Impact of Environmental Values and Information Awareness on the Adoption of Soil Testing and Formula Fertilization Technology by Farmers—A Case Study Considering Social Networks

Mengling Tian, Ruifeng Liu, Jian Wang, Jiahao Liang, Yefan Nian and Hengyun Ma

Abstract: The irrational application of chemical fertilizer affects agricultural land’s supply capacity and yield quality and may lead to serious agricultural non-point source pollution. Through scientific and accurate fertilization, soil testing and formula fertilization technology (STFFT) can effectively prevent excessive fertilizer use, improve its utilization efficiency, and have significant environmental and economic benefits. Based on evolutionary game theory, this paper constructed an evolutionary game model of farmers’ adoption of STFFT. We used a case study to reveal and verify the influence of farmers’ environmental values, information awareness, and social network on their adoption of STFFT and its mechanism. The findings were as follows: First, there are two optimal stable states in the evolutionary system; namely, all farmers adopt or do not adopt STFFT. Second, environmental values and information awareness positively correlate with farmers’ adoption of STFFT. Third, the strength of social networks can enhance the effectiveness of information awareness and environmental values, encouraging farmers to adopt STFFT. In addition, the social network plays a mediating role and moderating role in the influence of information awareness and environmental values on the farmers’ adoption of STFFT.

Keywords: environmental values; information awareness; adoption of soil testing and formula fertilization technology; evolutionary game; case study

1. Introduction

Farmers seek sustainable agriculture because of concerns about deteriorating environmental health, growing demand from consumers and importers for quality products with improved food safety, and the opportunity for high returns [1,2]. As a sustainable production technology, agricultural green technology has significant environmental and economic benefits [3,4]. It has been found that agricultural green technologies such as soil testing and formula fertilization technology (abbreviated as STFFT), straw returning, and pest control can, not only reduce the application of chemical fertilizers and pesticides and greenhouse gas emissions, reducing agricultural and environmental pollution [5], but can also reduce planting costs, improve the quality of agricultural products, and increase crop yields and prices, to increase farmers’ economic income [6]. In recent years, governments have introduced a series of policies and measures to promote agricultural green technology development. In terms of legal means, developed countries led by the United States have issued many laws and regulations to support the green development of agriculture. For example, in 1990, the U.S. government enacted the Organic Food Production Act and established the National Organic Standards Committee. In January 2011, the U.S. President
Barack Obama signed the FDA Food Safety Modernization Act. In terms of financial support, developed countries generally give large financial subsidies to the green development of agriculture. For example, in May 2008, the European Commission adopted a new round of the EU Common Policy Reform Draft, which promoted the decoupling of agricultural subsidies and output and also increased financial support for less developed rural areas. Since 1960, Japan’s agricultural scientific research funding has been increasing, reaching 151.8 billion yen (1 yen ≈ 0.0511 yuan, 2023) in 1976, and accounting for about 30% of the total government scientific research funding. In contrast, China promulgated its Agricultural Law for the first time in 1993 and revised it in 2002 and 2012. However, there are few laws related to green agricultural development, and the content and scope of support are also limited. The agricultural subsidy system is relatively simple, and the largest proportion of subsidies are comprehensive subsidies, belonging to indirect subsidies, with few subsidies to farmers and a low subsidy efficiency.

As a green agricultural technology, STFFT can realize scientific and accurate fertilization on plots with different fertilities, which is of great significance for improving rural environmental quality and ensuring agricultural land supply capacity and output quality [7]. STFFT can be traced back to the German chemist Michelich in the late 1930s. Meanwhile, the foundation work was completed by Bole et al. in the mid-1940s [8]. Bray first proposed the concepts of soil nutrient availability and crop relative yield and believed that quantitative mathematical models could measure the correlation between soil nutrient test values and crop yield. The Bray 1 and Bray 2 soil available phosphorus extractors proposed by Bray are still used by countries worldwide [9]. China’s second national soil survey, which took ten years to complete and started in 1979, laid the human, material, and technical foundations for STFF. As a result, a technology system of testing soil and applying formula fertilizer suitable for the agricultural situation and characteristics was established in the late 20th century. In 2005, China officially began to promote STFFT. As an environmentally friendly technology that reduces costs and increases efficiency, it should be widely welcomed by farmers. However, the actual scale of promotion of STFFT is still limited. Less than one-third of farmers adopt the technology in the production process in China [10].

According to the rational smallholder theory, farmers’ adoption of agricultural green technology is rational and economical. Whether they adopt green production technology depends on comparing adoption costs and expected benefits [12–14]. Based on the perspective of farmers’ technological cognition, Chavas and Nauges [15] found that farmers’ adoption decisions about new varieties were highly correlated with their cognition. As adopting green technology has positive externalities for environmental protection, it is not easy to realize the adoption of agricultural green technology only through the will of farmers. It must rely on the government, the market, and other external forces. Li, et al. [16] believed that government incentive policies make up for the losses caused by farmers’ adoption of green technology by providing financial subsidies or technical training, thus promoting the adoption of agricultural green technology by farmers. Eriksson [17] and Yang, et al. [18] held that in addition to incentive policies, the government could adopt supervision and restraint policies to regulate farmers’ production behavior. In addition, Montalvo [19] and Yu, et al. [20] confirmed that the price of green agricultural products is directly related to farmers’ income and can significantly affect their adoption behavior regarding agricultural green technologies.

There have been many studies on farmers’ adoption behavior of agricultural green technology. From the perspective of environmental values, the existing studies found that farmers with environmental protection awareness are more inclined to adopt agricultural green technology [21–24]. Tang, et al. [25] found that farmers with a strong sense of water conservation pay closer attention to water shortages and take the initiative to disseminate technical information. Furthermore, the strength of water-saving consciousness will di-
rectly affect farmers’ agricultural operation standards and irrigation water efficiency [26]. Gao, et al. [22] found that when farmers are more familiar with relevant environmental protection policies and regulations, they are more willing to adopt agricultural green technologies. From the perspective of information awareness, farmers’ adoption of green technology is limited to some extent by their level of information ability. On the one hand, compared with traditional production technology, agricultural green technology has a higher technical threshold. If the technology is not standardized, this may cause losses for farmers. On the other hand, the market of green agricultural products faces large price fluctuations, and farmers need to pay close attention to market dynamics to reduce risks [27]. Farmers with a strong information ability can access more and higher quality information resources, increasing their grasp of technology and the market and thus promoting their willingness to adopt green technologies [28]. Research from the perspective of information transmission has shown that effective external information transmission channels such as government propaganda, technical training, and neighborhood communication can reduce the number of farmers using pesticide [29–31]. Therefore, this has a positive influence on farmers’ adoption of ecological farming behavior. From the perspective of social networks, the existing studies have explored the relationship between social networks and farmers’ technological adoption based on the paradigm of behavioral economics and pointed out three main mechanisms. The first is the technology acquisition mechanism. Limited by education level, geographical location, information infrastructure, and other factors, farmers have fewer channels to obtain new technological information. A social network is an effective way, or even the only way, for farmers to obtain new technical information [32,33]. Research samples from different countries show that the more social network relationships farmers have, the higher their probability of knowing about and adopting new technologies [34–36]. The second mechanism is the social learning mechanism. As an incubator for social learning and communication among farmers, a social network enables farmers to learn about the adoption costs and output level of new technologies through the social network, which helps reduce the uncertainty around adopting new technologies and the risk of technological conversion [35,37,38]. Reimer, et al. [39] found that farmers’ adoption of conservation tillage techniques was influenced by the attitudes and feedback of neighbors or friends who had adopted the techniques. The third factor is the reciprocity mechanism. Farmers can obtain financial, physical, and labor help through social networks, which can help reduce the cost pressure when farmers adopt new technologies, effectively promoting the transformation of farmers’ willingness to adopt into actual adoption behavior [40].

