sustainability

Review

Diffusion of Agricultural Technology Innovation: Research Progress of Innovation Diffusion in Chinese Agricultural Science and Technology Parks

Xieyang Chen and Tongsheng Li *

College of Urban and Environmental Sciences, Northwest University, Xi'an 710127, China
* Correspondence: leetang@nwu.edu.cn; Tel.: +86-13072901278

Abstract: With the rapid development of agricultural technology in China, a new model of agricultural technology diffusion, represented by agricultural science and technology parks, has been formed. We systematically sort out the progress of agricultural technology diffusion-related research based on a proposed research framework of technology diffusion in agricultural science and technology parks. The growth mechanism of agricultural technology poles, agricultural technology diffusion system, and its characteristics are analyzed. An index system of technology diffusion environment evaluation is summarized. From the perspective of the "basic" paradigm, we discuss the characteristics of the time process (diffusion stage, diffusion speed, diffusion breadth) and the spatial process (diffusion effect, spatial pattern) of technology diffusion in agricultural science and technology parks and their influence mechanisms. The fundamental law of "point-axis" diffusion of technology diffusion in the park is summarized. From the perspective of the "adoption" paradigm, we analyzed the influencing factors and mechanisms of farmers' technology adoption. The effects of different environments and technologies with different attributes on farmers' adoption behavior are explored. Based on the latest research results, we summarized new business agents' technology adoption behaviors and mechanisms. Finally, we point out the issues that need to be further explored in studying the technology diffusion of agricultural innovations.

Keywords: agriculture; technology diffusion; technology adoption; agricultural science and technology parks; China

check for updates

Citation: Chen, X.; Li, T. Diffusion of Agricultural Technology Innovation: Research Progress of Innovation Diffusion in Chinese Agricultural Science and Technology Parks. *Sustainability* **2022**, *14*, 15008. https://doi.org/10.3390/su142215008

Academic Editor: Marko Vinceković

Received: 25 September 2022
Accepted: 9 November 2022
Published: 13 November 2022

1. Introduction

Agricultural technology innovation diffusion is a part of technology innovation diffusion. It refers to the process in which new agricultural technology, inventions, achievements, etc., start to spread from the source of innovation to the surrounding area and is adopted and used by most farmers and agriculture-related enterprises. The ultimate goal of diffusion is commercializing agricultural products after adopting agricultural technology. Agricultural technology innovation is fundamentally different from industrial technology innovation [1,2]; for example, the subjects of the former are more diversified than those of the latter. The object of agricultural innovation has the attributes of public goods or quasi-public goods; the process of agricultural innovation has discontinuity and relative independence of innovation links; the user system of agricultural innovation has unique characteristics, etc. Therefore, agricultural technology innovation has complex mechanisms in the diffusion process. Researchers from various disciplines, such as sociology, geography, and economics, have conducted long-term studies on the diffusion of agricultural technology innovation. Researchers have made many achievements and accumulated rich research experiences in many aspects [3–8], such as the influencing factors of innovation diffusion, user systems, diffusion types, diffusion processes, and diffusion models. In particular, in Ryan and Gross's research on the diffusion of hybrid corn seeds in Iowa, they constructed a paradigm for diffusion research and developed a typical survey method for farmers [9]. Geographer Hagstrom made a seminal contribution to the spatial process of agricultural technology diffusion [10]; however, the theoretical basis of Hagstrom's spatial diffusion theory and model is homogeneous space, so the diffusion model is too idealized. In application and practice, there are many discrepancies with reality [2].

Research on the diffusion of agricultural technology innovation in China started relatively late. The research content mainly focuses on promoting foreign theories and methods, researching the influencing factors of diffusion and the improvement of agricultural technology diffusion systems, and researching farmers' technology selection [11–13]. The research results are relatively few and still far from systematic. In general, Chinese research on agricultural technology diffusion can be divided into two major categories according to the purpose of the research and research objects. One category is the research on the adoption behavior of agricultural technology innovation with farmers as the research object. It focuses on the factors influencing the adoption of agricultural technology innovation, and the methodology focuses on behavioral analysis. The aim is to induce farmers' behavior and promote agricultural technology adoption [14–16]. Another type of research is the study of agricultural technology innovation diffusion laws and their influencing factors, with the overall characteristics of agricultural technology innovation diffusion as the research object. It tends to study the characteristics of the diffusion process, the factors affecting diffusion, and the diffusion rate, often borrowing mathematical models to reflect the diffusion process [17,18]. The theoretical basis of these studies is the S-curve theory.

Currently, agricultural technology diffusion research in China has shifted from macroscopic policy interpretation and theory introduction to microscopic research and mechanism studies [19]. Chinese research has begun to focus on the study of governmental public welfare agricultural technology diffusion services and the study of innovation in modern agricultural technology diffusion services [20]. It has also begun to focus on studying the intrinsic mechanism of agricultural technology diffusion and combining qualitative case analysis and quantitative analysis. However, most of the current disciplinary research theories are still borrowed from foreign agricultural technology theories, and there are fewer theoretical innovations based on Chinese localities. Agricultural technology diffusion research in China has now begun to focus on multidisciplinary cross-sectional research [21]. Knowledge from sociology, management, geography, behavior, and other related disciplines is combined with agricultural economics for analysis and evaluation. Attention has been paid to the impact of the social, environmental, and individual behavior dimensions on the diffusion of agricultural technology [19–21].

Technology zones/technology poles are one of the significant regional models of contemporary technological innovation. Numerous studies have shown that they are both cumulative, path-dependent historical growth processes and a product of national technology policies [22]. Technology regions/technology poles grow and develop through localized innovation clusters and drive the development of the entire region through their diffusion effects [23–25].

Agricultural Science and Technology Park (ASTP) is a new model of agricultural technology innovation and achievement transformation that emerged from the modernization of China's agriculture in the 1990s [24]. It is a technology zone/technology pole for developing Chinese agriculture and agricultural regions. Therefore, technology diffusion in ASTPs is China's leading regional model of agricultural technology diffusion. Since 2001, the development of China's national ASTPs has undergone a pilot phase, a comprehensive promotion phase, and now has entered an innovative development phase. China has built 295 national ASTPs in seven batches, covering all provinces, municipalities, and autonomous regions [26], as well as tens of thousands of provincial-, municipal-, and county-level ASTPs and modern agricultural demonstration zones. Various ASTPs at all levels are tasked with both agricultural science and technology innovation [24]. Moreover, they need to promote regional agricultural restructuring, quality and efficiency improvement, and the overall development of agricultural areas through innovation diffusion.

Therefore, this paper first introduces the developmental evolutionary process of agricultural technology innovation diffusion and the main research contents of agricultural technology innovation diffusion in China. Secondly, it focuses on the primary regional model of agricultural innovation technology diffusion in China: the research process of innovation diffusion with ASTPs as technology zones/technology poles. Finally, the article summarizes the progress of innovation diffusion research in Chinese ASTPs and discusses its implications, limitations, and future research (Figure 1).

