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Research on Agricultural Machinery Services for the Purpose of Promoting Conservation Agriculture: An Evolutionary Game Analysis Involving Farmers, Agricultural Machinery Service Organizations and Governments

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Abstract: Agricultural machinery services are an important guaranteed way to promote Conservation Agriculture. It is of great significance to study how to encourage farmers to choose agricultural machinery services to promote the standard implementation of Conservation Agriculture technology. In order to promote the implementation of Conservation Agriculture and improve the supply of agricultural machinery services, this paper identifies the stakeholders of normative Conservation Agriculture technology adoption behavior and the relationship between agricultural machinery service organizations, farmers and agriculture-related governments. An evolutionary game model was established to evaluate the decision-making characteristics of tripartite behavior and simulate the evolution trend of stakeholder behavior. The results show that agriculture-related governments, agricultural machinery service organizations and farmers can achieve evolutionarily stable strategies. The punishments and subsidies of agriculture-related governments and the supervision cost of all links of agricultural machinery social service organizations can significantly affect the behavior strategies of the three parties. The government set up reasonable subsidy and punishment mechanisms, and the agricultural machinery service organization controls the supervision cost of all links to ensure the stability of the three-party behavior strategy. This study provides theoretical guidance for scientific decision making and active cooperative development of the government, farmers and agricultural machinery service organizations and lays a foundation for countermeasures and suggestions to further promote farmers' implementation of Conservation Agriculture technology.

Keywords: Conservation Agriculture; agricultural machinery socialization service; evolutionary game; government management

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1. Introduction

The socialization of agricultural machinery services is an important part of the socialization of agricultural services as a whole [1]. With the progress of modern agricultural science and technology, the process of agricultural mechanization has been developed, and the technology and equipment applied in agriculture are increasingly improved under the support of science and technology [2]. In the past, traditional agricultural cultivation relied on labor and semi-mechanical equipment, production efficiency was low and farmers could not be freed from heavy production activities [3]. With the prominent issue of land degradation and the proposal of sustainable food production, the Food and Agriculture Organization of the United Nations has proposed that Conservation Agriculture techniques be promoted to farmers. Conservation Agriculture technology is an improvement of traditional farming technology, which requires the combination of agricultural machinery and agronomy and is considered a sustainable agro-ecological method of resource-saving agricultural production [4]. However, for countries with the characteristics of small farmers in large countries, such as China, the current rural areas are faced with labor shortages and a low prevalence of agricultural machinery and experience problems such as farmers being unable to work and being unable to move [5]. So, "who will farm and how to farm" is a practical problem that needs to be solved at present. The development of agricultural machinery service organizations is just a practical way to effectively alleviate the bottlenecks of the rural labor force and promote an organic connection between small farmers and modern agriculture [6]. The socialized service of agricultural machinery refers to the socialized service subject that outsources some or all links of agricultural production, such as cultivation, planting, prevention and harvesting, to specialized management on the basis of not changing the land contract management rights [7]. The socialized service of agricultural machinery can not only promote the specialization, standardization and intensification of agricultural production processes, but it can also become a "pioneer army" to promote the application of advanced and applicable technologies through the function of agricultural machinery carriers [8]. It has realized the rapid improvement of new mechanization technology in key production links of crops, especially further deepening, experimentation, demonstration and promotion of protective agricultural technology, which has promoted new supporting technologies of agricultural mechanization and made ecological mechanization technologies such as mechanical subsoiling, straw returning and precision seeding widely used [9]. Therefore, it is of great significance to develop the social service of agricultural machinery, promote the effective connection between small farmers and modern agriculture and encourage the promotion and implementation of Conservation Agriculture and other technologies.

In recent years, Conservation Agriculture has developed rapidly around the world, and Conservation Agriculture technology has been promoted in more than 100 countries [9]. In Asia, the FAO has implemented Conservation Agriculture projects in countries such as China, India, Kazakhstan and Uzbekistan [4]. Meanwhile, China's Northeast Black Soil Conservation Agriculture Action Plan Implementation Guidance stipulates that the protective agricultural technology operation process requires following the first straw mulching to avoid bare wintering of farmland, then no-tillage sowing to complete ditching, sowing, fertilization, suppression and other compound operations all at once, reducing soil movement as much as possible. In order to better promote and popularize the implementation of Conservation Agriculture technology, the Chinese government has introduced relevant subsidy policies [10]. For example, under the premise of sufficient straw cover, it is necessary to implement low-tillage and no-tillage operations; that is, each link must be guaranteed to be completed in accordance with the operating standards, and in this case, the agricultural machinery social service subject is given a subsidy of 20–40 CNY/mu [11]. This requires agricultural machinery operators at all stages to implement technologies in accordance with policies and regulations to ensure appropriate subsidy funds [12].

After decades of experimental research and demonstration application, the application of Conservation Agriculture has been proven to be feasible in China [9]. However, questions remain about the standardization and effectiveness of Conservation Agriculture practices [13]. Due to the perspective of China's kinship society and farmers' rational attitudes, farmers sometimes choose different links of implementing Conservation Agriculture technology from multiple service organizations according to the price of service providers or their kinship relationships when purchasing Conservation Agriculture technology services [14]. This situation may lead to the non-standard operation of previous agricultural machinery operators, which causes subsequent agricultural machinery operators to not receive due policy subsidies, and the agricultural machinery service organizations will shift their responsibilities to each other [15]. At the same time, poor technical results due to non-standard and mismatched operation links will make farmers question the protective agricultural technology and affect its further implementation and promotion. Therefore, how to promote farmers choosing the socialized service organization of agricultural machinery to complete the implementation of all aspects of Conservation Agriculture, so that the socialized service organization of agricultural machinery can complete the implementation of technology in accordance with the policy requirements, to obtain government subsidies, and to reduce the cost of technology adoption of farmers, is an urgent problem to be solved.

Agricultural machinery socialized service organizations providing whole-link technical services is one of the important ways to overcome the non-standard implementation of Conservation Agriculture technology [16]. The existing research points out that agricultural machinery service organizations are gradually developing toward specialization and alliances. For example, the Baiwen Agricultural Machinery Professional Cooperative in Jilin Province of China established the agricultural machinery service alliance, integrating 13 agricultural machinery cooperatives into its own service alliance. By providing a comprehensive range of technical implementation services, this alliance likely aims to support local farmers throughout the agricultural process. In summary, promoting cooperation among agricultural machinery service providers to offer the whole link of comprehensive technical services is crucial for enhancing the standardization and effectiveness of Conservation Agriculture [17,18]. This approach also fosters greater collaboration and enthusiasm among various stakeholders involved in agricultural activities. Such initiatives play a vital role in advancing Conservation Agriculture and ensuring sustainable agricultural development.

The existing research on the socialized service of agricultural machinery mainly studies two aspects: single-service subjects and multi-service subjects. The research on the single-service subject category mainly commences with the supply and demand of the market, analyzes and compares the differences in the supply and demand structure of agricultural machinery social services from the perspective of farmers, and points out that the service decision of farmers is affected by factors such as resource allocation efficiency, geographical environment, market capacity, and subject type [19]. The aim is to explore and resolve the imbalance between supply and demand in the total amount and structure of services. The research of multi-service subjects mainly focuses on the decision-making influencing conditions of ordering behavior between farmers and service organizations within the context of government involvement. Some scholars have explored the interest correlation mechanism between farmers and agricultural machinery service organizations from the perspective of game theory, and contend that there is always a relationship of both confrontation and cooperation between the two, with the confrontation aspect outweighing the cooperative one [20]. Furthermore, there are also studies addressing the issue of imperfect contracts between farmers and service organizations, and conclusions have been drawn. In agricultural production, only when all production links are provided by the same agricultural machinery service organization can problems such as responsibility evasion of multiple service organizations be avoided [21]. In the research on the promotion of agricultural machinery services by government policies, it is concluded that in future agricultural production, the government incentive mechanism should pay attention to the guidance of the situation, in particular the two aspects of interest-driven and institutional environments, and shift the government's subsidies for agricultural production from the adoption of a single-service link and the adoption of multiple links to the adoption of all links [22,23].

In summary, the existing research has laid a solid foundation for the research of this paper. However, research on promoting the implementation of agricultural machinery social services is rarely conducted by focusing on the integration of multiple stakeholders involved in supply and demand into a cohesive system. Furthermore, there is a scarcity of studies examining the integrity and standardization of technical operations demanded by agricultural machinery service providers within the context of technology adoption. In reality, due to the 'small and scattered' characteristics of Chinese small farmers, they have long been free at the edge of the market and are in a weak position in the market transaction game [24]. Due to information asymmetry, they do not have the ability to bargain or select when purchasing agricultural machinery services. Given farmers' rational consumption psychology and their reluctance to take on additional agricultural risks, as well as their social ties [14,25], they pay more attention to the service price or the relationship with the service provider when purchasing agricultural machinery services. As a result, farmers frequently select multiple agricultural machinery service organizations to handle various aspects of their agricultural production operations. In this case, it will lead to the problem of poor technical effects caused by the improper connection of technologies implemented by agricultural machinery service organizations, which will affect the promotion of agricultural machinery services and new technologies [26]. This issue is particularly prominent in the context of the current global implementation of Conservation Agriculture technical norms. In order to solve this problem, based on previous studies, this paper proposes a three-in-one two-way interaction mechanism composed of government, farmers and agricultural machinery service organizations. From a stakeholder perspective, this study identifies the key participants involved in Conservation Agriculture service procurement within agricultural production. It clarifies the roles and cooperation pathways of each entity. Employing evolutionary game theory, it constructs a tripartite evolutionary model involving agriculture-related governments, farmers, and agricultural machinery service organizations. Through simulation and discussion, it analyzes the decision-making behaviors of these three groups during the promotion of social agricultural machinery services, revealing strategies that maximize their respective utilities. Furthermore, the study fosters greater cooperation enthusiasm among agricultural machinery service stakeholders and addresses issues stemming from opportunistic behaviors that could otherwise impede overall cooperative development.

The main contributions of this study are as follows: (1) We propose a cooperative development framework that integrates agricultural-related governments, farmers in need of agricultural machinery services, and agricultural machinery service organizations into a complex system. At the same time, the government serves as the backdrop to provide services such as supervision and management and policy support, thus avoiding the separation of agricultural machinery service demand and supply behavior from the market mechanism in the past. It can more effectively integrate system resources and optimize system cooperation efficiency. (2) Introducing the consumption psychological factors of farmers into the game model can effectively improve the scientific decision-making of farmers and agricultural machinery service providers. (3) Through system simulation and sensitivity analysis, this study identifies the key factors that affect each participant's strategic choice under different supervision policies.

The remaining sections of this paper are structured as follows: The second part discusses the relevance and application of the evolutionary game theory method, outlines the research problems, and establishes a tripartite evolutionary game model. This model is constructed by identifying stakeholders involved in the implementation of social services for agricultural machinery. In the third part, a tripartite replicated dynamic equation is introduced to analyze stable equilibrium strategies based on stakeholders' decision-making analysis and their respective interests and demands. In the fourth part, the evolutionary game process is simulated, and a detailed analysis is conducted on how changes in key simulation parameters influence the outcomes of the model. In the fifth part, the paper presents its conclusions, discussing the variations and outcomes of stakeholder strategies across different scenarios. It also provides recommendations based on these conclusions.

This study strives to address the conditions necessary for transitioning from complex interactions to collaborative cooperation among diverse stakeholders. Under government oversight, farmers can select agricultural machinery service organizations to deliver comprehensive technical support for Conservation Agriculture. This approach aims to optimize stakeholder benefits and mitigate the current challenge of low standards in Conservation Agriculture implementation. The paper intends to provide a theoretical foundation and policy guidance for enhancing stakeholder cooperation in agricultural machinery social services and advancing the standardization of Conservation Agriculture practices. Figure 1 depicts the research framework of this study.

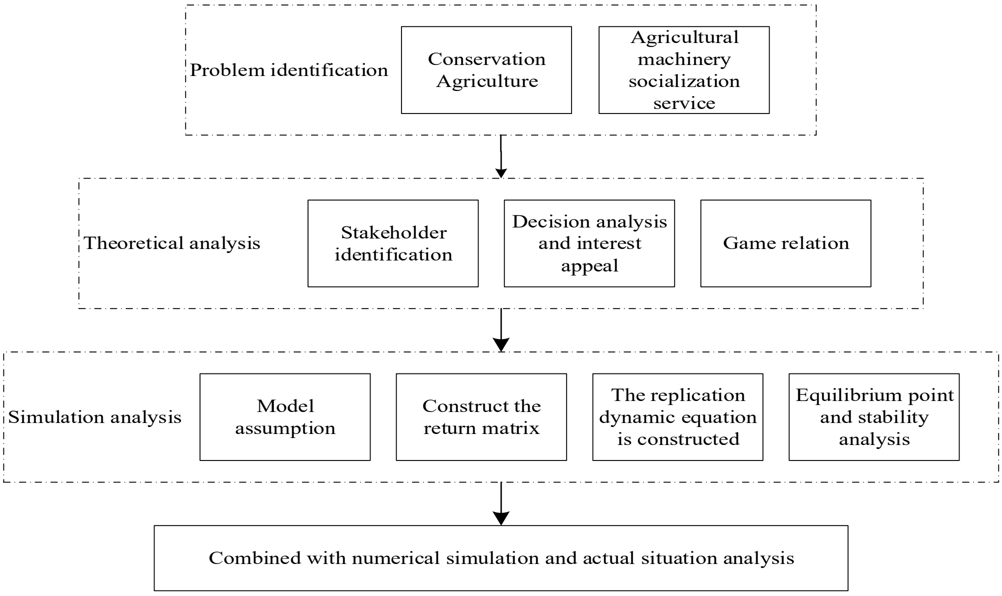


Figure 1. Research frame diagram of the article.

2. Theoretical Basis and Hypothesis of the Tripartite Evolutionary Game Model

2.1. Analysis of the Relationship between Stakeholders

The implementation of agricultural machinery socialized services involves a complex negotiation process, requiring continuous interaction and repeated thinking and decision-making among multiple subjects. It is necessary to understand the behavioral decision-making characteristics and dynamic interaction of stakeholders such as government, agricultural machinery service organizations and farmers [16]. The three stakeholders form an external interaction cycle and an internal decision-making game cycle. In the interactive external circulation, the agricultural machinery service organization responds to the policies formulated by the government to mobilize farmers to adopt services. The agricultural machinery service organization bears the cost of agricultural production while obtaining government policy subsidies and the service fees paid by farmers. The decision-making game among the three stakeholders constitutes an internal cycle [27,28]. Farmers will decide whether to choose all aspects of agricultural machinery services according to their own wishes and thinking [18,29]. Service organizations also have a choice to provide all aspects of agricultural machinery services or single and multi-link services [17]. Agriculture-related governments will supervise and manage agricultural machinery service organizations, evaluate the rewards and punishments for service organizations based on the conclusions obtained from supervision, and plan the level of supervision and management for the next year based on the conclusions obtained from supervision [30,31].

As regulators and managers, agriculture-related governments will promulgate relevant incentive policies to enhance the opportunities for agricultural machinery service organizations to provide services and increase the willingness of farmers to adopt corresponding services [32,33]. On the one hand, the government provides corresponding financial subsidies to organizations and farmers who actively engage in agricultural machinery services, and the financial support for farmers is reflected in the reduction and exemption of operating costs by agricultural machinery service organizations [18]; on the other hand, the government will also give some penalties to farmers for non-standard implementation of Conservation Agriculture and bad behavior, such as in the straw processing link, which occurs when the implementation of protective operation technology in straw processing link operation is not standardized by service organizations, which is reflected in the cancellation of the government's original financial subsidies to service organizations [34,35]. When the agriculture-related governments carry out loose supervision, there are no rewards or punishments for agricultural machinery service organizations and farmers.

Agricultural machinery service organizations are the main suppliers of agricultural machinery services. As the specific implementers of Conservation Agriculture, agricultural machinery service organizations aim to maximize the overall interests of the organization as the ultimate goal [36]. Agricultural machinery services determine the types of services they offer according to the type of market demand. At the same time, agricultural machinery service organizations will have additional supervision and management costs due to the need to monitor the quality of service operations and management coordination service associations [18]. From an economic perspective, on the one hand, agricultural machinery service organizations will provide specialized agricultural machinery services according to the needs of farmers and reduce farmers' operating costs through large-scale operations [37]. On the other hand, agricultural machinery service organizations also provide the necessary conditions for the promotion and implementation of the technology promoted by the government.

Farmers are the demanders of agricultural machinery services. In addition to their own conditions, the demand for agricultural machinery services is also influenced by economic interests. Before farmers adopt protective agricultural technology, there will be some uncertainty about the effectiveness of its implementation. At the same time, they also subconsciously doubt the quality of agricultural machinery services for implementing Conservation Agriculture and worry that the quality of agricultural machinery services may affect crop yields [38], so they dare not rashly adopt an agricultural machinery service organization to implement all aspects of agricultural machinery services. If farmers can use all aspects of the service of an agricultural machinery service organization, in order to obtain government subsidies, agricultural machinery service organizations will standardize the implementation of each link of protective agricultural technology. Protective agricultural technology has positive externalities. The standardized implementation of this technology can bring environmental and ecological benefits to agriculture-related governments [39]. At the same time, a farmer's choice to purchase agricultural machinery services will also bring economic benefits to agricultural machinery service organizations.

According to the above analysis, we obtain the relationship between the stakeholders in agricultural machinery socialization services, as shown in Figure 2. Achieving a balance of interests among the three stakeholders helps mitigate opportunistic behaviors, fostering overall cooperative development and promoting the standardized implementation of Conservation Agriculture [15,40].

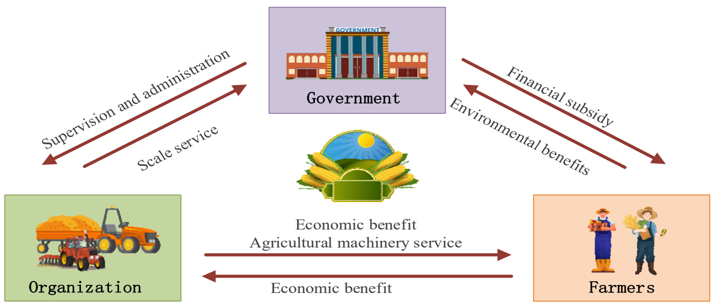


Figure 2. Logical relationship diagram of the three-party evolutionary game model.

2.2. Hypotheses

To analyze the above conditions, this paper puts forward the following assumptions on the behavior and interests of participants in the evolutionary game model. The eight combinations that can be obtained based on different strategies of various stakeholders are shown in Figure 3.

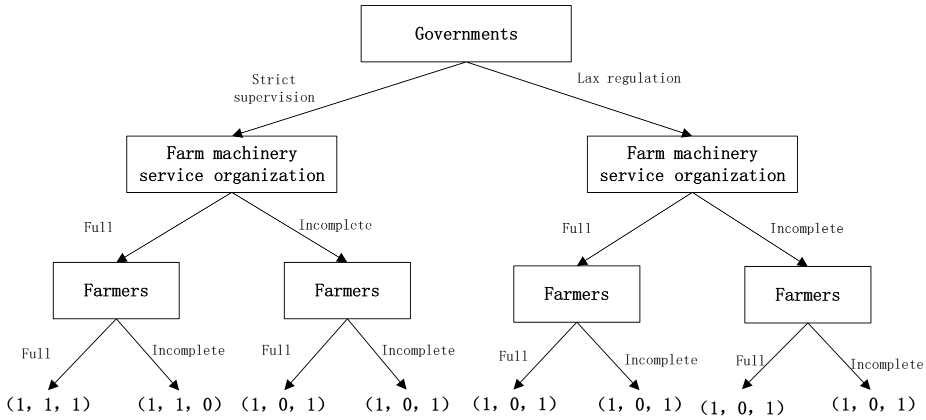


Figure 3. The decision tree of stakeholders.

H1. There are three participants in the evolutionary game. Agriculture-related governments, agricultural machinery service organizations and farmers face two strategic choices at the same time [41–43], as shown in Table 1. Among them, the full-link agricultural machinery operation service involves the land managed by the farmers in the year is handed over to the service organization for operation, and the agricultural machinery service organization is responsible for the implementation of the whole process from cultivation to sales. Non-full-link agricultural machinery operation services are self-managed by farmers. Agricultural machinery service organizations provide some links of mechanized services for farmers, and farmers pay corresponding service fees to agricultural machinery service organizations.

Table 1. Strategy selection of agricultural machinery service stakeholders in the evolutionary game.

Participant	Selection	Strategy
Agriculture-related government	1	Strict management of the provision of agricultural machinery operation services
	2	Loose management of providing agricultural machinery operation services
Agricultural Machinery Service Organization	1	Provide all aspects of agricultural machinery operation services
	2	Provide non-all aspects of agricultural machinery operation services
Farmers	1	Select all aspects of agricultural machinery operation services
	2	Choose not all aspects of agricultural machinery operation service

H2. Agriculture-related governments, agricultural machinery service organizations and farmers are all bounded rational participants, and all participants in the game are in the initial stage. In the process of game evolution, each participant's strategy will dynamically adjust with the passage of time, once the optimal strategy is stabilized. Additionally, other agents that may potentially impact the participants are not considered in this analysis

H3. In the game process, each player aims to maximize their benefit. An agricultural machinery social service organization is a service subject that can outsource some or all of the links of agricultural production such as farming, planting, prevention and harvesting to specialized management. Its spatial strategy is $\alpha = (\alpha_1, \alpha_2)$ = (provide all aspects of service, provide non-all aspects of service). The first choice for agricultural machinery service providers is to offer all links of agricultural machinery operation services, assuming that the probability of agricultural machinery service providers providing all links of agricultural machinery operation services is x. The second choice is to provide non-all links of agricultural machinery operation services, assuming that the probability of agricultural machinery service organizations providing all non-all links of agricultural machinery operation services is 1 − x, $x \in [0,1]$. The role of the farmer is the subscriber to the service, and its strategy is $\beta = (\beta_1, \beta_2)$ = (choose to use all aspects of agricultural mechanization services, choose to use non-all aspects of agricultural mechanization services). The first choice of farmers is to choose all aspects of agricultural machinery operation services, assuming that the probability of farmers choosing all aspects of agricultural machinery operation services is y. The second choice of farmers is to choose non-all aspects of agricultural machinery operation services, assuming that the probability of farmers choosing non-all aspects of agricultural machinery operation services is 1 − y, y ∈ $[0,1]$. Agriculture-related governments not only promote new technologies but also regulate them. Their strategy is $\gamma = (\gamma_1, \gamma_2)$ = (Strict management, loose management). The two choices of the agriculture-related government are to either manage the agricultural machinery service organization with strict oversight or with a more relaxed approach. Assuming that the probability of strict management of the agricultural machinery service organization by the agriculture-related government is z, the probability of opting for loose management is 1 − z, z ∈ $[0,1]$.

H4. An agricultural machinery service organization obtains R_1 from service. The mechanical cost of the service organization providing services for farmers is C_1. If the service organization provides all aspects of services, then they need to pay additional supervision and management costs C_{1s}, such as service supervision and mechanical scheduling.

H5. The basic operating income of farmers is recorded as R_2. Farmers' income growth is recorded as R_{2i} when choosing all aspects of the service. When choosing non-full-link services, the reduction in farmers' income is recorded as R_{2d}. However, for farmers who choose all aspects of service, there is a risk expectation C_2.

H6. When the government opts for strict management, it imposes constraints on the agricultural machinery service organization, safeguards the interests of farmers, and brings social benefits to the government, which is recorded as R_g. If the agricultural machinery service organization provides all aspects of services, the government policy reward is P. If the service organization provides non-full-link services, they will not receive rewards and may even be punished as F. The cost incurred by agriculture-related governments due to strict management is recorded as C_{g1}. When the government chooses a loose management strategy, the input cost is recorded as C_{g2},$(C_{g2} < C_{g1})$.

Based on the above assumptions and the income mix of each stakeholder, the payment matrix of the three-way game can be constructed, as shown in Table 2.

Table 2. The payment matrix of the game mode is established among the game subjects.

Strategy Combination	Income of Agricultural Machinery Service Organization	Income of Farmers	Income of Agricultural-Related Governments
Provide all links, choose all links, strict management	$R_1 - C_1 - C_{1s} + P$	$R_2 + R_{2i} - R_1 - C_2$	$-C_{g1} - P + R_g$
Provide all links, select all links, loose management	$R_1 - C_1 - C_{1s}$	$R_2 + R_{2i} - R_1 - C_2$	$-C_{g2}$
Provide all links, choose not all links, strict management	$R_1 - C_1 - C_{1s}$	$R_2 - R_{2d} - R_1$	$-C_{g1} + R_g$
Provide all links, choose not all links, loose management	$R_1 - C_1 - C_{1s}$	$R_2 - R_{2d} - R_1$	$-C_{g2}$
Provide not all links, choose all links, strict management	$R_1 - C_1 - F_1$	$R_2 + R_{2i} - R_1 - C_2$	$-C_{g1} + F + R_g$
Provide not all links, choose all links, loose management	$R_1 - C_1$	$R_2 + R_{2i} - R_1 - C_2$	$-C_{g2}$
Provide not all links, choose not all links, strict management	$R_1 - C_1 - F_1$	$R_2 - R_{2d} - R_1$	$-C_{g1} + F + R_g$
Provide not all links, choose not all links, loose management	$R_1 - C_1$	$R_2 - R_{2d} - R_1$	$-C_{g2}$

2.3. Model Construction

Taking into account the aforementioned premises, this paper delves into the respective interests of agricultural machinery service organizations, farmers, and agricultural-related governments under diverse strategic alignments. It subsequently introduces a three-party mixed-strategy game matrix, illustrated in Table 3, where the notations within the table are rooted in the assumptions meticulously outlined in Section 2.2. This approach facilitates a comprehensive understanding of the intricate interplay between the stakeholders and their strategic decisions. When the agricultural machinery service organization chooses to provide all aspects of the service strategy, farmers incur no additional expenses beyond the cost of purchasing the service. And agriculture-related governments will enforce strict supervision. At this point, the income of agricultural machinery service organizations is $R_1 - C_{1h} + W_1$, the income of farmers is $R_2 + R_{2i} + W_2$, and the income of agriculture-related governments is $-C_3 - W_1 - W_2 + S_3$. By applying the above assumptions, the profit matrix of the three-party mixed-strategy game can be obtained.

Table 3. Revenue matrix of the three-party mixed-strategy game.

		Agriculture-Related Government	Agricultural Machinery Service Organization: Provide All Aspects of Agricultural Machinery Operation Services (x)	Agricultural Machinery Service Organization: Provide Non-All Aspects of Agricultural Machinery Operation Services (1 − x)
Farmers	Select all aspects of agricultural machinery operation services (y)	Strict management (z)	$R_1 - C_1 - C_{1s} + P$ $R_2 + R_{2i} - R_1 - C_2$ $-C_{g1} - P + R_g$	$R_1 - C_1 - F_1$ $R_2 + R_{2i} - R_1 - C_2$ $-C_{g1} + F + R_g$
		Loose management (1 − z)	$R_1 - C_1 - C_{1s}$ $R_2 + R_{2i} - R_1 - C_2$ $-C_{g2}$	$R_1 - C_1$ $R_2 + R_{2i} - R_1 - C_2$ $-C_{g2}$
	Choose not all aspects of agricultural machinery operation service (1 − y)	Strict management (z)	$R_1 - C_1 - C_{1s}$ $R_2 - R_{2d} - R_1$ $-C_{g1} + R_g$	$R_1 - C_1 - F_1$ $R_2 - R_{2d} - R_1$ $-C_{g1} + F + R_g$
		Loose management (1 − z)	$R_1 - C_1 - C_{1s}$ $R_2 - R_{2d} - R_1$ $-C_{g2}$	$R_1 - C_1$ $R_2 - R_{2d} - R_1$ $-C_{g2}$

3. Model and Analysis

3.1. Replication Dynamic Analysis

According to the selection probability of stakeholders in Hypothesis 3 and the income matrix in Table 3, we can derive the expected return model for participants. We assume E_{ij} and $\overline{E_i}$ represent the expected income and average income of the participants, respectively. Here, $i = 1, 2, 3$, respectively, represent agricultural machinery service organizations, farmers and agriculture-related governments, and $j = 1, 2$ represent two different decisions available to participants. The expected benefits of different choices for agricultural machinery service organizations, farmers and agriculture-related governments are as follows:

$$E_{11} = yz(R_1 - C_1 - C_{1s} + P) + (1-z)y(R_1 - C_1 - C_{1s}) + (1-y)z(R_1 - C_1 - C_{1s}) + (1-y)(1-z)(R_1 - C_1 - C_{1s}) \quad (1)$$

$$E_{12} = yz(R_1 - C_1 - F) + (1-z)y(R_1 - C_1) + (1-y)z(R_1 - C_1 - F) + (1-y)(1-z)(R_1 - C_1) \quad (2)$$

$$E_{21} = xz(R_2 + R_{2i} - R_1 - C_2) + (1-z)x(R_2 + R_{2i} - R_1 - C_2) + (1-x)z(R_2 + R_{2i} - R_1 - C_2) + (1-x)(1-z)(R_2 + R_{2i} - R_1 - C_2) \quad (3)$$

$$E_{22} = xz(R_2 - R_{2d} - R_1) + (1-z)x(R_2 - R_{2d} - R_1) + (1-x)z(R_2 - R_{2d} - R_1) + (1-x)(1-z)(R_2 - R_{2d} - R_1) \quad (4)$$

$$E_{31} = xy(-C_{g1} - P + R_g) + (1-y)x(-C_{g1} + R_g) + (1-x)y(-C_{g1} + F + R_g) + (1-x)(1-y)(-C_{g1} + F + R_g) \quad (5)$$

$$E_{32} = xy(-C_{g2}) + (1-y)x(-C_{g2}) + (1-x)y(-C_{g2}) + (1-x)(1-y)(-C_{g2}) \quad (6)$$

According to the above formula, the average expected return of the three participants can be obtained as follows:

$$\overline{E_1} = xE_{11} + (1-x)E_{12} \tag{7}$$

$$\overline{E_2} = yE_{21} + (1-y)E_{22} \tag{8}$$

$$\overline{E_3} = zE_{31} + (1-z)E_{32} \tag{9}$$

According to the expected returns of the three participants, the replication dynamic equation is calculated as follows:

$$F(x) = \frac{dx}{dt} = x(E_{11} - \overline{E_1}) = x(1-x)(yzP + zF - C_{1s}) \tag{10}$$

$$F(y) = \frac{dy}{dt} = y(E_{21} - \overline{E_2}) = y(1-y)(R_{2i} + R_{2d} - C_2) \tag{11}$$

$$F(z) = \frac{dz}{dt} = z(E_{31} - \overline{E_3}) = z(1-z)(C_{g2} - C_{g1} + F + R_g - xF - xyP) \tag{12}$$

3.2. Stability Analysis of Evolutionary Game Model

When the formulas (10), (11) and (12) are equal to 0, eight equilibrium points can be obtained: E1 (0,0,0), E2 (0,0,1), E3 (0,1,0), E4 (1,0,0), E5 (0,1,1), E6 (1,0,1), E7 (1,1,0) and E8 (1,1,1). Whether each of these equilibrium points is asymptotically stable is still uncertain. Only when the Nash equilibrium is satisfied can the evolutionary stable strategy (ESS) be realized. The asymptotic stability of the equilibrium point is determined by the Lyapunov criterion (indirect method). It first solves the Jacobian matrix and its eigenvalues. According to the Lyapunov indirect method [41], if the eigenvalues of the Jacobian J are negative, the equilibrium point is the evolutionarily stable strategy (ESS). The equilibrium point is unstable if at least one of the J matrices is positive. The J matrix has an eigenvalue with zero real part and the other eigenvalues are negative; at this time, the equilibrium point is critical and the stability cannot be determined by the sign of the eigenvalue. In order to analyze the trend of evolutionary stability among government, farmers and consumers, we establish the Jacobian matrix as shown in Equation (13). The eigenvalues of the Jacobian matrix are obtained by taking the first-order partial derivatives of F (x), F (y) and F (z) to x, y and z, respectively. The eigenvalues of each equilibrium point are shown in Table 4.

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{bmatrix} \tag{13}$$

$$J_{11} = (1-2x)(yzP + zF - C_{1s}) \tag{14}$$

$$J_{12} = xz(1-x)P \tag{15}$$

$$J_{13} = x(1-x)(yP + F) \tag{16}$$

$$J_{21} = 0 \tag{17}$$

$$J_{22} = (1-2y)(R_{2i} + R_{2d} - C_2) \tag{18}$$

$$J_{23} = 0 \tag{19}$$

$$J_{31} = z(1-z)(-yP - F) \tag{20}$$

$$J_{32} = -xz(1-z)P \tag{21}$$

$$J_{33} = (1-2z)(C_{g2} - C_{g1} + F + R_g - xF - xyP) \tag{22}$$

Table 4. Stability analysis of the equilibrium point.

Equilibrium Point	Eigenvalue	Stability
E1 (0,0,0)	$\lambda_1 = -C_{1s}$ $\lambda_2 = R_{2i} + R_{2d} - C_2$ $\lambda_3 = C_{g2} - C_{g1} + F + R_g$	(−,s,+) Unstable point
E2 (0,0,1)	$\lambda_1 = F - C_{1s}$ $\lambda_2 = R_{2i} + R_{2d} - C_2$ $\lambda_3 = C_{g1} - C_{g2} - F - R_g$	When $F < C_{1s},\ R_{2i} + R_{2d} < C_2,\ C_{g1} < C_{g2} + F + R_g$ is a asymptotically stable point.
E3 (0,1,0)	$\lambda_1 = -C_{1s}$ $\lambda_2 = C_2 - R_{2i} - R_{2d}$ $\lambda_3 = C_{g2} - C_{g1} + F + R_g$	(−,s,+) Unstable point
E4 (1,0,0)	$\lambda_1 = C_{1s}$ $\lambda_2 = R_{2i} + R_{2d} - C_2$ $\lambda_3 = C_{g2} - C_{g1} + R_g$	(+,s,s) Unstable point
E5 (0,1,1)	$\lambda_1 = P + F - C_{1s}$ $\lambda_2 = C_2 - R_{2i} - R_{2d}$ $\lambda_3 = -C_{g2} + C_{g1} - F - R_g$	(+,s,−) Unstable point
E6 (1,0,1)	$\lambda_1 = C_{1s} - F$ $\lambda_2 = R_{2i} + R_{2d} - C_2$ $\lambda_3 = -C_{g2} + C_{g1} - R_g$	When $F < C_{1s},\ R_{2i} + R_{2d} < C_2,\ C_{g1} < C_{g2} + R_g$ is a asymptotically stable point.
E7 (1,1,0)	$\lambda_1 = C_{1s}$ $\lambda_2 = C_2 - R_{2i} - R_{2d}$ $\lambda_3 = C_{g2} - C_{g1} + R_g - P$	(+,s,s) Unstable point
E8 (1,1,1)	$\lambda_1 = C_{1s} - P - F$ $\lambda_2 = C_2 - R_{2i} - R_{2d}$ $\lambda_3 = -C_{g2} + C_{g1} - R_g + P$	When $C_{1s} < P + F,\ C_2 < R_{2i} + R_{2d},\ C_{g1} + P < C_{g2} + R_g$ is an asymptotically stable point.

The Jacobian matrix can be used as the basis for determining evolutionary stability. At each equilibrium point, if all the eigenvalues J are less than 0, the equilibrium point is an evolutionarily stable strategy; if the eigenvalues of J are greater than 0, it is an unstable point; if one of the eigenvalues of J is greater than 0, it is a saddle point. Substituting the equilibrium point into Equation (13), the eigenvalues and positive and negative eigenvalues of the eight equilibrium points can be obtained, as shown in the table, where '+', '−' and 's' represent positive and negative eigenvalues greater than 0 and less than 0, respectively.

The sign of the eigenvalues of the Jacobian matrix at each equilibrium point is analyzed according to Table 4. When $F < C_{1s}$, $R_{2i} + R_{2d} < C_2$, and $C_{g1} < C_{g2} + F + R_g$, the sign of E2 (0,0,1) Jacobian matrix is '−, −, −', and E2 (0,0,1) is the evolutionary equilibrium point (ESS) of the system. At the same time, when $F < C_{1s}$, $R_{2i} + R_{2d} < C_2$, $C_{g1} < C_{g2} + R_g$, it is clear that E6 (1,0,1) is the evolutionary equilibrium point (ESS) of the system. When $C_{1s} < P + F$, $C_2 < R_{2i} + R_{2d}$, $C_{g1} + P < C_{g2} + R_g$, E8 (1,1,1) is also the evolutionary equilibrium point (ESS) of the system. According to the analysis in Table 4, it can be concluded that E2 (0,0,1), E6 (1,0,1), E8 (1,1,1) are evolutionary stable points (ESS) under certain conditions.

This strategic combination E8 (1,1,1)= (providing full process services, selecting full process services, and strict management) is a stable strategic combination by the agricultural socialized service supply and demand system which includes agricultural machinery service organizations, farmers and agriculture-related governments. However, when the cost of providing full-process services is too high (greater than the sum of non-full-process service costs, lobbying costs, other costs, and government rewards and punishments) and lobbying costs are greater (greater than the sum of farmers' speculative costs and government rewards and punishments), providing non-full-process services, selecting non-full-process services, and strict management will also be a stable strategic combination of the system. Obviously, the combination of strategies E2 (0,0,1) = (providing full-process services, selecting full-process services, and strict management) is superior to the combination of strategies (providing non-full-process services, selecting non-full-process services, and strict management). Therefore, agriculture-related governments need to punish agricultural machinery service organizations by providing non-whole process services. It will increase the cost of the agricultural machinery service organizations. Agriculture-related governments could improve the level of rewards and punishments, and promote the development of an agricultural service scale management system to the strategic combination of E6 (1,0,1) = (providing whole process services, selecting whole process services, strict management). These measures aim to provide strong support for the healthy development of agricultural production. At this point, in the three possible stable points E2 (0,0,1), E6 (1,0,1) and E8 (1,1,1), the combination strategy of E8 points is the optimal combination. However, the agricultural socialized service system is a complex system, and the influence of various factors on the main body of the system and the internal influence mechanism require further study.

4. Simulation Analysis of Evolutionary Game

In order to more intuitively and clearly reflect the behavior changes in agricultural machinery service organizations, farmers and agriculture-related governments under different numerical conditions, combined with the actual situation, Matlab2019 a was used for simulation. When the system evolves to the E8 (1,1,1) ideal state, the parameters need to meet the following conditions: $C_{1s} < P + F$, $C_2 < R_{2i} + R_{2d}$, $C_{g1} + P < C_{g2} + R_g$. Some parameters are valued by referring to the research of relevant scholars. The initial values for this paper are obtained in three ways. Firstly, through policy announcements from agriculture-related governments. In this part, we mainly consider the amount of government compensation for agricultural machinery. Secondly, according to the classical literature and China Statistical Yearbook, we summed up the relevant agricultural machinery service institutions to find conservation tillage land area data. Thirdly, the initial value is calculated through field investigation and expert consultation. We conducted field investigations and investigation in Harbin, Mudanjiang, Shuangyashan, Daqing and other places in Heilongjiang Province(for China), surveyed 89 farmers and 12 agricultural machinery service organizations on the spot, and interviewed agriculture-related government staff to obtain the original data. Through expert consultation, the estimated initial values were determined. The distribution of specific parameters is shown in Table 5, and the influence of changes in each parameter on the evolution process and results is discussed, respectively.

Table 5. Initial allocation of variable parameters.

Parameter	C_{1s}	C_2	C_{g1}	C_{g2}	P	F	R_{2i}	R_{2d}	R_g
Numerical Value	5	10	4	2	5	8	6	6	10

4.1. Effect of Initial Value on Strategy Evolution

In order to evaluate the evolution and stability under initial conditions, we need to set different initial probabilities and perform multiple evolution simulations to observe the evolution trajectory of the system. According to the setting method of Tian et al. and Huang et al., the actual initial probability is not all 0 or 1, but the initial probability of stakeholders is set to 0.1–0.9 [41,44], and the growth steps are 0.15, 0.1 and 0.2. However, considering that too dense evolutionary paths will affect the degree of image recognition, we have chosen to set the initial decision probability growth step to 0.15 [45] and conducted a total of 216 simulations. As Figure 4 illustrates, under the current policy of our country, the strategy ultimately converges towards stability at (1,1,1); that is, the agricultural machinery service organization chooses to provide all aspects of service, the farmers choose to use all aspects of service, and the government chooses strict management.

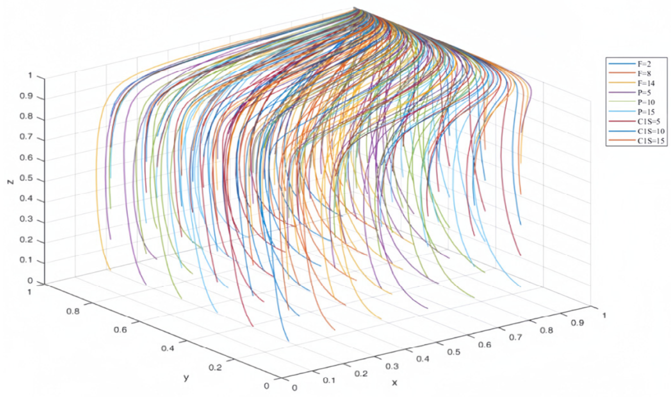


Figure 4. The evolutionary trajectory of the three-party game model in the actual situation.

The reason for this result is that China is vigorously promoting the socialized service of agricultural machinery throughout the entire process. The government promotes the development of this service by imposing certain penalties and offering subsidies, thereby achieving considerable results. Agricultural machinery service organizations can only obtain government subsidies and maximize their benefits if they implement all aspects of services according to policy requirements. Farmers use agricultural machinery service organizations to implement all aspects of Conservation Agriculture services, thereby ensuring the standardized implementation of protective agricultural technology. Only the standardized implementation of protective agricultural technology can achieve the economic benefits of the technology itself, and farmers will obtain the technical benefits that the technology should have, which also improves the possibility of farmers choosing the whole link of agricultural machinery services [46–48], such as increasing food production and reducing costs [49,50]. At the same time, the implementation of all aspects of agricultural machinery service organizations ensures the standardized implementation of Conservation Agriculture, and the standardized implementation shows good economic benefits, which will promote the further promotion of protective agricultural technology so that the government can finally realize the ecological benefits of sustainable development. Although agricultural machinery service organizations will generate additional supervision and management costs when providing full-link agricultural machinery services, under the strict supervision of current policies, agricultural machinery service organizations will receive government subsidies for providing full-link agricultural machinery services [51]. Failure to provide full-link agricultural machinery services may face punishment and force them to change to providing full-link agricultural machinery services.

4.2. Sensitivity Analysis under the Change in Government Reward and Punishment Intensity

The figure illustrates the probability of agricultural machinery service organizations, farmers and governments choosing to provide full-link agricultural machinery services, adopt full-link agricultural machinery services and strict management, respectively, with the unit of time being a year. Taking $(x_0, y_0, z_0) = (0.5, 0.5, 0.5)$ as an example, this paper observes the influence of the changes in punishment, subsidy and management cost on the evolution trend of the evolutionary game model.

4.2.1. Changes in Penalties

When the government's fines for agricultural machinery service organizations are set at 2, 8, and 14, respectively, by changing the parameter values, the evolutionary stability strategy of the participants is obtained, as shown in Figures 5 and 6. It can be seen from Figure 5 that the increase in F will accelerate the selection of full-link agricultural machinery services by agricultural machinery service organizations. It shows that a large punishment can stimulate the rural service organization, improve the probability of the agricultural machinery service organization to provide the whole link of agricultural machinery service, and make it stable at 1, so so as to realize the optimal decision of (1,1,1).

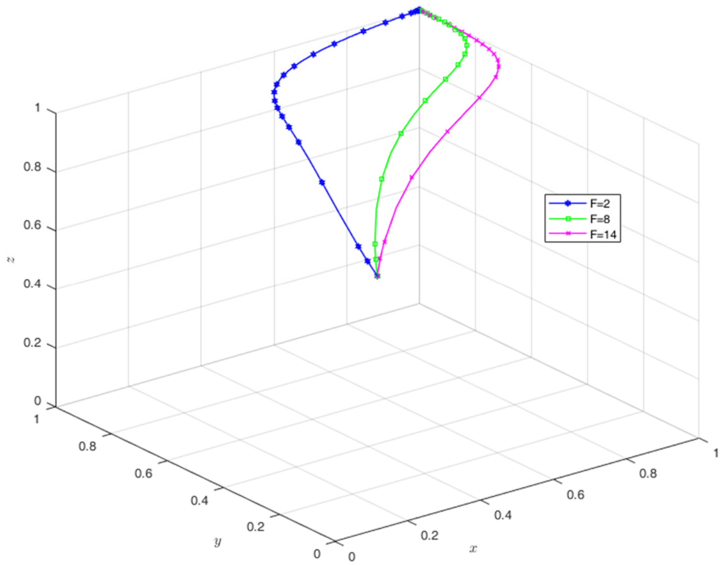
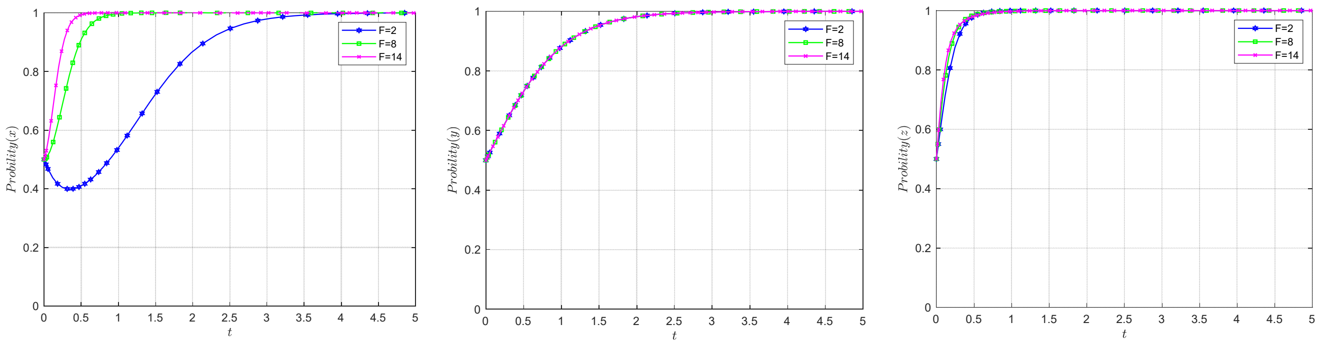


Figure 5. The sensitivity of F change in the three-party game model.



(**a**) Agricultural Machinery Service Organizations (**b**) Farmers (**c**) Agriculture-related government

Figure 6. Stakeholders' sensitivity to F change.

Combined with Figure 6, Figure 6a–c represent the impact of penalty value changes on agricultural machinery service organizations, farmers and the government, respectively. It can be seen that the increase in government punishment has little effect on farmers' behavior decision-making, but mainly affects the behavior decision-making of agricultural machinery service organizations. This further shows that under the current policy situation, it is advisable for the government to realize the behavior of agricultural machinery service organizations to provide full-link agricultural machinery services by adopting punishment measures. Therefore, considering the current situation, the government should increase or maintain the current punishment, which can not only further enhance the likelihood of agricultural machinery service organizations providing full-link agricultural machinery services, but also is conducive to the implementation of Conservation Agriculture.

4.2.2. Changes in Subsidies

By changing the parameter values, when the government's subsidies to agricultural machinery service organizations are set at 5, 10 and 15, respectively, the evolutionary stability strategies of the participants are obtained, as shown in Figures 7 and 8. It can be seen from Figure 7 that the increase in P will lead to fluctuations in the decision-making processes of agricultural machinery service organizations and governments. This shows that high subsidies do not enable agricultural machinery service organizations to provide stable services across all aspects of operation, nor can the government maintain strict management for a long time, resulting in instability in the entire system.

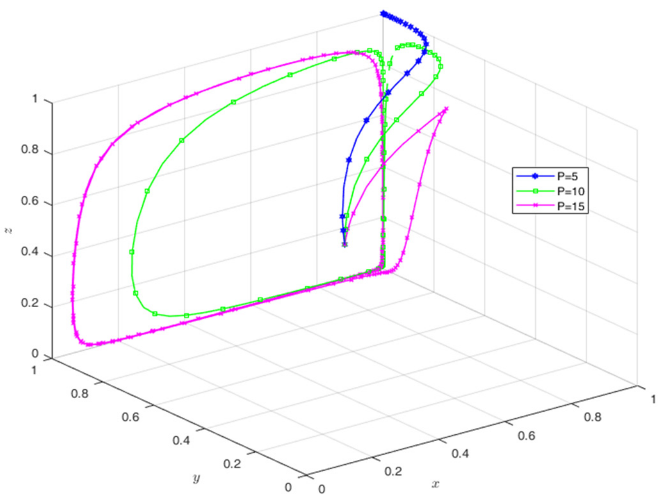
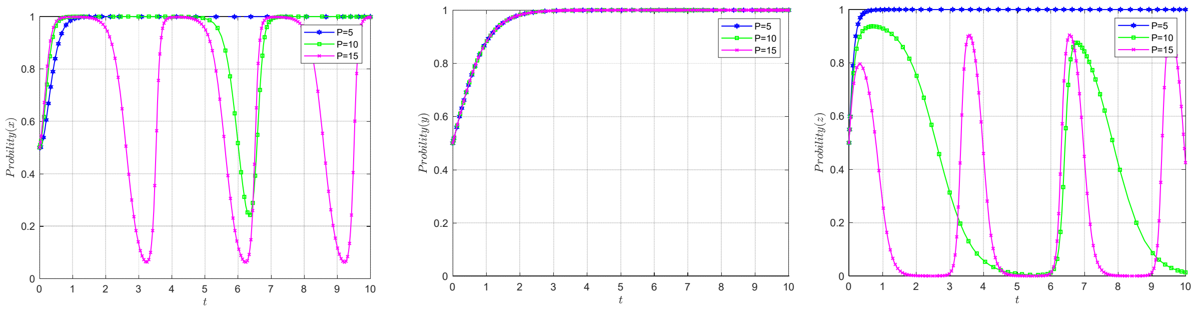


Figure 7. Sensitivity of P change in the three-party game model.



(**a**) Agricultural Machinery Service Organizations (**b**) Farmers (**c**) Agriculture-related government

Figure 8. Sensitivity of each stakeholder to P change.

It can be seen from Figure 8 that the strategy of agricultural machinery service organizations fluctuates with the increasing subsidy of agriculture-related governments. Figure 8a–c represent the effects of changes in P-values on agricultural machinery service organizations, farmers, and governments, respectively. Firstly, after the strategy of providing all links of operation is stable, the probability of providing all links of operation strategy decreases with the change in time, showing a wave shape. The choice of agriculture-related governments and agricultural machinery service organizations are opposed, exhibiting a reverse fluctuation. This shows that when the subsidy is large, the income of the agricultural machinery service organization increases in the early stage, but as time passes, the agricultural machinery service organization will have the situation of service slackness, and can not guarantee to provide all links of agricultural machinery service for a long time. When the subsidies of agricultural-related governments continue to increase, their costs also increase and their net income decreases, which will also make agriculture-related governments unable to guarantee long-term strict management.

4.2.3. Changes in the Cost of Supervision and Management in the Whole Process of Agricultural Machinery Service Organization

By changing the parameter value, when the supervision and management cost of the whole link service provided by the agricultural machinery service organization is 5, 10 and

15, respectively, the evolutionary stability strategy of the participants is obtained, as shown in Figure 9. From Figure 9, it can be seen that the increase in C_{1s} affects the decision-making of agricultural machinery service organizations. The increase in supervision costs will lead to an increase in the time required for agricultural machinery service organizations to provide stable all-link operation services. When the supervision cost becomes too high, agricultural machinery service organizations will provide non-all-link operation services, so that the stability point of the system will be shifted to (0,1,1).

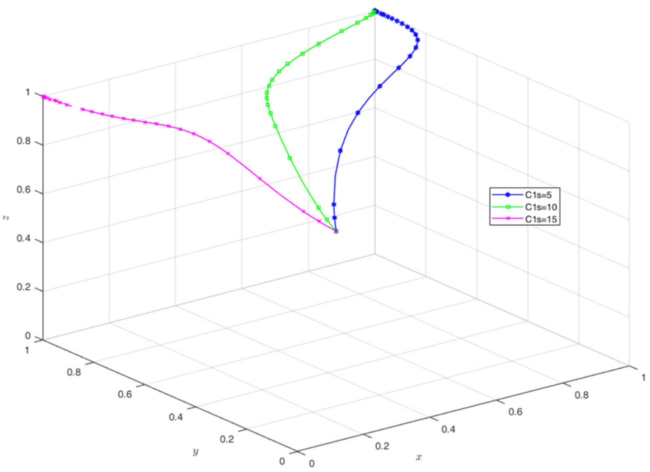
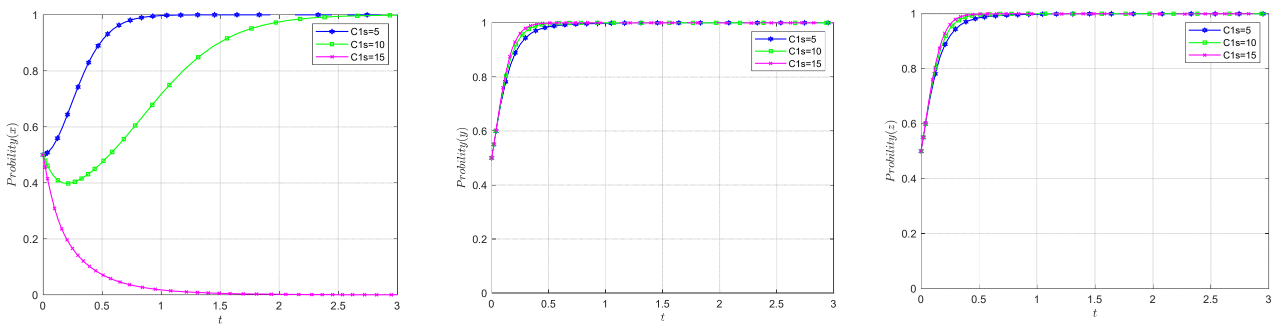


Figure 9. The sensitivity of the three-party game model to the change in C_{1s}.

Combined with Figure 10, Figure 10a–c show the effects of changes in C_{1s} values on agricultural machinery service organizations, farmers, and governments, respectively. It can be seen that the whole-link supervision and management cost of agricultural machinery service organizations has little impact on the behavioral decisions of farmers and governments, and it only affects the behavioral decisions of agricultural machinery service organizations. This further shows that when the agricultural machinery service organization provides the whole link operation service, it is necessary to keep the supervision cost to a reasonable range, prevent the enthusiasm of the agricultural machinery operators to provide the whole link service due to the high supervision costs, and ensure the stability of the income of the agricultural machinery service organization.



(**a**) Agricultural Machinery Service Organizations (**b**) Farmers (**c**) Agriculture-related government

Figure 10. Stakeholders' sensitivity to A change.

5. Conclusions and Discussion

5.1. Conclusions

This paper defines three stakeholders of agricultural machinery service adoption behavior for the purpose of promoting Conservation Agriculture, namely agricultural machinery service organizations, farmers and agricultural-related government. Based on the evolutionary game theory, the evolutionary game model of agriculture-related governments, agricultural machinery service organizations and farmers to promote agricultural machinery service promotion is constructed, and the influence of key parameter changes on the strategic evolution trajectory of these stakeholders is simulated. The main conclusions are as follows:

First of all, agriculture-related governments, agricultural machinery service organizations and farmers can achieve an evolutionary stability strategy (ESS); that is, under the condition of meeting the point (1,1,1), with the strict management of the government's choice, agricultural machinery service organizations tend to provide comprehensive agricultural machinery services, and farmers also tend to cooperate with agricultural machinery service organizations to select comprehensive agricultural machinery services. The behavioral decision-making reaches an ideal state, which is conducive to the formation of a positive agricultural machinery service adoption relationship.

Secondly, the simulation results indicate that the punishment intensity, subsidy intensity by agricultural-related government and the supervision cost parameters of agricultural machinery service organizations to implement all links of operations significantly affect the behavior strategies of the three parties. Agricultural-related governments to increase subsidies and penalties help agricultural machinery service organizations to provide farmers with all aspects of agricultural machinery services. The government's policy compensation incentives have a direct impact on the type of agricultural machinery services and an indirect impact on the services selected by farmers. When a supportive policy system such as financial subsidies is established, farmers will choose all aspects of agricultural machinery services to maximize their benefits, thereby promoting the normative implementation of agricultural technology.

Finally, only when the agriculture-related governments establish a reasonable subsidy and punishment mechanism and the agricultural machinery service organization keeps the supervision cost of all links in a reasonable range can the stable realization of the three-party behavior strategy be guaranteed and the enthusiasm for agricultural machinery operators to provide full-service links be prevented from being dampened by excessive additional costs such as supervision. At the same time, it is necessary to ensure the stability of the income of agricultural machinery service organizations, which requires the support of additional national policies.

5.2. Discussion

With the promotion of Conservation Agriculture globally, farmers' farming methods have also changed, and no-tillage operations have gradually replaced traditional tillage operations, and new agricultural machines such as no-tillage machines have become necessary devices for implementing Conservation Agriculture [7]. In countries with the characteristics of small farmers in large countries, such as China, problems such as labor shortages and low quantities of agricultural machinery are common. Agricultural machinery service organizations actively work together to provide services for all production links, which can not only eliminate the problem of poor cooperation and non-standard implementation caused by different main body operations in multiple links but also effectively alleviate the bottleneck of rural labor, which is a good solution to the problem of "who will farm and how to farm" [6]. Therefore, it is of great significance to study how to enhance the cooperation and enthusiasm among stakeholders in agricultural machinery socialization services. By addressing these issues, we can mitigate the influence of stakeholders' opportunism and other behaviors, thereby improving the standardization and adoption rate of Conservation Agriculture technology implementation.

In the context of promoting Conservation Agriculture, the stakeholders of agricultural machinery socialization service include agriculture-related government, agricultural machinery service organizations and farmers. The three stakeholders can realize the evolutionarily stable strategy (ESS); that is, under the condition of satisfying the point (1,1,1), the behavioral decision reaches the ideal state, which is conducive to forming a positive relationship of agricultural machinery service adoption. Han et al. also concluded that in the game relationship between village committees, farmers and service organizations, when the ideal state is reached, the formation of farmer–trusteeship relationship is accelerated [23]. This is because the role of the government in the game is more prominent, and the reputation effect of the village committee is enhanced, which means that farmers have greater trust in the services or information they promote [52]. At this point, strict supervision of the government and absolute obedience of service organizations are necessary findings for steadily promoting the whole link of social agricultural machinery services. The research conclusions of Huan et al. also prove that encouraging the implementation of agricultural socialization services can address the needs of farmers, promote the adoption of sustainable agricultural technologies by small farmers, release the vitality of agricultural production, and assist in transforming traditional agriculture into sustainable agriculture [32].

In addition, this paper also elucidates the conditions for the stability of the tripartite behavior strategy; that is, agriculture-related governments establishing a reasonable subsidy and punishment mechanism and agricultural machinery service agencies controlling the supervision cost of each link within a reasonable range, thereby ensuring the stable implementation of the tripartite behavior strategy. This is similar to the research conclusions of some scholars that financial support is necessary but excessive subsidies will indeed escalate the financial burden of the government, and then impede the management capabilities of the government, thus affecting the stable relationship between the three parties [41]. This is due to the reasonable subsidy mechanism, which can moderate the impact of additional costs caused by supervision when agricultural machinery operators provide the whole link of services. Considering the role of the market, the reduction in cost will also affect the service price and thus improve the choice willingness of farmers. But this must be aimed at not affecting the government's ability to manage and set reasonable subsidized prices where local economic conditions permit [53]. Indeed, under these conditions, promoting the overall cooperative development of agricultural machinery social services is crucial for achieving the ultimate goal of advancing technology implementation and ensuring its standardization and effectiveness.

It should be noted that the evolutionary game model constructed in this paper simplifies the decision-making behavior of all participants to a certain extent, and factors such as farmers' kinship-based influence and technical cognition are not included in the model. In addition, the model only takes the government, farmers and agricultural machinery service organizations as stakeholders, and does not consider the influence of other stakeholders on the three parties. In the future, variables such as farmers' attitudes, cognition, and kinship-based factors can be introduced into the game model. This will allow for a more comprehensive examination of the cooperative development relationship among stakeholders, based on a wider range of data and subject types.

6. Policy Recommendations

Agricultural machinery services is a basic agricultural production mode suitable for addressing China's current issues of aging population and labor mobility [54]. In order to encourage active and collaborative agricultural machinery service relationships, promote the application of standardized technology implementation by agricultural machinery service organizations, and facilitate the effective promotion of Conservation Agriculture, the following important policy recommendations are derived from the results of this study and are intended for future practice:

(1) Establish incentive and punishment policies for agricultural socialized service organizations with the goal of normative technology adoption.

Incentives and penalties are the means for the government to improve the ecological environment system, and play a pivotal role in farmers' choices of agricultural machinery services and adoption of agricultural technology. Most of the time, when farmers choose agricultural machinery services to implement agricultural technology, they mainly consider whether they can obtain economic subsidies [55]. For technologies with comprehensive economic subsidies such as Conservation Agriculture, farmers are more likely to consider adopting them to increase income, and agricultural machinery service organizations are also willing to promote such technologies. However, if the protective agricultural technology implemented by farmers or agricultural machinery service organizations is not standardized, they will not receive corresponding subsidies. In order to maximize their economic benefits, farmers and agricultural machinery service organizations will then form standardized technology implementation behaviors. Therefore, the policy of incentive type has a positive effect on the implementation of standardized agricultural technology by farmers and agricultural machinery service organizations. Of course, appropriate punishment warnings will also play a role; additionally, it is necessary to define the degree of punishment and warning, which can not dampen the enthusiasm of farmers to adopt new technologies [52,55]. Consequently, it is imperative to formulate suitable incentive and punishment policies for agricultural socialized service organizations, with the aim of normative technology adoption. This will not only facilitate farmers' adoption of agricultural machinery services but also significantly enhance the implementation of standardized agricultural technology by agricultural machinery service organizations.

(2) Reducing the cost of supervision and formulating reasonable service prices are the keys to the formation of a positive agricultural machinery service adoption relationship.

In the process of agricultural production, to ensure the implementation of agricultural technical specifications, agricultural machinery service organizations will incur additional costs, such as those related to inspection and acceptance. Similarly, agriculture-related governments will generate additional financial expenditures due to their supervisory role. If these additional costs are passed on to farmers by including them in the service fees, it will inevitably lead to farmers' adverse selection of agricultural machinery services or agricultural technology due to the excessive service costs. To address this, and to ensure strict management while simplifying the inspection and acceptance process, thereby reducing excessive cost expenditures [56,57], the state should introduce corresponding policies and regulations to standardize and institutionalize the supervision work. This will reduce unnecessary links and expenses in the production process of agricultural machinery service organizations and improve the efficiency of agriculture-related governments in the management aspect, while also saving the cost for service organizations in dealing with supervision [31]. Furthermore, the state can provide funds and other relevant support for the management of agricultural machinery services. This includes allocating special funds to local governments and offering relevant personnel training to promote the formation and healthy development of the adoption relationship of agricultural machinery services. Ultimately, providing reasonable service prices for farmers is the first step towards ensuring farmers' informed choices.

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