Many beneficial explorations have been made of STFFT adoption behavior. As the decision-makers and behavioral subjects of agricultural production, the individual characteristics and family production characteristics of rural households cannot be ignored, including gender, work experience, education level, technical training experience, land scale, and other factors that have an impact on the adoption of STFFT by rural households [41,42]. Furthermore, external factors such as neighborhood effect, government policy, and formula fertilizer supply institutions will affect farmers’ adoption of STFFT [11,43,44]. With the deepening of research, scholars have begun to pay attention to the impact of farmers’ social networks, green cognition, information acquisition ability, risk perception, and other factors on their STFFT adoption [35,45,46]. For example, Wu, et al. [47] found that the network resources of farmers, that is, relatives and friends, played an important role in their decision-making around STFFT adoption. In addition, social learning can effectively improve farmers’ adoption of STFFT by improving the predictability of agricultural production [47].

The existing research has lain a solid foundation for this paper. Nevertheless, there are few works in the literature analyzing farmers’ adoption of agricultural green technology (i.e., STFFT in this study) based on game theory, especially using evolutionary game and simulation methods. The existing studies that used evolutionary game methods to analyze farmers’ adoption of agricultural green technologies mostly focused on the game relationships between multiple subjects and generally only examined the impact of
objective factors, ignoring the impact of farmers’ psychological characteristics. Within the theoretical framework of behavioral economics, human behavior is affected by cognitive biases and social factors. In reality, individual farmers also frequently communicate with other surrounding farmers to exchange information with each other. Therefore, the mutual influence between farmers must be fully considered. At the forefront of game theory research, evolutionary game theory re-examines the concept of game equilibrium from the perspective of evolution [48]. As a result, it has unique advantages in explaining changes in social institutions, the formation of social habits, and social norms [49–51]. In terms of this study, this paper investigates the long-term behavioral game among finite rational farmers. Evolutionary game theory can well describe the adjustment process and local dynamic equilibrium of the strategy of whether farmers adopt STFFT in a long-term repeated game process among finite game groups [52]. Owing to the difference in farmers’ environmental values and information awareness, the adoption logic of STFFT may differ. In addition, the influence of social networks should be considered when environmental values and information awareness play a role in farmers’ adoption of STFFT. Therefore, the information channel and learning function of social networks play a key role in farmers’ technology adoption [38]. Farmers communicate and learn about adopting new agricultural technologies through internal relationship networks [53], which can accelerate the dissemination of new technological information among farmers [54]. Improving farmers’ cognition and knowledge of technology [38] can reduce uncertainty around technology adoption [55] and improve the effect of agricultural technology adoption. This paper aimed to explore the impact of environmental values and information awareness on farmers’ adoption of STFFT. In particular, this study considered the mediating and moderating effects of social networks and constructed a game model of STFFT adoption between any two undifferentiated farmers, to analyze the impact and mechanism of farmers’ environmental values and information awareness on STFFT adoption, which is helpful to crack the “black box” of the low adoption rate of agricultural green technology among Chinese farmers. Moreover, it has important theoretical and practical significance for formulating and perfecting farmer incentive policy.

This study has three main contributions. First, based on an evolutionary game theory perspective of “bounded rationality,” the study changes the constraint conditions of the traditional evolutionary game by considering environmental values and information consciousness and provides a theoretical logical framework for understanding farmers’ adoption behavior for STFFT. Second, some studies have considered social networks, interpersonal factors, and psychological factors such as environmental values and information awareness. However, in particular, they failed to consider the dependence of environmental values and information awareness on farmers’ social networks when they decide on their technology adoption behavior. Therefore, this study incorporated environmental values, information awareness, and social networks into a unified analytical framework; explored the influence mechanism of the three factors on farmers’ adoption of STFFT; further investigated the influence effect of social networks on farmers’ adoption of environmental value and information awareness on agricultural green technology; and expanded the analytical framework of existing studies. Third, this study takes the adoption process of STFFT of corn farmers in Linzhou, Henan Province, China, as an example and uses the case study method to verify and simulate the solution conclusions within the evolutionary game model. Combined with the characteristics of rural society in China, this case study explores the uniqueness of farmers’ adoption of STFFT under the Chinese system and culture. In addition, it provides a “Chinese version” of empirical support for understanding the impact of environmental value, information awareness, and social networks on farmers’ adoption of agricultural green technology and its mechanism.

The rest of this paper is structured as follows: The second part builds a dynamic strategic game model of farmers’ green technology adoption behavior, discusses the stable conditions under different equilibrium states, and the influence mechanism of environmental value, information awareness, and social network on farmers’ adoption of STFFT, and
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then carries out a simulation. The third part selects typical cases to verify the conclusions. Finally, the fourth part gives the research conclusions and policy implications.

2. Game and Simulation Analysis

2.1. Basic Hypotheses

Evolutionary game theory studies the specific learning, imitation-dynamic process, and stability of bounded rational groups. According to the principle of evolution, each randomly selected participant represents a particular population. If the participant’s behavioral strategy mutates, and the behavioral strategy brings higher benefits than other participants, other participants will imitate the participant’s behavior, and this strategy will develop in the population. This paper first constructs the interaction rules between individual farmers, and then simulates the dynamic process of farmer group evolution by replicating the dynamic model. Based on this, this article makes the following hypotheses:

Hypothesis 1. Farmer A and farmer B, with the same individual characteristics, planting scale, and social networks, constitute a set of players, i.e., \( I = \{1, 2, 3 \cdots n\} \).