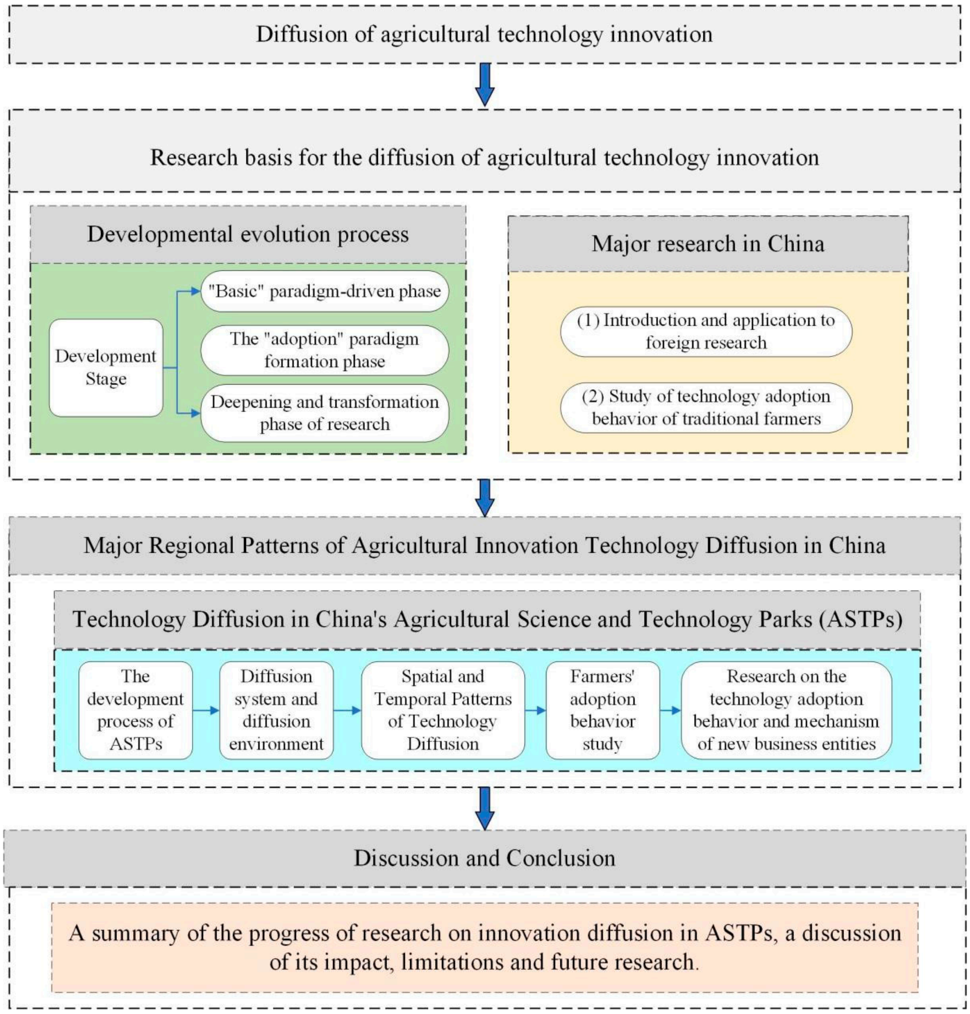

Figure 1. Research framework.

2. Research Basis for the Diffusion of Agricultural Technology Innovation

2.1. Development Stages of Agricultural Technology Innovation Diffusion Research

Two representative views have been formed in agricultural technology innovation diffusion research: the "basic" view and the "adoption" view. From the "basic" viewpoint, the research on the process and laws of agricultural technology diffusion, influencing factors, and diversification patterns has been relatively mature. From the "adoption" viewpoint, the research on the technology adoption behavior of traditional farmers has also made significant progress [27]. Research on the diffusion and adoption of agricultural technology innovation can be divided into three stages.

Phase I: Multidisciplinary Research and "Foundational" Paradigm Dominated Phase

Since the 1920s, many disciplines, such as anthropology, sociology, economics, and geography, have actively explored the diffusion of agricultural technologies. For example, Wissler [8] focused on the influence of different social cultures on technological diffusion, Kuznets [7] proposed the "S" curve of technological change, and Bryce Ryan and Neal Gross [22] used the first participatory approach to technological adoption behavior. Hagestrand [10] proposed the "MIF" model and the "four-stage" model of technological diffusion from a geospatial perspective, and Mansfield [8] constructed an S-shaped model of technological diffusion. In 1962, Rogers summarized the four main factors affecting agricultural technology diffusion [25]. These pioneering studies and their results became the theoretical basis of agricultural technology diffusion research and gradually formed a top-down "foundation" paradigm. This paradigm has the following essential characteristics: It takes the overall characteristics of agricultural technology diffusion as the research object. It mainly studies technology diffusion characteristics, diffusion influencing factors, diffusion rate, and other aspects and mainly uses mathematical models to express the diffusion process and characteristics.

Phase II: The "Adoption" Paradigm Formation Stage

In the 1970s, many scholars recognized the limitations of the existing research paradigm, i.e., the neglect of farmers' technology adoption behavior. The diffusion models and laws developed in the existing research could not guide the practice well. Researchers have shifted their perspective towards farmers and paid attention to studying agricultural technology adoption behavior [28]. Theodore Schultz's rational smallholder theory, James Scott's farm risk-avoidance theory, and Chayanov's labor-avoidance theory have become the theoretical basis for the study of farmers' behavior [20,21]. Technology adoption motives, adoption decision models, and influencing factors are the main concerns of this paradigm. The emphasis on farmer cultivation, farmer assessment, farmer experimentation, and the focus on "participatory farmer technology development (FPTD)" [29] became essential for analyzing, and later, inducing farmers' technology adoption behavior.

Phase III: Deepening and Transformation of The "Adoption" Paradigm

Since the 1990s, the perspectives, methods, and contents of international research on farmers' technology adoption behavior have been deepened and transformed [2].

(1) Changes in research perspectives. First, there is a shift from the study of adoption behavior to the study of adoption results. This change in perspective is mainly caused by the agricultural subsidy policies of European and American countries. In order to encourage farmers to adopt agro-environmental technologies, the government offers them certain subsidies. However, the ecological benefits that are ultimately achieved do not meet the EU's "green standards". Therefore, this has prompted researchers to think about the existing research paradigm and move toward the adoption of outcome studies [30–33]. Second, there is a shift from outcomes-based research to utility-based research. In the vast majority of sub-Saharan Africa, 66% of the population lives in rural areas, and over 90% rely on agriculture as their primary source of livelihood. Agriculture is a powerful option for stimulating economic growth and overcoming poverty to enhance food security in this region [34–37]. Agricultural research and technological improvements are essential to increase agricultural productivity. In this context, many scholars have begun focusing on the utility of adopting agricultural technology [38–40]. Third, there has been a shift from static to dynamic research. Leggesse [41], Francisco [42], Lambrecht [43], and others have shown that farmers' technology adoption behavior is a dynamic psychological process. It includes five stages: cognition, interest, evaluation, experimentation, and application. Instead of analyzing only one of these stages, a dynamic tracking study should be conducted on the adoption process.

(2) Changes in research methods. In order to improve and enhance the traditional methods of characteristic analysis, ratio analysis, and influence factor analysis in the study of farmers' technology adoption behavior, many scholars have been actively exploring new research methods [44]. For example, Brooke et al. [45]. used participatory farmer assessment (PRA) to study farmers' needs, preferences, and local production conditions. Balmain [46] combined the meta-automata model to simulate farmers'

optimal behavior in agro-ecosystems. Berger [47] used the subject space model to simulate farmers' socio-spatial interactions, in order to try and better understand the diffusion process of technological innovation and resource-use change. Davis et al. [48] proposed the Technology Acceptance Model (TAM) from farmers' rational behavior theory. Venkatesh [49] and Lee et al. [50] argued that the TAM model succinctly and effectively describes the inherent logical connections among external variables, usefulness perceptions, ease of use perceptions, and information technology, providing a method that can effectively explain technology adoption behavior.

(3) Extension of research content. This aims to focus on the more profound research on the factors influencing farmers' decision-making behavior [51–54]. Emphasis is placed on public good technology adoption behaviors such as agricultural and environmental protection [55]. How to change farmers' technology adoption preferences to improve the applicability of agricultural sustainability technologies has received attention [56]. The impact of financial institutions' agricultural credit systems on agricultural technology adoption has received attention [57,58]. Attention is also being paid to new business agents, such as cooperatives in agricultural technology diffusion.

2.2. Major Research on the Diffusion and Adoption of Agricultural Technology Innovation in China

Researchers in China have studied the diffusion and adoption of agricultural technology innovations in two main ways: on the one hand, they have introduced and applied foreign research, focusing on diffusion models and the diffusion-efficiency analysis of agricultural technologies [59]. On the other hand, the research focuses on the technology adoption behavior of traditional farmers [60].

Chinese researchers are relatively late in studying the technology adoption behavior of farmers. Earlier studies focused on the study of farmers' technology adoption behavior and psychological characteristics; the analysis of farmers' technology adoption motives, incentives, utility, and risk; and farmers' technology demand intentions [61]. Recent studies have focused on environmentally friendly technology adoption, the technology demand of new agricultural operators, innovation diffusion in ASTPs, and farmers' technology adoption behavior [62]. At present, research progress is focused on three areas.

(1) A study of farmers' willingness to demand technology. Farmers' technology adoption characteristics based on the demand perspective mainly include behavioral and psychological characteristics. Li Qifeng et al. [63] used the participatory assessment method (PRA) to empirically analyze the main grain-producing areas in northeast China. They found that about 50% of farmers demand new agricultural technologies, 89.4% of farmers are happy to receive technology extensions, but 50% do not receive extension services. Shi Shaobin's [64] survey found that farmers show strong demand for agricultural technology, especially technical guidance services, and farmers' willingness to pay for technology is influenced by education level, income, surrounding farmers, and whether they are members of cooperatives.

(2) Research on decision-making behavior. This study focuses on the utility analysis of "rational small farmers" in pursuit of utility maximization [61]. The study also investigates the risk analysis of "survival smallholders" in pursuit of risk minimization. Huang et al. [65] found that farmers' perceived economic efficiency, quality assurance, and household wealth have significant effects on their planting decision behavior. There are many differences between farmers' decision perceptions and their behavior in practice. Weiyi Yang proposed that farmers' decision on technology adoption is a choice under limited rationality. He constructs a single-farm technology adoption model and a multi-farm technology adoption model to verify the influence of various psychological factors on decision-making behavior. The study found that surrounding farmers easily influence farmers' technology adoption behavior. Therefore, the bene-

fits of communication, the scope of communication, and the cost of communication are essential factors influencing the decision-making behavior of farmers' herding effect.

(3) Research on the influencing factors of technology adoption behavior. We found that the influencing factors can be divided into two types of forces: drivers and hindrances at the macro level. At the micro level, they are divided into eight aspects: farmers, technology, environment, economy, location, policy, resources, and society. Among them, farmer characteristics and household characteristics have a long-term and profound impact on the technology adoption behavior of Chinese farmers [66–70]. Chu and Rainbow et al. [71] found that farmers who were members of cooperatives and trained in agricultural technology were more likely to adopt environmentally friendly agricultural technologies. The larger the farming size and the more concentrated the plots, the more likely the farmers will adopt soil testing technologies. The subsidy policy is conducive to a good technology adoption environment [72].

The above study is based on the empirical analysis method. A binary choice model, i.e., the logistic model, was used more frequently, followed by a game model. Few studies have used participatory farmer assessment methods, multiple regression models, data envelopment models, technology acceptance models, multi-intelligence body models, and structural equation models. Behavioral analysis methods are gradually gaining attention. Zhou Rong [73] combined the theory of planned behavior (TPB) and social network theory (SN) to construct the mechanism of the occurrence of agricultural technology adoption behavior.

2.3. Descriptive Statistical Analysis of Diffusion and Adoption Studies of Agricultural Technology Innovations

The Science Citation Index Expanded (SCIE) and Social Sciences Citation Index (SSCI) databases of the Web of Science Core Repository were used as search sources. The terms "Diffusion" or "Adopt" with "Agriculture" or "Agricultural technology" were set as a condition. The literature related to agricultural innovation research was searched. SATI software was used to count the number of articles and keywords from 2000 to 2021. Figure 2 shows that the number of articles published annually on the diffusion and adoption of agricultural technology innovation has increased significantly since 2000, from 7 (2000) to 24 (2021). Over the years, the number of emerging keywords has also increased from 45 (2000) to 253 (2021), a six-fold increase, the peak of which appeared in 2019 (37 articles). This indicates a significant increase in international scholarly studies on the diffusion and adoption of technological innovations in agriculture (Figure 2).

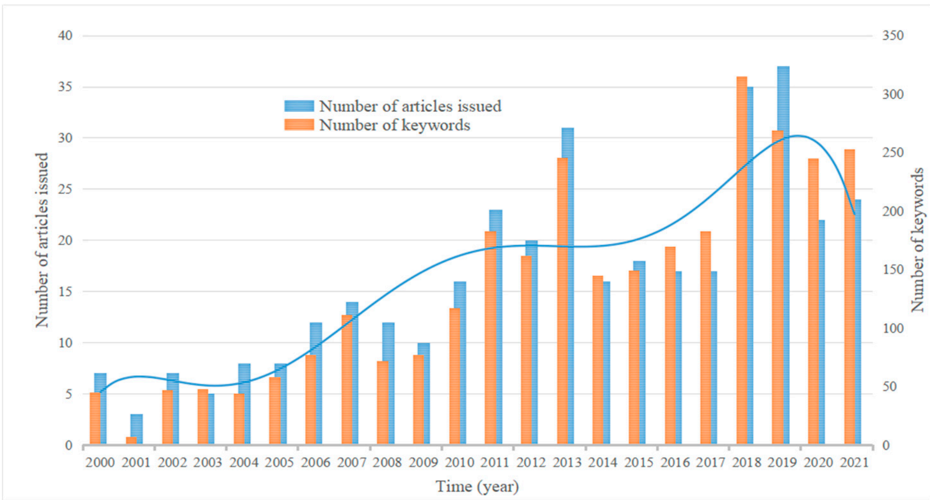

Figure 2. Annual changes in the number of articles and keywords published in international journals on agricultural innovation diffusion and adoption themes.

China Knowledge Network (CNKI) was used as the data source. We set "agriculture" or "farmers" with "diffusion" or "adoption" or "Select" as the search condition. Core journals or CSSCI journals were set as the document type. The literature on the diffusion and adoption of agricultural technology innovation in China was searched. SATI software was used to count the number of articles and keyword information from 2000 to 2021. The results show that the annual number of articles published on the diffusion and adoption of agricultural technology innovation in China had increased significantly since 2000. The number of articles has increased from 2 (in 2000) to 14 (in 2021). Over the years, the number of emerging keywords has also increased seven-fold, from 8 (2000) to 53 (2021), the peak of which appeared in 2018 (23 articles). The results indicate a significant growth in Chinese scholars' diffusion and adoption of agricultural technology innovations (Figure 3).

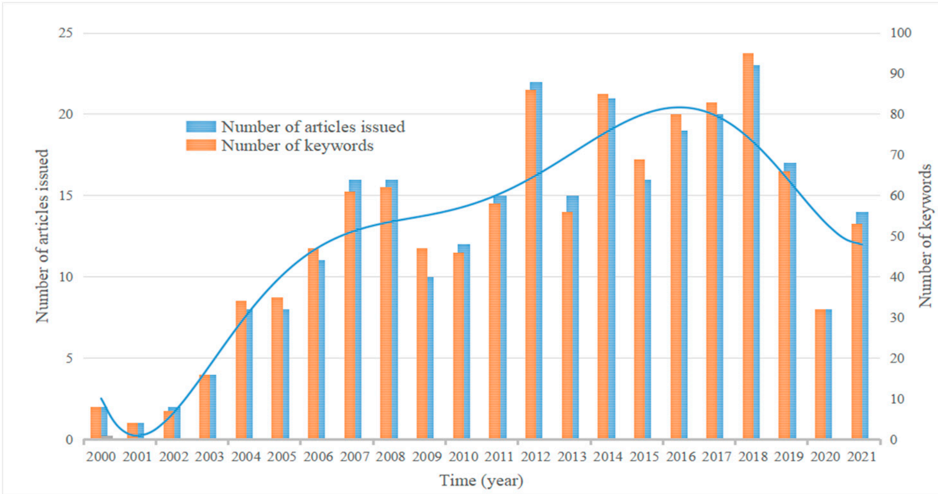

Figure 3. Annual changes in the number of articles and keywords published in Chinese journals on agricultural innovation diffusion and adoption themes.

3. Major Regional Patterns of Technology Diffusion of Agricultural Innovations in China: Technology Diffusion in ASTPs

3.1. Technology Diffusion in China's ASTPs

ASTP is the technology diffusion process from innovators to adopters. It is also a process of spatial movement from the source of innovation to the diffusion area, and the technology "potential difference" between the park and the surrounding area is the basis and driving force of technology diffusion [35]. Following the research idea of "pattern-structure-process-mechanism", the research framework of ASTPs is based on "structure-process-mechanism" [2]. The research framework of ASTPs starts from the spatial pattern of technology "potential energy" in the parks. It analyzes the internal structure and external environment of the technology diffusion system. Then, the top-down diffusion perspective and the bottom-up adoption perspective are explored. We explore the characteristics of technology diffusion and farmer adoption processes in ASTPs, the influencing factors, and their mechanisms (Figure 4).

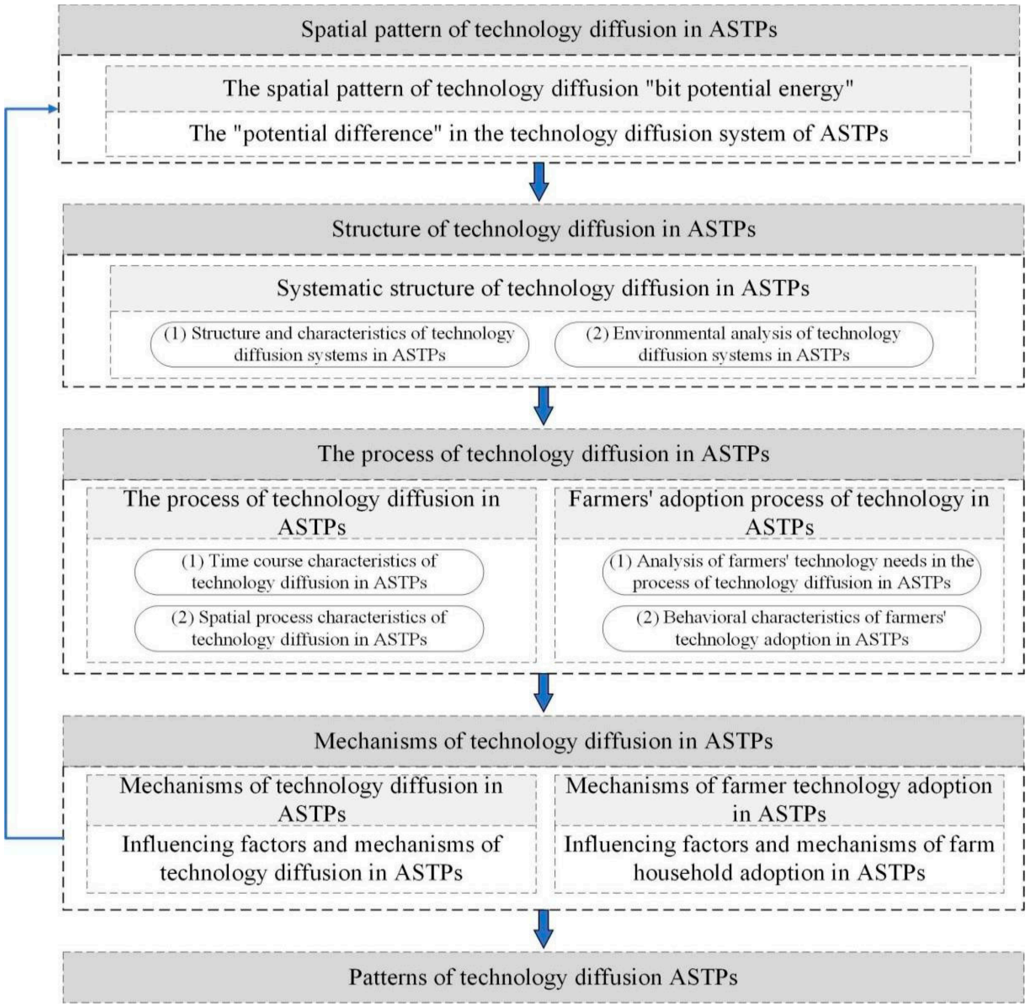

Figure 4. The research framework of ASTP technology diffusion.

3.2. The Development Process of Technology Diffusion in Chinese ASTPs

ASTPs are the technological poles of agricultural innovation and development. They are generally composed of a core, demonstration, and radiation areas. The formation of technology poles is in the clustering of innovation elements, innovation organizations, and innovation industry space. It is also the process of enhancing the technological "potential energy" of the technological pole and its technological "potential difference" with the surrounding areas (Figure 5).

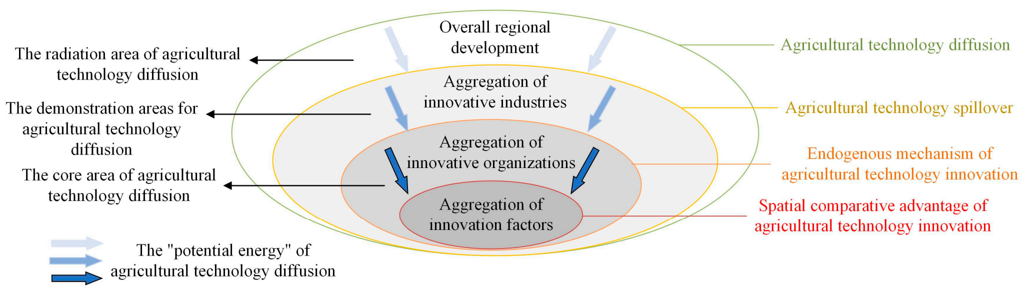

Figure 5. The schematic diagram of the ASTP growth progress.

Spatial comparative advantage is the basis for the locational choice of economic activities. Spatial comparative advantage depends not only on spatial factor endowment and geographical location, but also on the social costs that have been precipitated over time. This includes physical inputs (infrastructure) and benign conditions that affect the efficiency of transactions. In addition, an effective policy system is also a source of "innovative" comparative advantage. There is a dense distribution of innovative factors, such as agricultural-related universities, research institutions, and human resources with high knowledge and skills. With the government's spatial planning, favorable policies, and capital investment, the comparative spatial advantage will attract the further concentration of innovative factors. Technology poles are formed through the polarization effect.

Spatial proximity does not necessarily create interconnectedness among organizations. An innovation network is key to effectively combining various organizations into one. It can create a more technological competitive advantage [74]. The motivation for agricultural technology innovation stems from the pursuit of monopoly profits (including economic benefits, social status, and personal values) introduced by the innovation subjects. The spatial proximity and mutual exchange of innovation sources such as agricultural and forestry universities, research institutions, and agro-related enterprises form knowledge flow. In particular, the acquisition of "tacit knowledge" by Wei provides the possibility of accelerating the accumulation of knowledge and innovative technologies and promoting the production of innovative products. The high-risk and high-reward nature of science and technology innovation and the time lag in the transformation and application of science and technology results. These characteristics stimulate the creation and clustering of new specialized service organizations. In turn, they attract and stimulate the clustering of various types of organizations providing life services and the construction of high-quality infrastructure. This can create a more technological competitive advantage and attract innovation sources and other organizations to the park. It also strengthens the "innovation climate" [75] that generates new technologies. Under this endogenous growth mechanism of innovation, universities, research institutions, enterprises, intermediary service organizations, and other innovative organizations are further concentrated. They gradually form technological nuclei, the spatial polarization effect is further strengthened, and technological spillover effects appear.

Technology spillover is the positive externality of technology. It is the reason for the formation of technological or industrial agglomeration, as innovative technologies are continuously generated. Moreover, it penetrates pre-production, production, and post-production. Universities, research institutions, agricultural enterprises, and service organizations are interconnected. Localized "innovation networks", including knowledge, production, social support, etc., are formed. Innovation clusters are formed through fierce competition and close cooperation within and among the networks [76]. The cluster will generate external economies of scale, which will create new enterprises and attract enterprises outside the cluster. The scale and advantages of the cluster are accumulated and expanded, which reflects the self-reinforcing process of "path dependence" and "cumulative causation" [77]. The technology pole is formed, the technology "potential energy" is further enhanced, the spatial diffusion effect is strengthened, and the technology spillover effect is outstanding.

Along with the continuous generation of innovative technologies, ASTPs have gradually grown into technology highlands with high "potential energy". The technology "potential difference" between the park and the surrounding areas becomes the internal driving force of technology diffusion. The innovative technology continues to spread to the surrounding areas and penetrate the industry, and it drives the overall development of the region. However, in reality, this process does not happen naturally. The combination of various factors inside and outside the park restricts the speed and effect of the diffusion of innovative technologies. This, in turn, affects the realization of the functions of ASTPs.

3.3. Technology Diffusion System and Diffusion Environment in Chinese ASTPs

Technology diffusion in ASTPs involves five essential elements: a technology innovator, the technology itself, diffusion channel, adopter, and diffusion environment in the ASTP. The interrelationship and interaction among these elements determine technology diffusion's spatial and temporal process. At the same time, the technology diffusion process affects the factors and their interrelationships, thus, forming a complex system [8] (Figure 6). The technology diffusion system in ASTPs has spatio-temporal completeness (i.e., time and space are simultaneously influential and equally crucial for technology diffusion in the ASTP system); potentiality (i.e., the technological "potential difference" between the ASTP and the surrounding area, the driving force of technology diffusion); and hierarchy (the ASTP system has different levels of spatial scales and technological "potential", i.e., the technology "potential difference" between the ASTP and the surrounding area is the driving force for technology diffusion).

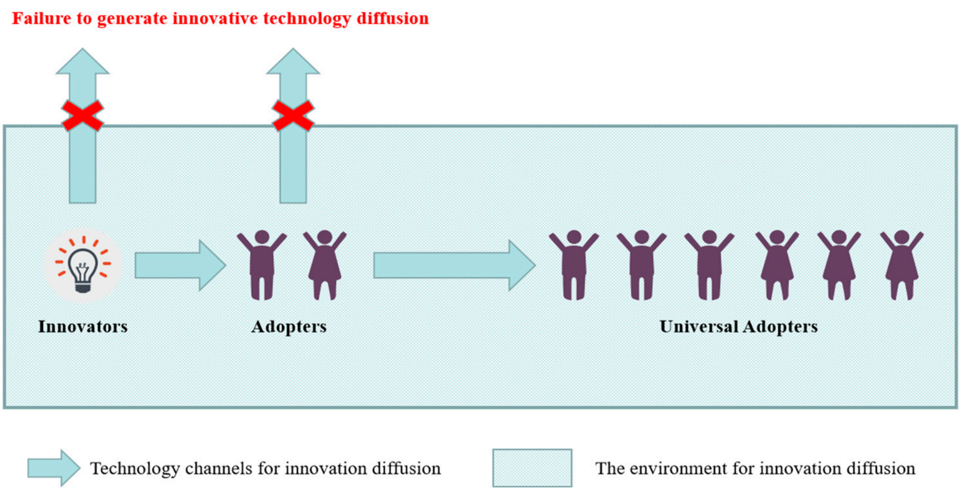

Figure 6. The ASTP technology diffusion system.

The technology diffusion environment in ASTPs synthesizes many external factors affecting technology diffusion in the system. The technology diffusion environment acts on the whole process of technology diffusion. It affects the spatial flow of technology, and diffusion's speed, mode, and effect. From the viewpoint of technology flow, the diffusion environment suitable for technology performance will produce inherent traction on the ASTP technology and, vice versa, will prevent the occurrence of technology diffusion; moreover, the diffusion environment affects the speed and effect of technology diffusion. A good diffusion environment accelerates the speed of technology diffusion, while it becomes resistant to the diffusion of agricultural technology. Regarding the spatial performance of technology diffusion, the geographical location and similar socio-economic environment adjacent to the ASTP can show spatial continuity. Technology diffusion can show spatial continuity and spread; otherwise, it may show jumping [24].

Evaluating the technology diffusion environment in ASTPs is based on specific criteria and methods. This evaluation is used to conduct a comprehensive analysis of various factors affecting technology diffusion in the ASTP and to qualitatively or quantitatively measure the strengths and weaknesses of the comprehensive environment, as well as to improve the diffusion environment according to local conditions and enhance the efficiency of agricultural technology diffusion. The technology diffusion environment of the ASTP generally includes six subsystems, such as the natural ecological environment and agricultural development level. Each subsystem involves several factors, and each factor has several reference indicators (Figure 7). Since the leading technologies of different ASTPs are geographically specific, the evaluation indexes of the technology diffusion environment of specific ASTPs are determined. It is necessary to consider both the specificity of the technology itself and the area radiated by the ASTP, as well as the scale differences of the study territory [2]. The evaluation index system assigns specific weight values to each factor through hierarchical and principal-formation analyses. The total evaluation value of the technology diffusion environment in the study area can be measured using an appropriate mathematical model [8].

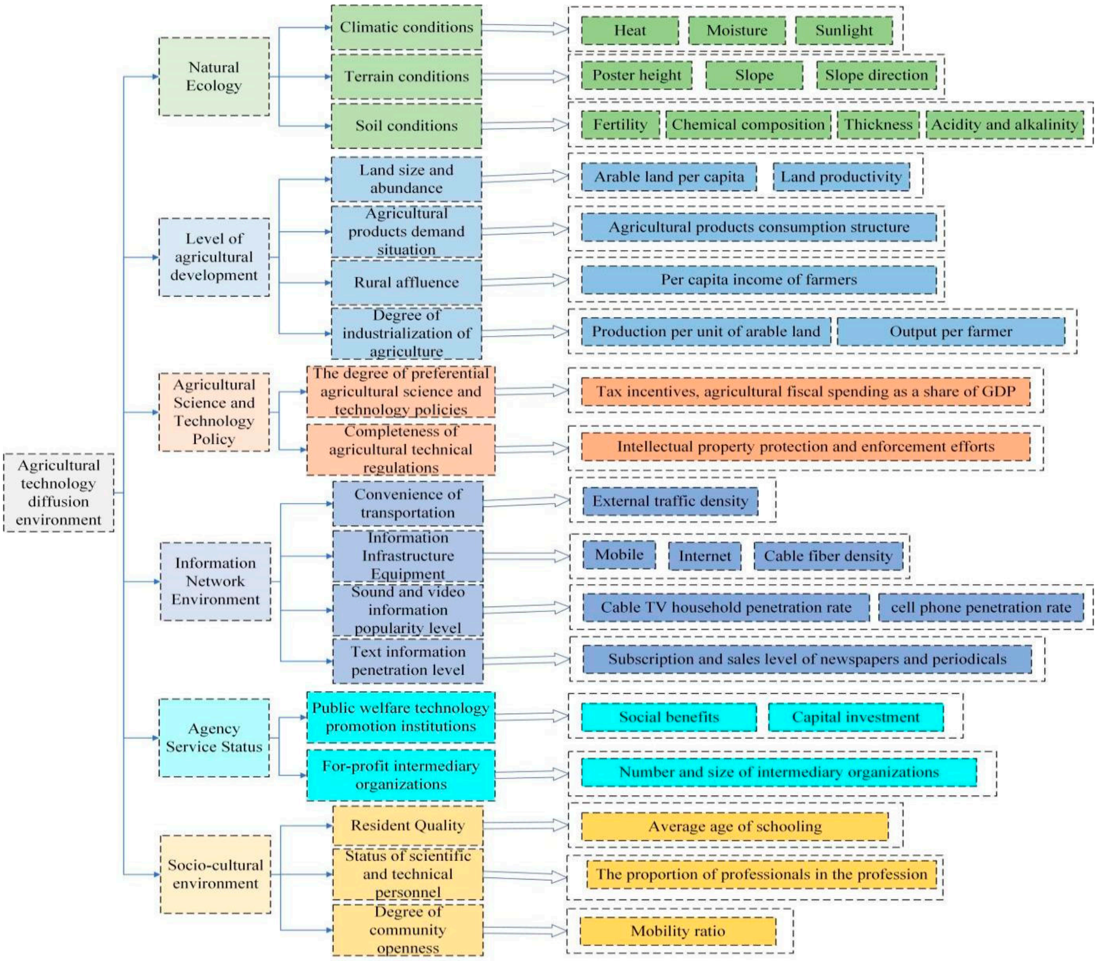

Figure 7. The evaluation system of agricultural technology diffusion environment.

3.4. Spatial and Temporal Patterns of Technology Diffusion in Chinese ASTPs

From the top-down "foundation" paradigm, we analyze the time process (diffusion stage, diffusion speed, diffusion width, diffusion depth) and spatial process (diffusion effect, spatial form) of technology diffusion in ASTPs to explore its spatial and temporal laws.

Agricultural technology diffusion is the process from the emergence of new technology to its understanding by farmers. It is trialed by "technology innovators", emulated by early adopters, and then widely adopted. Many studies have proved that the cumulative adoption rate of technology shows an "S" curve over time. The technology diffusion stage and diffusion range show an overall consistent trend. However, there are significant differences between the same diffusion curve and different curves. The difference in the geometric form of the slope size and change reflects the difference in the diffusion rate and its influence mechanism. Therefore, by analyzing the changes in the diffusion rate of technologies, it is possible to trace the main events that contribute to the change in the diffusion rate at the corresponding time. By analyzing the reasons behind the events, we can explore the mechanism of technology diffusion in ASTPs.

There are numerous innovative technologies in ASTPs. They can be classified into three categories according to their commercialization and the strength of public attributes: commercial technology, intermediate technology, and public welfare technology by comparing fruit tree cultivation technology (operational), wheat seed technology (intermediate), and soil and water conservation cultivation technology (public good). The diffusion characteristics of technologies with different attributes and underlying mechanisms can be revealed [78]. The study shows that agricultural technology diffusion's "S" curve is universal. Although the slope of the curve varies significantly within the same attribute technology and between different attribute technologies, it is consistent with the "S"-shaped curve in general. The diffusion process can be divided into the initial start-up stage, rapid growth stage, and stable advancement. At the same time, the diffusion intensity and the intrinsic mechanism of different technologies and diffusion stages are very different. The proliferation impetus of public benefit technology mainly originates from the government. The intensity of government input is closely related to diffusion, and the speed of diffusion is accelerated if the driving force increases and decreases sharply if the opposite happens. The first sudden change in the speed of operational technology diffusion is due to the great impetus generated by the excellent market benefits of technology adoption. The diffusion speed reaches a certain level and enters a stable promotion stage. The curve's second inflection point occurs when the diffusion speed starts to decline due to a variety of external resistance. The initial impetus of intermediate technology diffusion mainly comes from the government. With the benefits of early technology demonstration, market forces start to act. The coupling of government and market forces forms the characteristic curve of intermediate technology diffusion [79].

The spatial process of technology diffusion is manifested as the process of information and material flow. It is essentially the interaction process between technology and various elements in space. Generally speaking, distance decay is one of the essential characteristics of the intensity of spatial interactions. Areas close to ASTPs are more likely to acquire and be the first to adopt innovative technologies. This diffusion advantage due to proximity to the diffusion source is called the "proximity effect". However, due to the spatial non-homogeneity, technological innovations will be first spread to higher-level areas by "leapfrogging".

Moreover, the new diffusion source will spread to the next level or the surrounding area, i.e., the "hierarchical effect". It is also possible for the source to spread vertically along the channel axis and then expand horizontally between the axes based on convenient communication channels, i.e., the "axial effect". The potential of innovative technology benefits increases the prominence of the demonstration effect in the diffusion process. When the technology is first used at a certain point, the excellent demonstration effect will cause it to spread rapidly in the concentrated area with a similar environment, i.e., the "agglomeration effect". Due to these effects, theoretically, the technology diffusion in ASTPs generally shows three spatial forms: extension diffusion, displacement diffusion, and hierarchical diffusion. However, in practice, because of the differences in agricultural technology, changes in diffusion environment, and different diffusion stages, the spatial diffusion of technology may take different forms.

The spatial characteristics of the diffusion of three types of technologies with different attributes–namely, public good, intermediate, and commercial—were studied. The diffusion of operational technology (fruit tree cultivation series technology) shows a more prominent scale-level diffusion and jump diffusion at macro and mesoscopic spatial scales due to the difference in natural conditions. At the microscopic spatial scale, the diffusion is in the form of proximity diffusion. The government mainly promotes the proliferation of public benefit technology ("splendid grass" soil and water conservation technology) from the ASTPs to the government-designated pilot sites. The intermediate technology is Xiaoyan 22 wheat seed technology. Due to the bulkiness of technology products, their spatial diffusion did not show signs of decay with distance but showed prominent spatial clustering characteristics [80] (Figure 8).

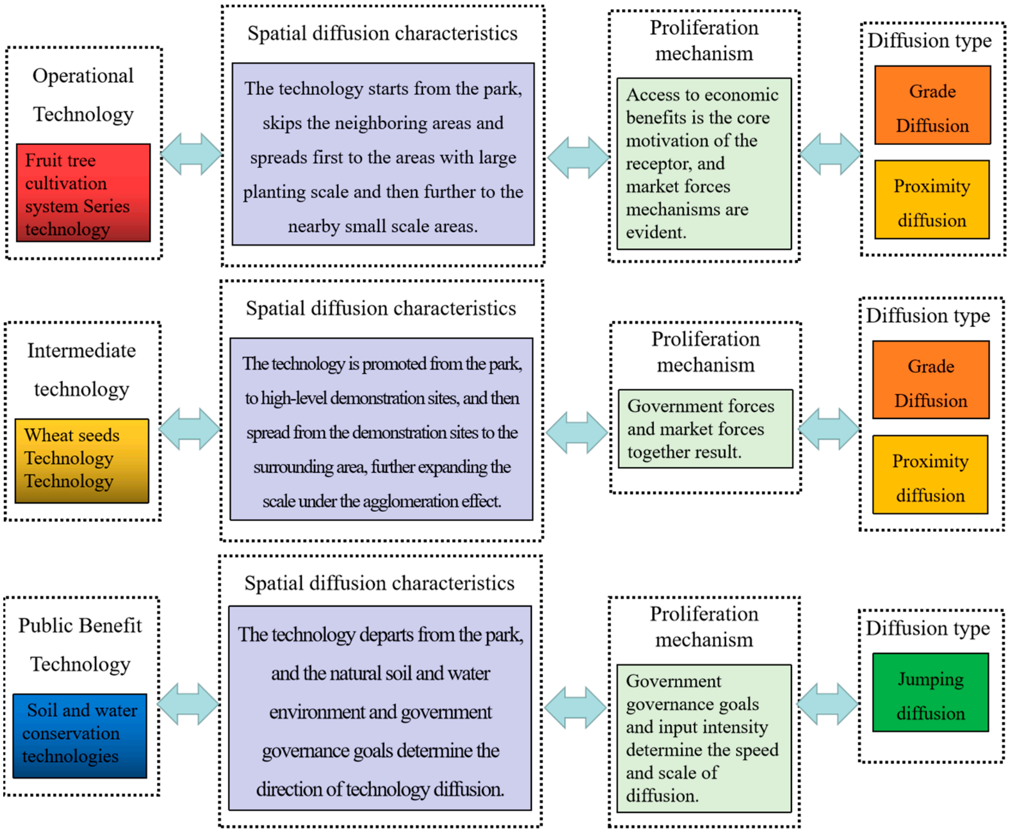

Figure 8. Spatial diffusion characteristics, mechanisms, and types of three agricultural technologies.

The technology diffusion system of ASTP has the characteristics of a "point-axis" system. Its technology diffusion also follows the general "point-axis" diffusion rule and presents certain unique features. In the technology diffusion system of ASTPs, the technology "innovation sources" are universities, scientific research institutions, and agriculture-related R&D organizations. The technology diffusion sources are demonstration bases, agriculture-related enterprises, agricultural cooperative organizations, and demonstration farmers. They constitute the "points" in the "point axis" system. The spatial channel of technology diffusion, as the spatial carrier of technology flow, information flow, and material flow, connects the "innovation source", "diffusion source", and many technology receivers [78]. It forms the "axis" on which technology diffusion depends. After the "innovation source generates the innovation technology", it often needs to be demonstrated and displayed in the ASTP. The technology is recognized and adopted through the first-level diffusion axis by some high-level "diffusion sources". [81] At this stage, technology diffusion is slow, and the macro spatial scale shows the characteristics of hierarchical jump diffusion. When the demonstration effect of the high-level diffusion source appears, the technology receptors begin to follow suit. The technology spreads to the next level of diffusion source through the secondary diffusion axis and spreads rapidly to the surrounding areas. The speed and intensity of diffusion increase rapidly, and the diffusion is in the vicinity of the spatial microscale [79]. As the scale of technology diffusion reaches a certain level, the diffusion rate decreases and is eventually replaced by new technology, thus, entering the "point-axis" progressive diffusion process of the next new technology (Figure 9).

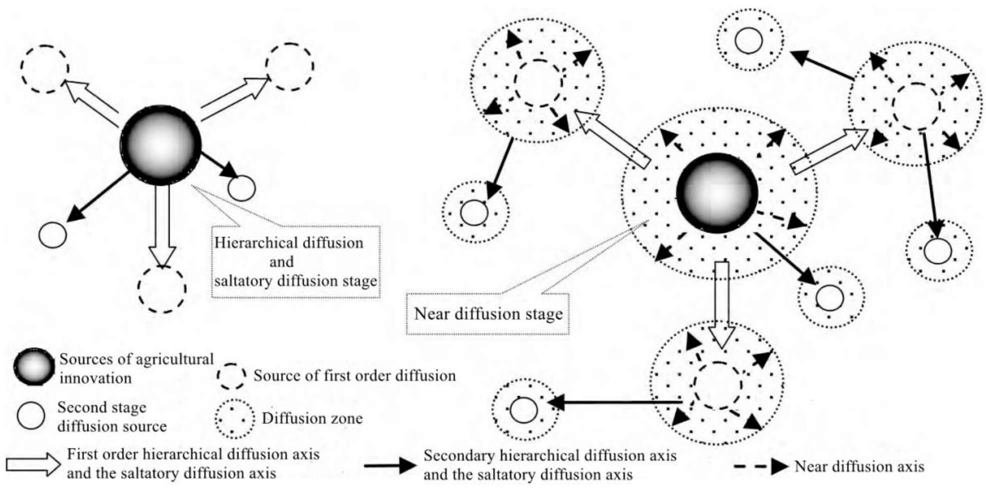

Figure 9. The schematic diagram of ASTP innovation temporal–spatial diffusion.

3.5. A Study on Farmers' Adoption Behavior of Technology Diffusion in Chinese ASTPs

The bottom-up "adoption" paradigm of technology diffusion in ASTPs starts from farmers' technology demand. It analyzes the influencing factors and mechanisms of technology adoption, the adoption process, and farmers' decision-making behavior. We explore the appropriate strategies to induce farmers' technology adoption behavior and promote the efficiency of technology adoption.

Farmers' technology adoption can be analyzed based on rational smallholder theory. Rational small farmers are pressured by competition to maximize profits (pedal car theory). Alternatively, endogenous demand is based on replacing some scarce resource (resource-induced theory). The adoption of new technologies is induced to achieve the goal of maximizing expected returns. Technology adoption by farmers is a complex decision-making process that consists of five stages: awareness, persuasion, evaluation, trial, and validation. These five stages are integrated and interact with each other. The awareness stage is a change in farmers' knowledge. In contrast, the persuasion and evaluation stages a change in attitude, and the trial and confirmation are a behavioral change—this psychological and behavioral change results from the interaction of many factors.

Technology demand is the source of technology adoption among farmers. Adoption is likely to occur when the technology supplied by ASTPs meets farmers' needs. However, farmers' final adoption of new technologies is influenced by many factors, which can be summarized in three aspects: farmers' characteristics, technology diffusion environment, and technical characteristics. The interaction between the demand for agricultural technology and these influencing factors forms an inducing and interfering mechanism for technology adoption by farmers in the ASTP (Figure 10).

There is an inducement of farmers' demand for technology in ASTPs. Firstly, due to the high relative price of certain factors of production in the agricultural production material market, farmers will seek technologies that save higher-priced resources to alleviate the constraints of scarce resources on agricultural development. For example, higher labor costs have increased the demand for labor-saving technologies. Moreover, the increasing scarcity of land resources makes land-saving technologies increasingly popular. Secondly, the demand preference of the actual consumer market for certain agricultural products will induce farmers to choose the corresponding agricultural technology to occupy the market first and gain excessive profits. For example, with the improvement of people's living standards the overall consumption tends to be green, with healthy food and leisure experience needs, and farmers' demand for the production technology of such products increases. High-tech agricultural technologies in ASTPs have many advantages, such as saving costs and increasing efficiency. They may increase the efficiency of agricultural production or induce farmers to adopt new technologies because they can meet new market demands or better meet current demands. In conclusion, the interaction of resource scarcity substitution, market consumption orientation, and the advantages of new technologies in farmers' agricultural technology adoption forms the mechanism for farmers' to adopt technology.

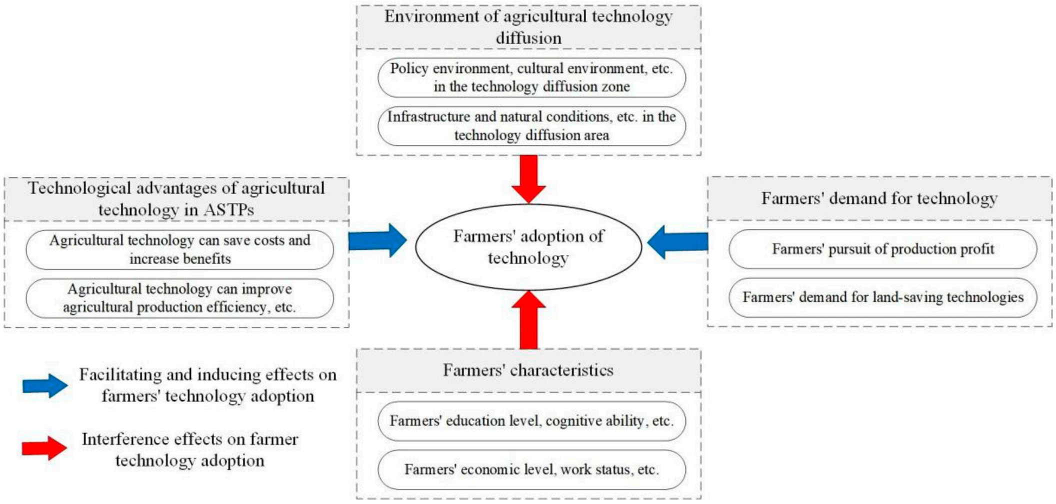

Figure 10. The influencing factors and mechanism of farmers' technology adoption.

Farmers' technology adoption behavior is induced by farmers' technology demand and the technological advantages of the ASTP at the same time. It is also affected by many factors, such as farmers' characteristics and the environment of agricultural technology diffusion. For example, whether farmers adopt a new technology or not is based on their knowledge of the technology. The main factors determining farmers' perception of the technology are their own long experience in agricultural production and their literacy and knowledge level. Education can increase farmers' understanding and acceptance of new technologies. In terms of the farm household economy, economic income, on the other hand, interferes with farmers' technology adoption behavior because it affects their risk tolerance. However, part-time farmers whose primary source of income is non-agricultural may lose interest in adopting new agricultural technologies due to low comparative agricultural returns. The environment of agricultural technology diffusion includes the quiet environment, such as policies and culture in the diffusion area, and the challenging environment, such as infrastructure and natural conditions. The variability of the environmental elements, such as the ease and accessibility of information channels and the extent of policies and services, can directly facilitate or hinder farmers' adoption of new technologies. It may also change farmers' technology adoption behavior by influencing their perceptions and preferences. The interaction between farmers' characteristics and the external environment constitutes the interference mechanism of farmers' technology adoption.

Technology characteristics, farmer characteristics, and technology environment constitute the main influencing factors of agricultural technology adoption [58]. Studies on the influence of farmer characteristics on technology adoption behavior are numerous and comprehensive, while studies on the technology diffusion environment are relatively rare.

Based on survey data from traditional farming areas in China, we analyzed the differences in technology adoption among farmers for different attributes such as apple-planting series technology, wheat seed technology, and water-saving irrigation technology under different technology environments. The study showed that the technology environment significantly influenced farmers' technology adoption behavior in the diffusion area. The soft technology environment was more influential than the challenging environment. Regarding water-saving irrigation technology, the national support policy is the main incentive for farmers to adopt water-saving irrigation technology in the high agro-technological environment zone. In the medium agro-technological environment zone, the natural environmental conditions of the farming area and the number of times farmers received training significantly impacted their adoption behavior. In areas where the technology diffusion environment is poor, farmers' adoption behavior is more influenced by the ease of information and risk awareness [80]. Farmers' technology adoption behavior varies considerably for different attribute technologies. This is reflected in the fact that farmers prefer to adopt operational technologies with low investment costs and significant, predictable benefits, regardless of the diffusion environment. The adoption rate of water-saving irrigation technology (public good) was lower than that of apple-planting technology (business) and wheat seed technology (intermediate). In the case of apple-planting series technologies, the adoption rate of bagging technologies was higher than that of new seedling technologies with long production cycles, reflecting the risk-averse psychological characteristics of farmers towards new technologies with long production cycles [82].

3.6. Research on the Technology Adoption Behavior and Mechanism of New Management Subjects in the Diffusion of Innovation in ASTPs

Farmers' cooperatives and agricultural enterprises are the leaders of China's modern agricultural development and the critical targets of innovation diffusion in ASTPs. Based on the logic of "park construction-innovation diffusion-technology adoption-new business entities leading-accelerated development of agricultural areas", three national ASTPs—Yangling, Dingxi, and Wuzhong—were selected based on the theories and methods of economic geography, behavioral geography, and system science, and construct a diffusion space consisting of a core area and a diffusion area (demonstration area + radiation area). Among them, Yangling is a comprehensive ASTP of national significance with a high degree of development, Dingxi is a regional park dominated by potato technology and industry, and Wuzhong is a regional park dominated by animal husbandry technology and industry. By studying the technology adoption behavior and adoption mechanism of the three types of new management subjects in this diffusion space, we reveal the inner mechanism of innovation diffusion in ASTPs under the guidance of the technology demand of new management subjects, and explore the methods of comprehensive development in agricultural areas driven by the joint diffusion of park innovation and new management subjects (technology adoption) [24].

By building a sustainable agricultural system that integrates "park", "technology", "adoption body", and "environment", we can create an intensive technology adoption system. The technology adoption of new management subjects (agricultural enterprises, farmers' cooperatives, and family farms) can be viewed as the process of "acquiring technology information, forming willingness to adopt, and making adoption decisions". Through comprehensive research, we can identify new management subjects' technology sources and preferences and their technology information linkages with the park. The impact of technology information linkage on technology information acquisition and adoption can be analyzed. It can be found that ASTPs are the most trusted technology sources for new business subjects. The parks have established extensive technical information links with new business subjects. This technical information linkage significantly contributed to the new management subjects' acquisition and adoption of apple dwarf anvil technology information [83].

The main factors affecting new business entities' access to technical information were identified. In terms of public extension service access, extension intensity, extension quality, and technical information linkage with the park significantly and positively influenced the technical information access of new business entities. In terms of social networks, social network size and weak social ties significantly promote technical information acquisition, while social network density and solid social ties significantly inhibited technical information acquisition. