b was positive, and the TP_n was negative. In other words, the TP of the 13 farms in Eastern mainly depends on the pull of the TP_b. The TP_n of the 11 farms in Western Farms is positive, and the TP_b is negative. It means that the TP_n is the main driving force for Western Farms's TP. The collectively managed farms, especially the state-owned farms, e.g., the Western Farms, have been in large-scale and intensive production and management modes. The implementation of the government policies was relatively efficient, and the promotion and application of the advanced production technologies and equipment were rapid. It is often the priority choice for the government to maintain the grain production and cultivate key farmers. Therefore, in this farmland management mode (UMCO), the technological progress was often driven by the overall level of the national agricultural technological progress, and the TP was more dependent on the TP_n, which was brought by the time accumulation. The farms in the DMCF mode were often run by a family unit. Due to the constraints of the family farmers' incomes, it is difficult to accept advanced technologies with a high investment, and they are more inclined to use technologies with a lower investment and faster benefits, such as labor, chemical fertilizer, and small portable agricultural machinery equipment. Under this DMCF mode, the effect of biased production technology progress is more obvious.

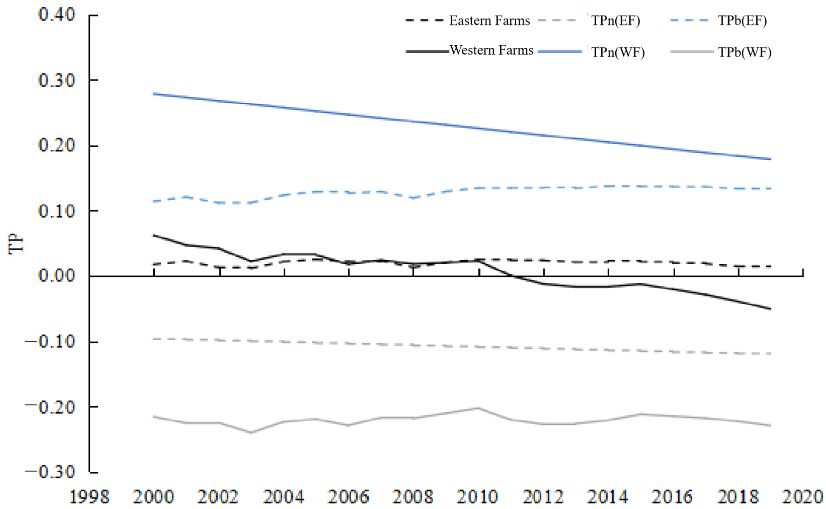

Figure 3. Average TP change trend.

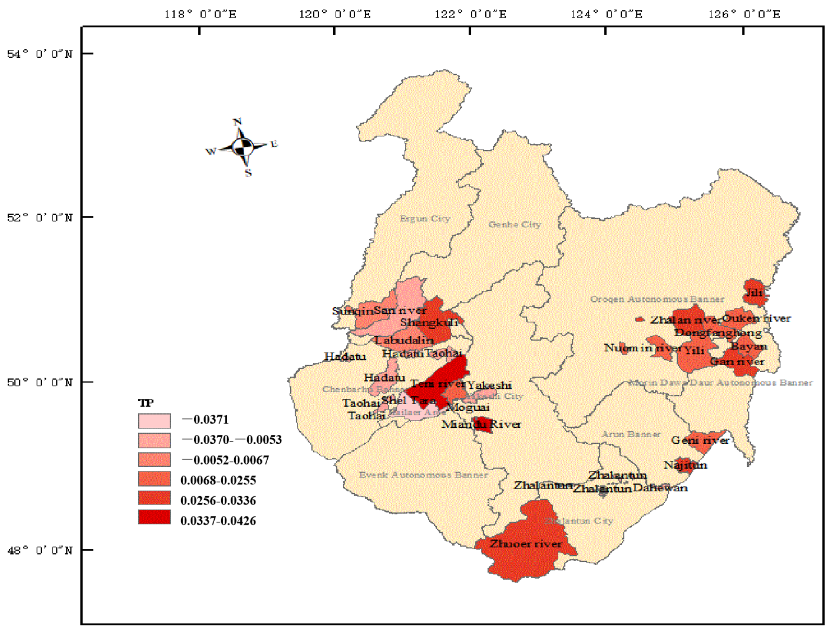

Figure 4. Average TP distribution of the 24 farms (2000–2019).

With the changing time, the TP of Eastern Farms increased slightly, while the Western Farms's TP decreased at a rate of 0.5%. In the early 21st century, the TP of Western Farms was much higher than that in Eastern Farms. By early 2012, with the slowdown of the TP_n, the TP in the Western Farms fluctuated negatively, showing a more obvious backward trend. In 2004, China fully liberalized the grain purchase and sales market, implemented the multi-channel management of purchases and sales, and established a direct subsidy system for farmers. The national agricultural policy stimulated investment in agricultural production, especially in state-owned farms. For example, in the early 21st century, the Hailar Farm Administration attached great importance to the investment in water conservancy facilities and large-scale modern agricultural machinery and equipment, forming a deep foundation of the agricultural technology. According to the survey data, the average number of large and medium-sized tractors and the self-propelled combine harvesters owned by the 11 farms in Western before 2010, was 1–3 times higher than that in the Eastern Farms (Figure 5). However, when the equipment and machinery became obsolete due to loss, the production capacity of the Western Farms gradually decreased, and there was a lack of strong and sustained technical support in the later period, which resulted in the weakening of the TP and a trend of a higher start and lower ending. Following the group reform in 2012, the Eastern Farms began to rapidly increase the input of the large and medium-sized tractors and combine harvesters, which greatly promoted the growth of the TP.

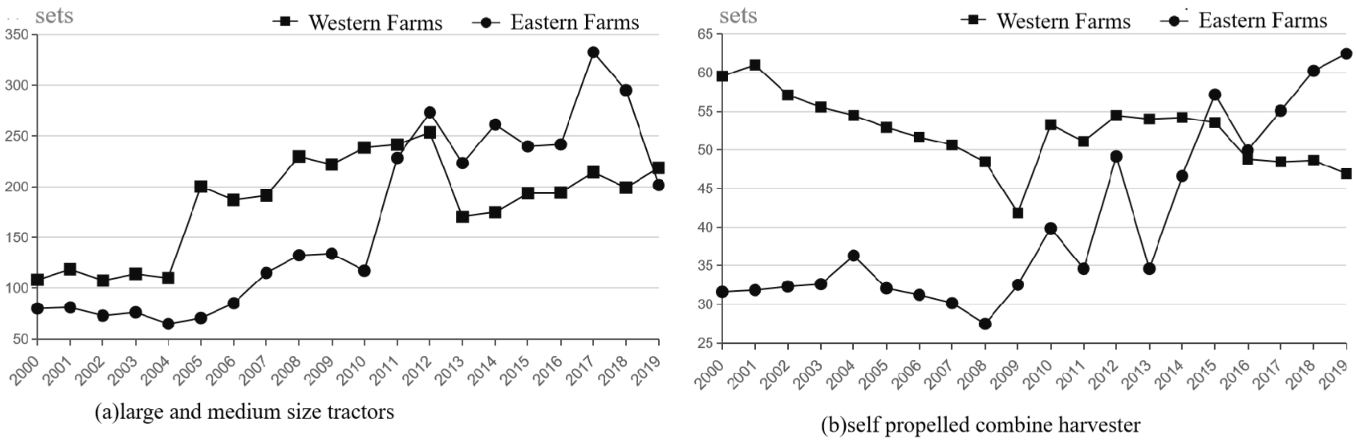

Figure 5. Average annual possession of the large and medium agricultural machinery.

4.2.2. The More Significant Change in the Returns to Scale (SRC) of the Farms in the UMCO

Modern agricultural production is equipped with a large number of large-scale mechanical equipment, irrigation systems, and other fixed essential production factors. As long as the farm does not reach the maximum capacity of the fixed factors, expanding the scale production will continue to bring the returns to scale, that is, they are economies of scale, but this state is only a short-term phenomenon. Without technological progress, the long-term state of the agricultural production will tend to decrease the returns to scale. The SRC in the Eastern and Western Farms are generally negative (Figures 6 and 7), and the annual average SRC is also negative (Western Farms, −0.57% and Eastern Farms, −2.63%), which confirms the universality of the law of the diminishing marginal returns. In contrast, the decline rate of the SRC in Western Farms was relatively slow, and the average decline rate was 2.06% lower than that in the Eastern Farms. The fundamental reason for this is that the operators of the Western Farms have stronger advantages in choosing agricultural technology, in order to adapt to the agricultural-scale production.

The UMCO mode of the Western Farms has a stronger overall planning function for the public production than the DMCF of the Eastern Farms. Farms managed in the UMCO mode can increase the public infrastructure construction with public investment instead of private investment, thereby changing the structure of the input elements, and increasing the production per unit area, thus reducing the cost of the private grain production [50]. The farms operated in the DMCF mode do not have enough financial capacity to build or improve the public infrastructures, such as irrigation and transport facilities, and can only increase the food productivity by increasing the labor inputs or by adopting the technology with less cost. Previous research demonstrated that the differences in the agriculture infrastructure (e.g., irrigation, transport facilities, etc.) exacerbate the gap in the rice productivity between developed and developing countries [51]. Therefore, the improvement in the construction of the agricultural production infrastructure is not only the basis for improving the grain production capacity but also the main factor in improving the international agricultural competitiveness.

Figure 6. SRC trend in Eastern Farms and Western Farms.

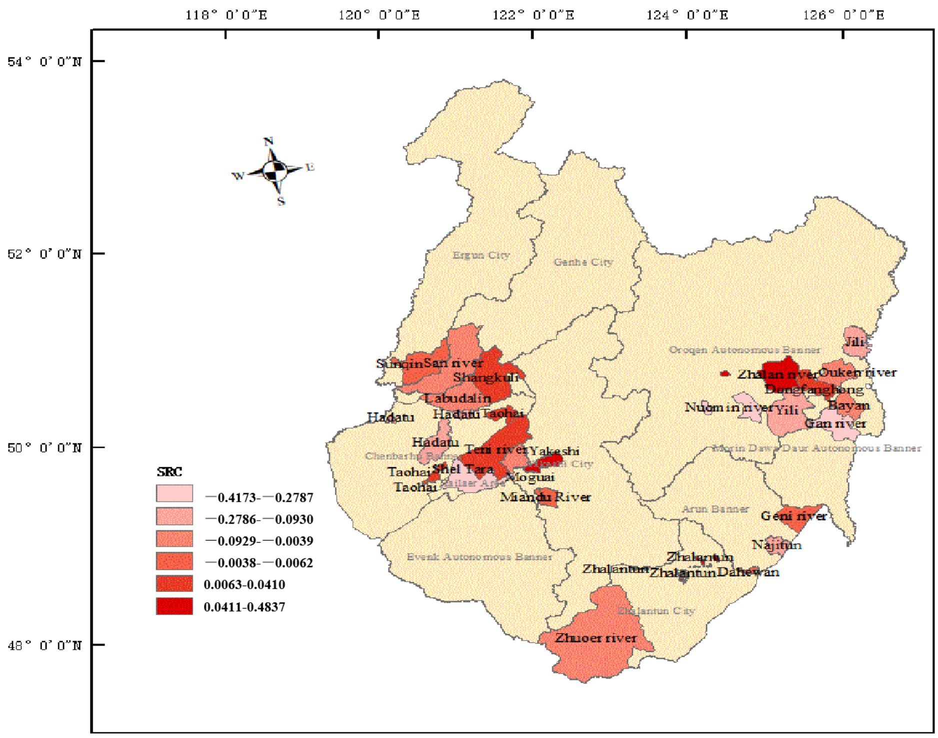

Figure 7. Average SRC distribution of the 24 farms (2000–2019).

In addition, the study also finds that the group reform has a great influence on the production management of the Eastern Farms. The Hailar Farmland Administration and the Greater Khingan Mountains Farmland Administration merged in 2012. Considering the different management modes of the subordinate units of the group, the farm reclamation group established a parent-subsidiary relationship with the capital as a link and formed a three-level management mode of the "group headquarters → professional subsidiaries → farms". Under the new management mode, the returns to scale of the 13 farms in Eastern Farms showed significant growth.

4.2.3. Higher TE of the Farms in the DMCF

The average TE of the Eastern Farms is higher than that of Western Farms. The loss of technological efficiency of the 13 farms in Eastern Farms was between 13% and 29%, with an average TE of about 78%; the technological efficiency loss of the Western Farms was between 19% and 38%, with an average technological efficiency of 73% (Figure 8). The DMCF mode can better motivate the enthusiasm of farming so that their TE is higher than that of the UMCO. This phenomenon was particularly evident before the group reform in 2012, when the overall technical efficiency of the Eastern Farms was higher than that of the Western Farms (Figure 9). As mentioned above, if the coordination of the public infrastructure cannot cover sufficiently the production of the family decentralized farms, the farms in the DMCF mode will focus more on increasing the technology utilization by increasing the labor input or the allocation of the production factors, in order to reduce the production costs. It can be seen that, compared with the UMCO mode, which has a strong overall planning ability in the public production link, the DMCF mode has more advantages in the private production link. In addition, the self-financing operation mechanism of the DMCF mode allows them to adopt more flexible management methods, such as working outside or non-agricultural farming during non-farming periods, and purchasing socialized services during busy farming periods, in order to complete the agricultural production. This not only reduces the transaction costs of transportation and accommodation in urban and rural areas, but also increases the productive income and expands the source of family income. Moreover, private farmers and agricultural service intermediaries make full use of their respective advantages in grain production, which will further improve the technological efficiency of the grain production. It is worth noting that the technological efficiency of the decentralized family farms shows a significant downward trend after the unified management of the reclamation group, mainly because the unified management of the group limits the freedom of operation of family farms and loses some technological efficiency.

With the development of agricultural science and technology, and the improvement of farm management efficiency, the TE of the two modes shows an increasing trend. The growth rate of the TE in the Western Farms (16.6%/10a) was higher than that in the Eastern Farms (1.8%/10a). From 2016 to 2019, the TE in the Western Farms was 79.3%, which was higher than that in the Eastern Farms (72.6%). Affected by natural disasters, the grain output of the Eastern and the Western Farms was seriously reduced in 2001, 2003, and 2016, and the production technology was limited. The technological efficiency of the farms in the two modes, showed varying degrees of fluctuation, and the influence of natural disasters in Western Farms was more serious. In 2001 and 2003, there are eight and five farms in Western Farms, whose disaster rate was more than 85%, and in 2016, the disaster rate of six farms in Western Farms, was more than 90%, which increased the fluctuation of the technological efficiency of the Western Farms.

Under the two modes, the technological efficiency progress showed a steady fluctuation, as a whole, with the average annual rate of the TEC in the Western Farms (2.39%), slightly lower than that in the Eastern Farms (8.28%). The fluctuation range was relatively larger in 2000–2005 and 2015–2019, as shown in Figure 9. On the one hand, affected by natural disasters, the loss of the technological efficiency is serious, resulting in negative fluctuations in the technological efficiency progress rate, and the impact of the natural disasters on the technological efficiency loss was more obvious in Western Farms. On the other hand, after the natural disasters, the farm capital, factors, and other inputs increased to restore production, and the corresponding technological efficiency progress rate also increased significantly. In the Western Farms, the technological efficiency changes of the Suqin, Sanhe, Labdalin, and Hadatu farms, were particularly prominent. The survey found from 2000 to 2003, the four farms took the lead in purchasing large and medium-sized advanced agricultural machinery, such as large and medium-sized tractors, seeders, and combine harvesters, and the average number of purchases was more than the other farms, which increased the technological efficiency of the four farms, in 2004, by more than double, compared with the previous year.

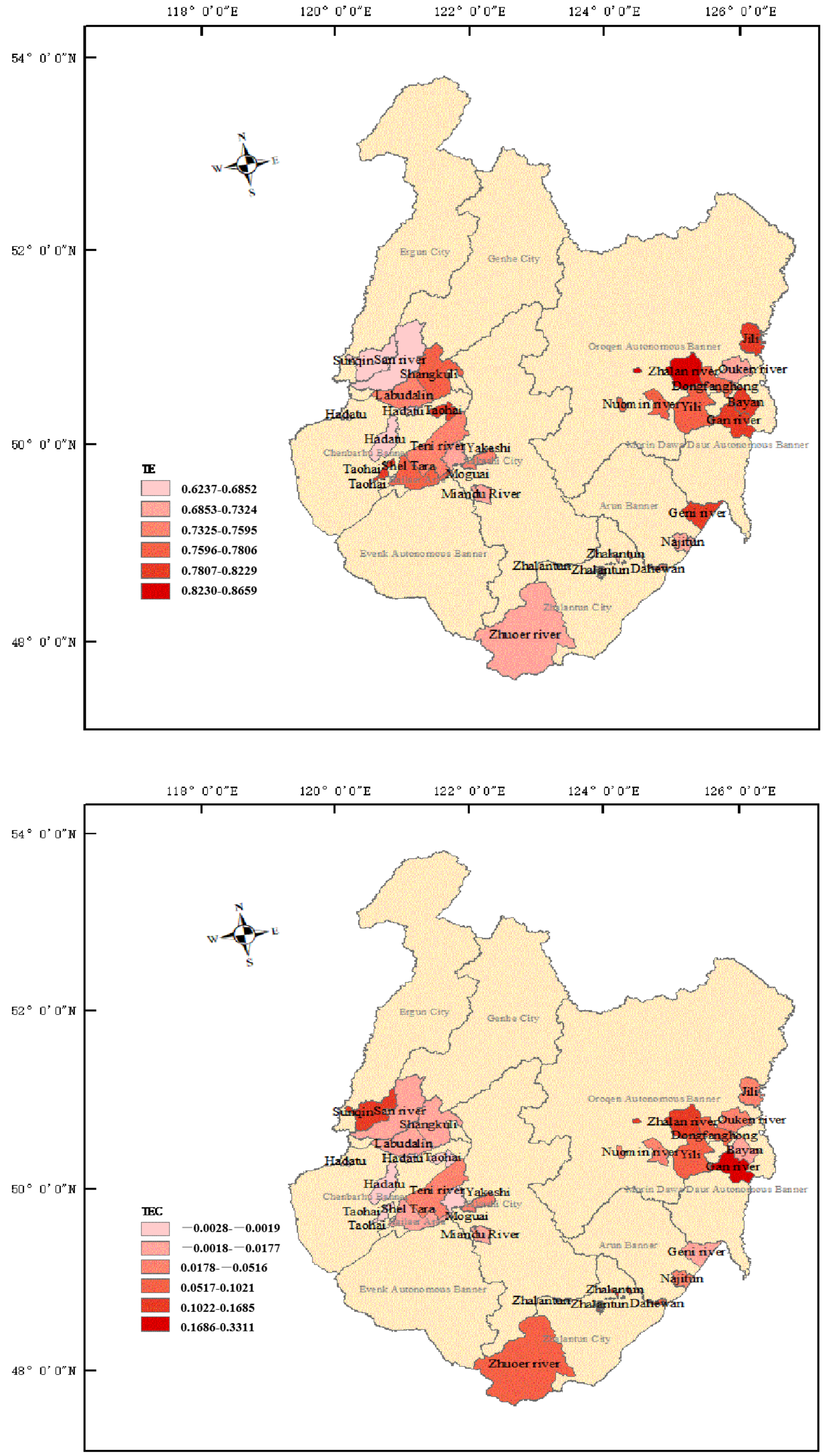

Figure 8. Average TE and TEC distributions of the 24 farms (2000–2019).

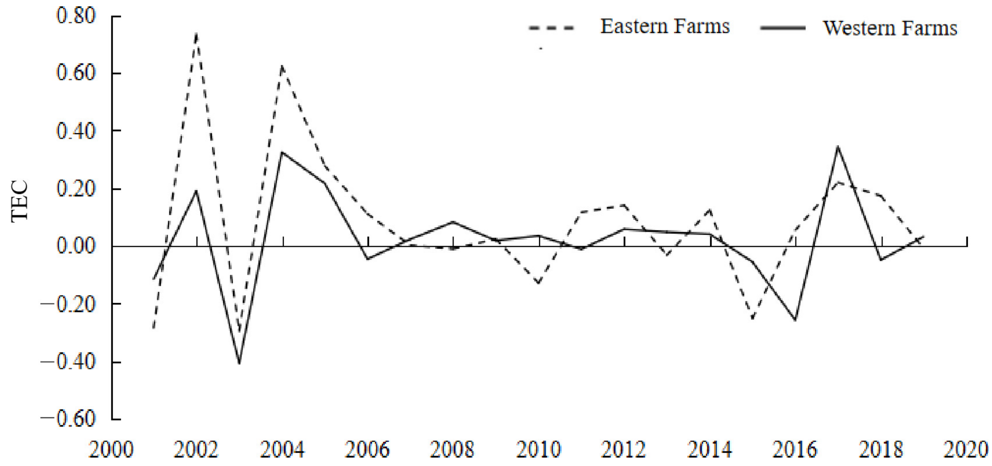

Figure 9. The TEC change trend (2000–2019).

4.2.4. Overall Characteristics of the TFPG

The changing trend of the TFPG of the two modes showed different characteristics. The TFPG in the Western Farms showed a steady declining trend with a rate of 7%/10a; the TFPG in the Eastern Farms showed a steady increasing trend, with a rate of 5.8%/10a (Figure 10).

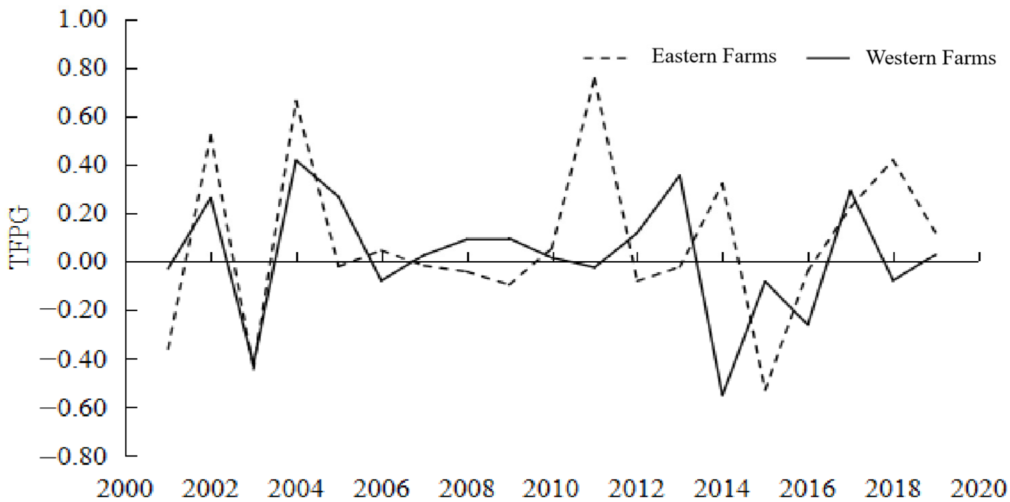

Figure 10. The TFPG change trend (2000–2019).

From 2000 to 2019, the average TFPG of the 13 farms in Eastern Farms was greater than that of the 11 farms in Western Farms. The average annual TFPG in the Eastern Farms, managed by the decentralized family, was 7.65%, and the average annual TFPG in the Western Farms, managed by the collective organizations, was 2.25%. That is caused mainly by the higher TP_b and TEC of the grain production in the DMCF mode than those in the UMCO mode. Among the 24 farms, the Zhalan river farm in Eastern Farms has the highest TFPG, and the Hadatu farm in Western Farms has the lowest TFPG, as shown in Figure 11. Another possible reason is that the extreme climate has more impact on the UMCO farms than on the DMCF farms. Due to the limitation of funds, the DMCF farms are unable to purchase agricultural machinery with large investments, and prefer to adopt technical options, such as improved varieties and fertilizers, to save farmland, in order to increase the output. These technologies that increase the land productivity are flexible in application and have a prominent role in mitigating the impact of the extreme climates on food security. However, in the face of extreme climate shocks, the flexibility of the production adjustment and the enthusiasm of farm employees in the UMCO farms, which are more dependent on the capital-intensive technologies, such as a large infrastructure and agricultural machinery, are less than those in the DMCF farms.Therefore, the extreme climate has a greater negative impact on the TFPG of the grain production in the UMCO mode. Prior to the merger of the group, especially before 2010, the TFPG of the UMCO farms was higher than that of the DMCF farms. After the group merger, the TFPG of the DMCF farms was significantly higher than that of the UMCO farms. It shows that the management mode of large farms co-ordinate small farms, formed with the merger of the agricultural reclamation group, not only strengthened the overall function of the collective organizations in the infrastructure construction, public services, product sales, and other aspects, but also effectively mobilized the enthusiasm of family management.

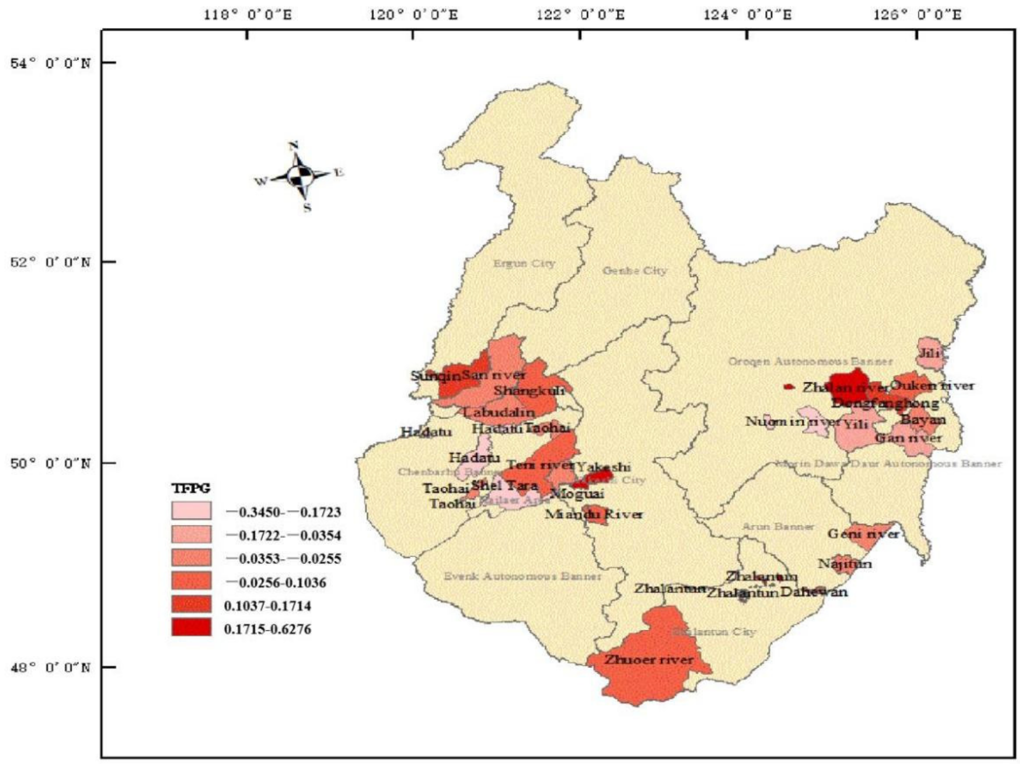

Figure 11. Average TFPG distribution of the 24 farms (2000–2019).

The comparison results of the TFPG, TP, SRC, and TEC, between the DMCF and UMCO modes in the Hulunbuir Agricultural Reclamation Group, are shown in Table 6.

Table 6. The calculation results of the various indexes under the two kinds of land allocation modes.

Indicators	Land Management Modes	
	13 Farms in Eastern Farms (DMCF)	**11 Farms in Western Farms (UMCO)**
TFPG	higher, 7.65%	lower, 2.25%
TP	higher, 1.99%; affected by TP_b; stable	Lower,0.43%; affected by the TP_n; declining
TE and TEC	Higher in the TE and the TEC; 78% and 8.29%	Lower in the TE and TEC; 73% and 2.39%
SRC	Lower, −2.63%	higher, −0.57%

5. Conclusions and Recommendations

With the acceleration of industrialization and urbanization in China, people pay more and more attention to the efficiency of land use. The absolute amount of agricultural land and its production capacity play a decisive role in the national food security. In the process of the farmland system reforms, agricultural land is also accelerating its transfer. The impact of the scale change caused by land transfer on the TFPG has attracted much attention, but there is little literature that deeply focuses on the change of farmland management modes caused by the land transfer, which also has an impact on the agricultural TFPG. That may be because it is difficult to find out the varied management modes with a similar natural environment, institutional environments, production organization, and management conditions. Fortunately, we found the Hulunbuir Agricultural Reclamation Group with farms which have similar external conditions and two agricultural land management modes: the collective unified management and the decentralized household management. In this paper, with the translog function and the SFA model, we calculated and compared the TP, SRC, TEC, and TFPG of the grain production, to acquire the specific technology progress condition of the farms in the UMCO and DMCF modes, using data from 24 farms of the Hulunbuir Agricultural Reclamation Group. The main results are as follows:

In terms of the cumulative changes of the narrow technological progress, the TP in the UMCO mode changes with the inverted U-shape, and is mainly driven by a neutral technological progress; the TP in the DMCF mode changes with a steady rising trend, driven more by the biased technological progress. From the change in the SRC, the advantage of the UMCO mode is stronger than that of the DMCF mode. On the one hand, the farmland scale in the UMCO mode is larger than that in the DMCF mode, which is more conducive to the production of large agricultural machinery, improved labor production efficiency and land utilization rate. On the other hand, the UMCO mode has a stronger construction and coordination ability of the public infrastructure and its services.

In general, with the continuously improving agricultural technology and management levels, the TE for both modes shows an increasing trend. In contrast, the farm in the DMCF model adopts a fine-grained management, which further promotes its technological efficiency. Generally speaking, the TFPG in the DMCF mode is greater than that in the UMCO mode, mainly because of the high TP_b and TE in the DMCF farms. Another possible reason is that the extreme climate has more impact on the UMCO farms than on DMCF farms.

By comparing the technological progress rate of the grain production under the two land management modes, it was found that they have their advantages and disadvantages in promoting technological progress. Based on the above research conclusions, this paper draws the following policy implications: Firstly, the guarantee mechanism of scientific and technological innovations should be improved to ensure the application, protection, and management of the agricultural scientific and technological achievements, transform the scientific and technological achievements into market competition advantages, mobilize the social resources to invest in scientific and technological innovation through the benefits return mechanism, and further improve the quality of the agricultural scientific and technological innovations. Secondly, taking full advantage of the collective organizations in the public production and services, increasing the investment for the infrastructure construction with the government, market, and village collective funds, and saving the private investment costs to improve the land production efficiency. Thirdly, make full use of the agricultural insurance to improve the comprehensive agricultural production support ability, and the farmers' ability to deal with the extreme climate, effectively.

The study's exploration of the farmland management in the Hulunbuir Agricultural Reclamation Group provides an example and some suggestions for the farmland management of other farm reclamation regions and also other developing countries where farmland allocation and management are expected to a achieve high grain production. The study also has some shortcomings that deserve further exploration. First, during the investigation of the Hulunbuir Agricultural Reclamation Group, the input costs of labor, fertilizer, machinery, and seeds in the 13 farms in Eastern Farms, did not have detailed statistics, so this study did not calculate the resource allocation efficiency of the Hulunbuir Agricultural Reclamation Group. In addition, the universality of the conclusions obtained from the case study still need more empirical testing. Second, the basic assumption of Pareto's optimal resource allocation, is that farmers have the complete economic behavior and the factor market can achieve complete competition. However, these strong assumptions are difficult to achieve for China's grain market, where production is part-time, and policy is strong. In other words, the guiding effect of the research results on the real production technology in the context of a fully competitive market, depends on whether the development of China's grain market is more market-oriented or more policy-oriented.

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