Hypothesis 2. Due to limited human cognition, perception, and expression ability, farmer A and farmer B can only make decisions based on bounded rationality.

Hypothesis 3. Farmer A and farmer B have two strategies to choose from: to “adopt” or “not adopt” agricultural green technologies. At any given time, the proportion of farmers adopting the two strategies is \( x \) and \( 1 - x \), respectively.

Hypothesis 4. The fertilizer costs and crop benefits of farmers using traditional production methods for agricultural production are \( C_0 \) and \( E_0 \), respectively; the fertilizer costs and crop benefits of farmers adopting STFFT for agricultural production are \( C_1 \) and \( E_1 \); the extra time and energy cost of applying soil testing and formula fertilizer is \( C_f \).

According to the existing policy and practical experience, in the short term, \( C_0 > C_1, E_0 > E_1 \). The expected risk cost of farmers adopting STFFT is \( C_{R0} = C_{R0} - \alpha B_1 - \alpha B_e \), where \( C_f \) represents the risk cost expectation of risk-averse farmers for STFFT. \( B_1 \) and \( B_e \) represent part of the risk cost expectation that farmers with information awareness and environmental expectations of adoption. At this point, the expected risk cost of farmers adopting STFFT is \( C_{R1} = C_{R1} - \alpha B_1 - \alpha B_e \), and \( C_{R0} > C_{R1} \). Table 1 reports the benefit matrix of farmers’ adoption behavior of STFFT from the perspective of social networks.

Table 1. Benefit matrix for farmers’ adoption behavior of STFFT.

<table>
<thead>
<tr>
<th>Farmer B</th>
<th>Adopt</th>
<th>Not Adopt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( E_1 - C_1 - C_f - C_{R1} )</td>
<td>( E_0 - C_0 - \alpha B_1 - \alpha B_e )</td>
</tr>
<tr>
<td></td>
<td>( E_1 - C_1 - C_f - C_{R1} )</td>
<td>( E_1 - C_1 - C_f - C_{R0} )</td>
</tr>
<tr>
<td></td>
<td>( E_1 - C_1 - C_f - C_{R0} )</td>
<td>( E_0 - C_0 - \alpha B_1 - \alpha B_e )</td>
</tr>
<tr>
<td></td>
<td>( E_0 - C_0 - \alpha B_1 - \alpha B_e )</td>
<td>( E_0 - C_0, E_0 - C_0 )</td>
</tr>
</tbody>
</table>

2.2. Evolutionary Game Model

According to Table 1, we can calculate the expected revenues of farmers with or without STFFT, denoted as \( U_x \) and \( U_{1-x} \), respectively, and the average revenue is \( U \).

\[
U_x = x(E_1 - C_1 - C_f - C_{R1}) + (1-x)(E_1 - C_1 - C_f - C_{R0})
= E_1 - C_1 - C_f - xC_{R1} - (1-x)C_{R0}
\] (1)
According to Taylor and Jonker [56], the replicated dynamic equation can be used to analyze the adjustment process of dynamic strategies of low-rational and bounded-rational farmers. In this study, the replication dynamic equation of farmers adopting STFFT can be expressed as F(x):

\[
F(x) = \frac{dx}{dt} = x(1 - x)[E_1 + C_0 + x(aB_i + aB_e) - C_1 - C_f - xC_{R1} - (1 - x)C_{R0} - E_0]
\]  (4)

2.3. Analysis of the Evolutionary Stability Strategy

According to evolutionary game theory, a replicated dynamic system is stable when players experience multiple games without changing their strategies. At this point, the strategy mix for all participants is the evolutionarily stable strategy (ESS). According to the principle of differential equation stability, when farmers adopt the reproduction dynamic equation \( F(x) = 0 \) of STFFT, and when the first derivative is less than 0, the evolution system reaches a stable state. This means that the strategies of all farmers no longer change with time, and the choice of the farmers is the optimal strategy. It can be concluded that \( x = 0, 1, \) or \( \frac{C_1 + C_f + E_0 + C_{R0} - C_0 - E_1}{aB_i + aB_e + C_{R0} - C_{R1}} \) are the evolutionary stability points of farmers.

\( F'(x) \) can be obtained by calculating the first derivative of the replication dynamic equation of farmers adopting STFFT, which can be expressed as

\[
F'(x) = \left[E_1 + C_0 + x(aB_i + aB_e) - C_1 - C_f - xC_{R1} - (1 - x)C_{R0} - E_0\right] \\
-2x[E_1 + C_0 + x(aB_i + aB_e) - C_1 - C_f - xC_{R1} - (1 - x)C_{R0} - E_0] \\
+x(aB_i + aB_e + C_{R0} - C_{R1}) - x^2(aB_i + aB_e + C_{R0} - C_{R1}) \\
= (1 - 2x)[E_1 + C_0 + x(aB_i + aB_e) - C_1 - C_f - xC_{R1} - (1 - x)C_{R0} - E_0] \\
+ (X - X^2)(aB_i + aB_e + C_{R0} - C_{R1}) \\
= (1 - 2x)(E_1 + C_0 - C_1 - C_f - E_0 - C_{R0}) + (2x - 3x^3)(aB_i + aB_e + C_{R0} - C_{R1})
\]  (5)

According to Friedman [57], evolutionary stability strategies must satisfy pure strategy Nash equilibrium, while other forms of Nash equilibrium are unlikely to be stable strategies in the system. Therefore, this study does not consider the \( x = \frac{C_1 + C_f + E_0 + C_{R0} - C_0 - E_1}{aB_i + aB_e + C_{R0} - C_{R1}} \) mixed strategy situation and only discusses \( x = 0 \) or 1.

**Situation 1.** When \( E_1 + C_0 + 2aB_i + 2aB_e > C_1 + C_f + E_0 + C_{R1}, x = 1 \) is the evolutionary stability strategy for farmers.

In other words, no matter whether other farmers adopt STFFT, the expected revenue obtained by adopting STFFT is always greater than that without adopting it. This indicates that the environmental cognition and utility cognition obtained by farmers with environmental value and information awareness not only offset the expected risks of farmers adopting STFFT but also fill the gap between the economic benefits for crops obtained by the traditional and STFF methods in the short term. In this case, adopting STFFT is the optimal strategy for all farmers.

**Situation 2.** When \( E_1 + C_0 + aB_i + aB_e < C_1 + C_f + E_0 + C_{R0}, x = 0 \) is the evolutionary stability strategy for farmers. Regardless of whether other farmers adopt STFFT, the expected revenue obtained without adopting the technology is always greater than the revenue when adopting it. Therefore, in this case, all farmers will not adopt it. This indicates that, on the one hand, environmental values and information awareness have small effects on farmers, which cannot offset the expected risk of adopting STFFT. On the other hand, farmers who adopt STFFT need to invest more time and energy, and the economic benefits of crops in the short term will decline. Therefore, not adopting STFFT is the optimal strategy for all farmers.
To verify the above conclusions, this paper used Matlab 2021b software to simulate the evolution of farmers’ technology adoption behavior strategy. When the size relationship between the parameters satisfies the above two inequalities, the dynamic evolution path of the game of all farmers is as shown in Figure 1a, b. Probability (×) represents the proportion of farmers in player set I who adopt STFFT, and \( t \) represents the evolution time. According to Figure 1a, regardless of the proportion of farmers who choose to adopt STFFT in the initial state, all farmers will choose to adopt STFFT after a period of time, as long as the inequality conditions in situation 1 are met. As can be seen from Figure 1b, regardless of the proportion of farmers who choose to adopt STFFT in the initial state, all farmers will choose not to adopt STFFT after a period of time, as long as the inequality conditions in situation 2 are met.

![Figure 1](image)

**Figure 1.** Evolution of farmers’ adoption strategy for STFFT. (a) When situation 1 is satisfied, the evolutionary steady state of the system. (b) When situation 2 is satisfied, the evolutionary steady state of the system.

Furthermore, to discuss the influence of key parameters, namely environmental value, information awareness, and social networks, on farmers’ adoption of STFFT strategy, this paper simulated the STFFT adoption behavior of farmers. We assigned values to the parameters in the model as follows: \( E_1 = 5, E_0 = 7, C_1 = 2, C_0 = 3, C_f = 1, C_e = 8, C_0 = 9, B_e = 6, B_k = 6, \alpha = 1 \). In addition, according to the above analysis, the initial proportion of farmers who choose to adopt STFFT has no significant impact on whether farmers ultimately adopt this technology. Therefore, we set the initial proportion of farmers who adopt STFFT to 0.5, indicating that farmers are neutral towards STFFT in the initial state.

### 2.3.1. Impacts of Information Awareness, Environmental Values, and Social Networks on Farmers’ Adoption of STFFT

Under the condition of keeping the other parameters unchanged, the utility brought by farmers’ information awareness, environmental values, or social network strength was adjusted, respectively, and we could obtain Figure 2a–c. According to Figure 2a, farmers’ information awareness has no significant influence on their adoption behavior for STFFT, which is reflected in the value of \( B_i \) not affecting the final strategy of farmers, even if \( B_i = 0 \), farmers still choose to “adopt”. With the increase in \( B_i \), the rate of “adoption” of all farmers increased. This indicates that farmers with higher information awareness have a strong will to adopt soil testing technology and formula fertilization. Figure 2b shows that environmental values significantly impacted farmers’ behavior in adopting STFFT. This is reflected in that, when \( B_e = 0 \), farmers choose the “not adopt” strategy, and with the increase in \( B_e \), the speed of all farmers choosing “adopt” increases. According to Figure 2c, the simulation results show that with an increase in \( \alpha \), farmers’ strategies evolve from “not adopt” to “adopt”, and the speed of choosing “adopt” gradually accelerates. In addition, expanded social networks significantly improved farmers’ adoption of STFFT.
When the strength of the farmer's social network increased, the proportion of corn growers in this region using STFFT was less than 40% of the annual sown area of crops in Linzhou, which is about 440,000 mu. Corn is one of the main crops in Linzhou and the main source of farmers' planting income. In addition, farmers' enthusiasm for adopting STFFT in this area was not high. The awareness of farmers regarding STFFT and "how" this affects farmers is remarkable. By 2021, the popularizing area of formula fertilizer in Linzhou reached remarkable results. By 2021, the popularizing area of formula fertilizer in Linzhou reached 565,000 mu, reducing efficiency by more than 22 million yuan (1 yuan = 0.146 US dollars). This indicates that farmers with higher information awareness have a remarkable influence on farmers' adoption of STFFT.

### Figure 3. Mechanism of the impact of social networks on farmers' adoption of STFFT

- **(a)** When $\alpha = 0$, the impact of information awareness on farmers' adoption of STFFT.
- **(b)** When $\alpha = 0.5$, the impact of information awareness and environmental values on farmers' adoption of STFFT.
- **(c)** When $\alpha = 1$, the impact of information awareness and environmental values on farmers' adoption of STFFT.

#### 2.3.2. Mechanism of Social Networks Influence on the Adoption Behavior of Farmers for STFFT

We further discussed the specific mechanism of social networks on the adoption behavior of farmers for STFFT. The values $\alpha$ of farmers' social network strength were assigned as 0, 0.5, and 1, indicating that the strength of farmers' social network increased successively. As shown in Figure 3, when the farmers' social network strength $\alpha = 0$; that is, when the farmer has no social network, the farmer always chooses the "not adopt" strategy. In other words, improving information awareness and environmental values did not affect farmers' strategies. This indicates that the influence of information awareness and environmental values on farmers' adoption of STFFT is related to their social networks. When the strength of the farmers' social network $\alpha = 0.5$, with an increase in information awareness and environmental awareness, the farmers' strategy changes from "not adopt" to "adopt". When the strength of the farmer's social network $\alpha = 1$, all farmers choose the "adopt" strategy. This indicates that the strength of farmers' social networks can enhance the effectiveness of information awareness and environmental values in encouraging farmers to adopt STFFT.

### Figure 3. Mechanism of the impact of social networks on farmers' adoption of STFFT

- **(a)** When $\alpha = 0$, the impact of information awareness and environmental values on farmers' adoption of STFFT.
- **(b)** When $\alpha = 0.5$, the impact of information awareness and environmental values on farmers' adoption of STFFT.
- **(c)** When $\alpha = 1$, the impact of information awareness and environmental values on farmers' adoption of STFFT.

#### 3. Case Study and Verification

##### 3.1. Case Selection

In this study, corn farmers' adoption of STFFT in Linzhou city, Henan province, was taken as an example. The selection of the case in this paper mainly followed the principle of typicality [38], and the selection of particularity reflected the following two aspects. First, Linzhou city actively responded to the national call to promote STFF and achieved remarkable results. By 2021, the popularizing area of formula fertilizer in Linzhou reached
783,000 mu (1 mu ≈ 0.067 hectares), and the applied area reached 565,000 mu, reducing costs and increasing efficiency by more than 22 million yuan (1 yuan ≈ 0.146 US dollars). Second, the enthusiasm of corn growers in this area for adopting STFFT was not high. The annual sown area of crops in Linzhou is 869,000 mu, among which about 440,000 mu is corn, one of the main crops in Linzhou and the main source of farmers’ planting income. However, the Technical Guidance on 2022 Summer Corn STFF in Linzhou City showed that the proportion of corn growers in this region using STFFT was less than 40% of the whole, and the adoption level was still low. Therefore, in this context, choosing this case study to study the adoption behavior of corn farmers’ STFFT was of great significance.

3.2. Methodology

This paper used a case study to verify the conclusions of the evolutionary game above. First, a case study is suitable for exploring the “how”, “process”, and “mechanism” aspects. It is helpful to refine the theory or law behind a phenomenon and can also effectively demonstrate the integrity and dynamics of the research process [59]. Second, this study aimed to answer “what” is the mechanism of environmental values and information awareness of farmers regarding STFFT and “how” this affects farmers’ adoption of STFFT. Third, a single case study was adopted in this paper, to more conveniently conduct a logical review and reasoning about the key points involved and then identify the trigger conditions for farmers to adopt STFFT. This was conducive to deepening the theoretical interpretation of the moderating effect, mediating effect, and action mechanism between farmers’ social networks and environmental values, information awareness, and their adoption of STFFT.

3.3. Data Collection

The data used in this paper were based on a questionnaire survey of 642 corn farmers from 40 administrative villages in 12 townships in Linzhou City, Henan province, from July to September 2022. In this survey, a multi-stage sampling method was adopted to determine the survey objects, and on this basis, face-to-face interviews and structured questionnaires were conducted among the farmers. First, according to the purpose of the investigation and the introduction of the person in charge of the relevant departments of the Bureau of Agriculture and Rural Affairs, we choose representative towns as the research area. Second, based on careful consideration of township size, population and geographical location, and other factors, the typical sampling method was adopted to select 3–4 natural villages in each township. Finally, the random sampling method was adopted to select 15–20 farmers in each natural village as survey objects, and we conducted face-to-face interviews with each sample farmer. A total of 684 questionnaires were obtained in this survey. Excluding some questionnaires with missing data, 642 effective questionnaires were obtained, with an effective rate of about 94%.

3.4. Data Analysis

We utilized three stages for the coding analysis [60]. The first was selective coding. To ensure the accuracy of coding work, we divided the 642 questionnaires into groups without STFFT (Group 1) and groups with STFFT (group 2). The four project members (two professors and two doctoral students) were divided into two groups, and they screened and refined each dataset separately. When reading the case materials and encountering words related to the research questions, they were labelled and named according to the interviewee. Second, we formed a preliminary evidence chain through spindle coding. When sorting out the labels, the research group assigned labels to different motivations (i.e., environmental values, information awareness, and social networks) for farmers’ technology adoption behavior, one by one. On this basis, combined with the literature, we refined the milestone events and divided the stages of the STFFT adoption process of farmers in Linzhou City, Henan province. We identified the key factors and adoption intentions in each stage. Finally, we further verified and integrated the chain of evidence. Based on the completion of the first two stages, we gradually constructed the theoretical analysis
framework of this paper. We continued to compare data, literature, and emerging theories in our discussions until there was a strong match between the data and emerging theories. If the data were insufficient or the logic was unclear, we conducted supplementary research by phone, email, or WeChat until theoretical saturation was reached. The main structural dimensions are shown in Table 2. The dimensions and indicators of the key constructs are shown in Table 2. In Table 2, the classification of high, medium, and low levels is based on questionnaire measurements. In the questionnaire, we measured farmers’ environmental values, information awareness, and social networks through their recognition of different indicators. Farmers who answered “agree” correspond to high environmental values, high information awareness, and high social network. Farmers who answered “general” correspond to medium environmental values, medium information awareness, and medium social network. Farmers who answered “disagree” correspond to low environmental values, low information awareness, and low social network. In addition, the evaluation results in Tables 3–6 are based on the corresponding responses with the highest proportion of sample in each group. For example, the proportions of the first group (not adopting STFFT) who chose “agree”, “general”, and “disagree” when answering the question “Protecting the environment is to protect oneself” were 11.54%, 69.72%, and 18.74%, respectively. Based on this, we could evaluate the egoistic environmental values of the first group (not adopting STFFT) as “medium”. See Tables 3–6 for relevant coding results. The section on adduction in Tables 3–6 shows the original statements of the interviewees, assigned according to the evaluation results. NH1, NH2... represent interviewed farmer 1, the interviewed farmer 2... and so on.

### Table 2. Key variable measures.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Sub-Dimension</th>
<th>Index</th>
<th>Grades</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental values</td>
<td>Egoistic value</td>
<td>To protect the environment is to protect ourselves.</td>
<td>High, medium, and low</td>
<td>[61]</td>
</tr>
<tr>
<td></td>
<td>Altruism value</td>
<td>Environmental pollution seriously affects public health.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ecological value</td>
<td>The ecological environment is fragile and difficult to repair.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Information value awareness</td>
<td>Be aware of the importance of information to agricultural production.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information awareness</td>
<td>Information needs identification awareness</td>
<td>Be able to determine what type of agricultural information you need and when.</td>
<td>High, medium, and low</td>
<td>[62]</td>
</tr>
<tr>
<td></td>
<td>Information acquisition awareness</td>
<td>Willing to make the effort to obtain useful agricultural information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social networks</td>
<td>Clan social networks</td>
<td>(i). How often do you move around with relatives? (ii). How often do I communicate with my relatives about green technology? (iii). How often do relatives help during busy farm hours?</td>
<td>High, medium, and low</td>
<td>[63]</td>
</tr>
</tbody>
</table>

### 3.5. Results and Findings

#### 3.5.1. The Impact of Environmental Values on Farmers’ Adopting STFFT

Table 3 summarizes the evidence regarding the two construct levels of environmental values and adoption of STFFT. We assessed the environmental values of farmers and the adoption of STFFT based on the observation proportion of each group of samples and the case interview evidence. By observing the evaluation results for farmers’ environmental values and the adoption of STFFT, we found no correlation between farmers’ egoistic values and the adoption of STFFT. Although the Group 1 farmers had higher egoistic values, believed that environmental problems will eventually affect personal interests, and were willing to participate in environmental protection activities to reduce the negative impact of various environmental problems on themselves, out of a pursuit of personal interest,
risk-averse farmers may still make behavior choices contrary to their own ideas [64]. For example, farmers (NH1) believed that STFFT requires high time and energy costs, and that the benefits are not obvious in the short term. Hence, they chose not to adopt this technology. In contrast, the second group of farmers had lower egoistic values but adopted STFFT. This indicates there was no correlation between egoistic values and farmers’ adoption of STFFT. Accordingly, we put forward Proposition 1.

Proposition 1. The egoistic environmental values had no empirical correlation on farmers’ adoption of STFFT.

Farmers with altruistic environmental values and ecological environmental values regard individuals as a part of the whole of humanity. They believe that individual actions should be guided by the protection of the overall interests and the pursuit of the overall social and ecological benefits, so that they will prioritize green production technology, consistent with their values [65]. As shown in Table 3, farmers with higher values of altruism and for the ecological environment were more willing to adopt STFFT, and vice versa. Accordingly, we put forward propositions 2 and 3.

Proposition 2. There is a positive correlation between altruistic environmental values and farmers’ adoption of STFFT.

Proposition 3. There is a positive correlation between eco-environment values and farmers’ adoption of STFFT.

Table 3. Environmental values and farmers’ adoption of STFFT.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Group 1 (Not Adopt)</th>
<th>Evaluation</th>
<th>Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adduction</td>
<td></td>
<td>Adduction</td>
</tr>
<tr>
<td>Egoistic environmental values</td>
<td>High 69.72</td>
<td>To protect the environment is to protect ourselves (NH1); Protecting the environment has many benefits for individuals (NH4)</td>
<td>Low 38.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The power of individuals to protect the environment is too small (NH8); The environment is good, everyone lives comfortably (NH6)</td>
<td></td>
</tr>
<tr>
<td>Altruistic environmental values</td>
<td>Low 59.84</td>
<td>The rural environment is not as good as before, and it is difficult to restore (NH5); If the environment is damaged, just plant more trees (NH8)</td>
<td>High 53.88</td>
</tr>
<tr>
<td>Eco-environment values</td>
<td>Low 50.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5.2. The Impact of Information Awareness on the Farmers’ Adoption of STFFT

Table 4 shows the evidence of two construct levels for farmers’ information awareness and the adoption of STFFT. Comparing the farmers’ information value awareness in Group 1 and Group 2, it can be seen that the proportion of farmers with high information value awareness was higher in both the non-adopting and adopting groups, 38.01% and 40.22%, respectively. This shows that there was no correlation between farmers’ information awareness and adoption of STFFT. Comparing farmers’ information need identification awareness in Group 1 and Group 2, it can be seen that, although there is a positive correlation between the farmers’ information need identification awareness and
the adoption of STFFT in the non-adopting groups, there is no empirical correlation between farmers’ information need identification awareness and the adoption of STFFT in the adopting group. This shows that there is no correlation between farmers’ information need identification awareness and adoption of STFFT. A possible reason for this is that STFFT is highly regional, and the topography, soil distribution, soil nutrient content, maize planting layout, and fertilizer demand characteristics are different in different regions, which makes the practical application of STFFT more difficult. Although some farmers have strong information awareness, the influence of information value awareness and information need recognition awareness on the adoption of STFFT is gradually weakening due to the difficulty in breaking the threshold of technology adoption [66]. Based on this, this paper puts forward propositions 4 and 5.

Proposition 4. The information value awareness had no empirical correlation on farmers’ adoption of STFFT.

Proposition 5. The information needs recognition awareness had no empirical correlation on farmers’ adoption of STFFT.

According to Table 4, farmers in the non-adopting STFFT group had low information acquisition awareness, and 42.32% of farmers had low information acquisition awareness, while farmers in the adopting STFFT group had high information acquisition awareness, with 38.01% of farmers having high information acquisition awareness. This shows that there is a positive correlation between farmers’ information acquisition awareness and STFFT adoption. The awareness of information acquisition mainly affects farmers’ adoption of STFFT in two ways. First, information acquisition awareness helps farmers accumulate technical knowledge and experience. Generally speaking, the higher the farmers’ awareness and experience of new technologies for increasing crop yields, protecting the ecological environment, and reducing health costs, the stronger their willingness to adopt new technologies [67]. Farmers with a high awareness of information acquisition easily obtain more technical information from various diversified information acquisition channels, to help them break information barriers and realize the accumulation of technical knowledge and experience [68]. Second, information acquisition awareness helps improve farmers’ ability to factor in allocation. The factor endowment constraint of STFFT is relatively large. Farmers with a strong awareness of information acquisition can help reduce information asymmetry by obtaining policy, market, and production information, thus improving their ability to factor in allocation [69]. Therefore, this paper puts forward proposition 6.

Proposition 6. There is a positive correlation between information acquisition awareness and farmers’ adoption of STFFT.

Table 4. Information awareness and farmers’ adoption of STFFT.

<table>
<thead>
<tr>
<th>Farmers’ Adoption of STFFT</th>
<th>Group 1 (Not Adopt)</th>
<th>Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information value awareness</td>
<td>High 38.01</td>
<td>High 40.22</td>
</tr>
<tr>
<td>Evaluation Ratio/%</td>
<td>Corn planting information is useful for increasing corn production (NH11); Experience is as important as information (NH14)</td>
<td>Having more information helps increase production (NH13)</td>
</tr>
<tr>
<td>Information needs identification awareness</td>
<td>Low 38.54</td>
<td>Medium 68.27</td>
</tr>
<tr>
<td>Evaluation Ratio/%</td>
<td>Too much information sometimes to tell (NH12)</td>
<td>Do not know when and what information is needed (NH15)</td>
</tr>
</tbody>
</table>
Table 4. Cont.

<table>
<thead>
<tr>
<th>Farmers’ Adoption of STFFT</th>
<th>Group 1 (Not Adopt)</th>
<th>Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation</strong></td>
<td><strong>Ratio/%</strong></td>
<td><strong>Adduction</strong></td>
</tr>
<tr>
<td>Information acquisition awareness</td>
<td>Low 42.32</td>
<td>Sometimes the information is not necessarily useful (NH16); Unwilling to expend the cost and effort to obtain information (NH19)</td>
</tr>
<tr>
<td></td>
<td>High 38.01</td>
<td>Willing to put effort into obtaining production information (NH17); Very willing to learn and acquire production information (NH18)</td>
</tr>
</tbody>
</table>

3.5.3. The Mediating Effect of Social Networks on Information Awareness

Social Networks and Farmers’ Adoption Behavior of STFFT

According to Table 5, the social networks of farmers in the non-adopting group were generally lower, while those of farmers in the adopting group were generally higher, indicating a positive relationship between farmers’ social networks and the adoption of STFFT. For example, the farmers (NH19) of Group 1 had smaller social networks and weaker communication with social network members, making it more difficult for them to understand and apply STFFT, and thus they chose not to adopt the technology. The farmers (NH15) in Group 2, on the other hand, were well informed about STFFT through social interactions and chose to adopt the technology. A social network connects a group of individuals who share a close relationship. Farmers can pass on information and exchange experiences and opinions through the social network [70]. However, the isolation of different communities severely restricts the flow of information and leads people to become locked into the inherent behavior patterns of traditional productive thinking [71]. A social network is an important information acquisition channel in rural areas and the main form of interactive communication. This can be used as a supplement or substitute for productive assets, improve farmers’ labor productivity and promote the adoption of new technologies, which in turn can also expand rural families’ social network [72]. This virtuous cycle helps farmers eliminate the fixed thinking of traditional production modes and enhance their willingness to adopt new technologies [70]. Based on this, this paper puts forward proposition 7.

**Proposition 7. There is a positive correlation between social networks and farmers’ adoption of STFFT.**

Information Awareness and Social Networks

Table 5 summarizes the evidence about the level of information awareness and social network constructs. Farmers in the non-adopting STFFT group generally had lower social networks, while those in the adopting STFFT group generally had higher social networks, at 77.5% and 88.4%, respectively. By comparing the information awareness of farmers in the Group 1 and Group 2, it can be seen that when farmers’ information awareness increases, their social networks also increase. By comparing the information awareness of farmers in the first group and the second group, it can be found that the information value awareness, information needs identification awareness, and information acquisition awareness of farmers in the second group (adopting STFFT) were higher than those in the first group (not adopting STFFT). Correspondingly, the social network of farmers in the second group (adopting STFFT) was also higher than that of the first group (not adopting STFFT). This suggests that there is a positive relationship between farmers’ information awareness and their social networks. Therefore, we put forward propositions 8, 9, and 10.

**Proposition 8. There is a positive correlation between information value awareness and social networks.**
Proposition 9. There is a positive correlation between information needs identification awareness and social networks.

Proposition 10. There is a positive correlation between information acquisition awareness and social networks.

Table 5. Information awareness, social networks, and farmers’ adoption of STFFT.

<table>
<thead>
<tr>
<th>Information Value Awareness</th>
<th>Farmer Group 1 (Not Adopt)</th>
<th>Farmer Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Ratio/%</td>
<td>Adduction</td>
<td>Evaluation Ratio/%</td>
</tr>
<tr>
<td>High</td>
<td>38.01</td>
<td>High 40.22</td>
</tr>
<tr>
<td>Low</td>
<td>38.54</td>
<td>Medium 68.27</td>
</tr>
</tbody>
</table>

Table 5. Information awareness, social networks, and farmers’ adoption of STFFT.

<table>
<thead>
<tr>
<th>Information Needs Identification Awareness</th>
<th>Farmer Group 1 (Not Adopt)</th>
<th>Farmer Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Ratio/%</td>
<td>Adduction</td>
<td>Evaluation Ratio/%</td>
</tr>
<tr>
<td>Low</td>
<td>38.54</td>
<td>High 40.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Information Acquisition Awareness</th>
<th>Farmer Group 1 (Not Adopt)</th>
<th>Farmer Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Ratio/%</td>
<td>Adduction</td>
<td>Evaluation Ratio/%</td>
</tr>
<tr>
<td>Low</td>
<td>42.32</td>
<td>High 38.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Networks</th>
<th>Farmer Group 1 (Not Adopt)</th>
<th>Farmer Group 2 (Adopt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Ratio/%</td>
<td>Adduction</td>
<td>Evaluation Ratio/%</td>
</tr>
<tr>
<td>Low</td>
<td>77.5</td>
<td>High 88.4</td>
</tr>
</tbody>
</table>

The Mediating Effect of Social Networks

According to the above analysis, both information awareness and social networks can promote farmers’ adoption of STFFT, and there is a positive correlation between information awareness and social networks. Generally speaking, to improve the efficiency of information utilization, farmers with strong information awareness will be more proactive in transmitting and sharing information within their organization [73]. Through interpersonal communication of information, farmers master practical technical knowledge, enhance their trust in network members, and increase the frequency of communication with network members [74]. In this process, the scale of the social network obtained by farmers was gradually expanded, and the quality of the network continued to improve, which in turn affected the amount of information and resources farmers obtained during the adoption of STFFT, and ultimately affected their technology adoption behavior [75].

In particular, information awareness can help break the solidified social network problem in geographical locations, which is conducive to maintaining existing solid relationships, forming new weak connections, and assisting farmers in expanding social networks [76]. In particular, their information awareness represented by the integration of information resources helps to improve the convenience of information communication within social networks, dramatically reduces the cost of establishing and maintaining social relations, and is conducive to the expansion of social networks and the improvement of the strength of social networks [77]. Compared with the “circle” structure of the traditional social network, the social network under the influence of information consciousness presents a “chain” structure, with no clear boundaries [78]. Information awareness is helpful for increasing the number of contacts of social network members, deepening the
strength of social networks, and expanding the scale of the social network, as represented by the actual number of interaction relations of network members [79]. It can be seen that information awareness, as the guarantee of social information exchange, plays a unique role in deepening the strength of social networks. Accordingly, this paper puts forward Proposition 11.

**Proposition 11.** Social networks mediate between information awareness and farmers’ adoption of STFFT.

### 3.5.4. The Moderating Effect of Social Networks on Environmental Values

Table 6 summarizes the measurement results of environmental values, information awareness, social networks, and the STFFT adoption behavior of the two groups of farmers. For farmers with a higher social network, more environmental values led to a higher willingness to adopt STFFT. For example, comparing the environmental values and social networks of the farmers of Group 1 and Group 2, it was found that the farmers of Group 2 had a larger social network and generally higher environmental values, so they decided to adopt STFFT. On the contrary, the farmers of Group 1 had small social networks and generally less environmental values, so they choose not to adopt STFFT. Social networks create the necessary environment for cultivating and improving farmers’ environmental values [80]. Through interactive learning among their internal members, social networks enhance environmental cognition and promote the cultivation and improvement of individual environmental values [81]. This means that farmers with extensive interpersonal communication in social networks have more possibilities for improving the practice of their own environmental values. At the same time, the entire social network environment also plays a catalytic role in cultivating and improving farmers’ environmental values [82]. For example, social networks pay more attention to ecological and environmental issues, subtly improving farmers’ environmental values. Farmers may pay more attention to environmentally friendly technologies such as STFFT. Therefore, we put forward proposition 12.

**Proposition 12.** Social networks moderate the relationship between environmental values and farmers’ adoption of STFFT.

### Table 6. Measurement results of environmental values, information awareness, social networks, and farmers’ adoption of STFFT.

<table>
<thead>
<tr>
<th>Environmental Value</th>
<th>Information Awareness</th>
<th>Social Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Egoistic Value</td>
<td>Altruism Value</td>
<td>Ecological Value</td>
</tr>
<tr>
<td>Group 1</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Group 2</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

### 4. Discussion

Agricultural production is the main economic source for Chinese farmers and an important industrial pillar. However, the excessive dependence on the traditional agricultural production mode of chemical fertilizers and pesticides has led to the depletion of land resources and environmental pollution, which seriously threatens the sustainable development of agriculture. Therefore, seeking green agricultural production technology to replace traditional agricultural production technology has become the primary task for China, to achieve sustainable agricultural development. Much research has been devoted to revealing constraints on and changes to in farmers’ behavior toward green agricultural tech-
nologies and how to promote their adoption [83–85]. However, the use of green agricultural technologies has been generally low in developing countries since the 1970s [86,87].

The existing research mainly investigated the internal and external factors influencing farmers to adopt green agricultural technology by constructing econometric models [22,88]. This paper presents a virtual imitation of the utility of farmers’ environmental values, information awareness, and social networks in influencing their adoption of STFFT from internal factors and validates them using case studies. Due to the future-oriented nature of the simulation results, traditional out-of-sample fitting cannot validate them [89]. Therefore, the findings of this paper complement the existing research on the internal factors affecting farmers’ green technology adoption. For example, research on farmers’ adoption of green technologies in agriculture has generally confirmed that farmers’ environmental awareness affects their adoption behavior [90]. Nevertheless, it has also been demonstrated that farmers with self-interested environmental values may be more inclined to adopt green agricultural technologies that can bring direct economic benefits [91]. At the same time, social networks can provide opportunities for information exchange and cooperation, to expand farmers’ access to information, thus enhancing the influence of environmental values on farmers’ adoption of green agricultural technologies [92]. Our findings highlight the positive influence of social networks on farmers’ self-interested environmental values and green technology adoption, consistently with Liao, et al. [93] and Wang, et al. [94].

This shows that the social network of farmers can be an effective channel to promote the adoption of green technology by farmers. In particular, farmers with self-interested environmental values are more likely to be influenced by people who have adopted green agricultural technology in their social networks, thereby increasing their willingness and utility to adopt green agricultural technology. The positive impact of information access awareness on farmers’ adoption of agricultural green technologies has also been generally verified [95]. However, some studies have shown that farmers with a strong awareness of information acquisition may pay more attention to the risks and uncertainties involved in adopting green agricultural technologies. Some studies suggest that farmers’ concerns about adopting green agricultural technologies mainly stem from technological uncertainties, risks, and costs related to information access [15,96]. Our research suggests that despite the expected risks of farmers adopting green technologies in agriculture in the short term, farmers with a strong awareness of information acquisition will eventually offset their concerns about technology adoption with more comprehensive information. The reason for this is that farmers with a strong awareness of information acquisition will more actively participate in the study and understanding of green agricultural technology. As a result, they are more likely to acquire relevant knowledge and skills, enhancing their confidence and willingness to adopt green agricultural technology [97].

According to the conclusions of this paper, a social network plays an intermediary role in farmers’ information awareness and STFFT adoption. Furthermore, it plays a moderating role in the impact of environmental values on farmers’ adoption of STFTS (see Figure 4). This is also in line with China’s reality. In rural social networks, a lot of information is transmitted through communication between people, due to the limited sources and channels of information. Therefore, social networks can become an important way for farmers to understand and learn about STFFT. At the same time, social networks are also an important platform for forming and disseminating farmers’ values. As a result, they can communicate environmental concepts and values through social channels and promote farmers’ acceptance of STFFT.
works through information exchange and cooperation, thus promoting farmers’ adoption of STFFT. The study found that farmers with a strong awareness of information acquisition may pay more attention to acquiring relevant technologies, which has been generally verified in previous studies. 

Effective access to information can enhance the effectiveness of information awareness and environmental values, thus promoting farmers’ adoption of STFFT. Specifically, farmers with information awareness spread relevant information and knowledge of STFFT through their social networks, improving farmers’ technical cognition, offsetting the expected risks of farmers adopting STFFT, and promoting the adoption of this technology. By enhancing the environmental value of farmers, social networks fill the gap between the economic benefits of crops obtained using the traditional fertilization method and the STFFT method in the short term with environmental benefits, thus promoting the adoption of STFFT by farmers. 

In addition, the social network mediates between information awareness and farmers’ adoption of STFFT and has a moderating role between environmental values and farmers’ adoption of STFFT.

Third, regarding environmental values, farmers with environmental altruism values and ecological environment values take improving social and ecological aspects as their behavioral norm, thus promoting the adoption of STFFT by farmers. However, there is no correlation between self-interested environmental values and farmers’ adoption of STFFT. In addition, information transmission and the social pressure effect of the social network positively affect environmental values.

Fourth, information acquisition awareness enhances the strength of farmers’ social networks through information exchange and cooperation, thus promoting farmers’ adoption of STFFT. However, there is no correlation between the awareness of information values, the awareness of information need recognition, and the adoption of STFFT.

This study has important policy implications. First, the government should strengthen technology popularization and knowledge popularization. For example, the government could set up technical training centers in local village committees, agricultural technology...
stations, and other places; invite experts for field guidance and technical exchanges; and introduce the benefits and operational methods of STFFT to farmers. In addition, the government could establish relevant websites and social media accounts to popularize relevant knowledge and technology to farmers online, to improve their awareness of STFFT.

Second, the government could increase support for environmentally friendly agriculture and establish relevant incentive mechanisms, such as giving certain tax incentives or financial subsidies to farmers who use STFFT. In addition, the government could also strengthen the publicity around environmental protection, guide farmers toward the concept of green development, cultivate environmental awareness, and promote green and sustainable agricultural development. Third, the government could encourage the establishment of agricultural cooperatives, farmers’ specialized cooperatives, and other organizations, to organize exchange activities among farmers to strengthen communication and cooperation, as well as share the experience of using STFFT to improve farmers’ confidence and the adoption rate of STFFT. In addition, the government could also strengthen the contact and coordination between agricultural technical experts and farmers and provide farmers with more professional technical support and services.

There are three limitations to this study. First, this paper constructed an evolutionary game model to analyze the adoption of STFFT only from the farmers’ perspective, without considering the influence of other stakeholders. Therefore, in the future, the adoption of agricultural green technology by different stakeholders could be considered. Second, although the causal mechanism of environmental values, information awareness, and social networks on STFFT adoption was investigated in the case study, the quantitative causal relationship between them cannot be accurately estimated. Therefore, future studies could use more precise research methods, such as experimental studies, longitudinal studies, or analysis based on big data, to more accurately estimate the causal quantitative relationship between these factors. Third, this study only focused on a typical case in Linzhou city, Henan province, China, which may have regional restrictions. Therefore, it is necessary to expand the research scope further, to ensure the applicability and generalization of the research results.

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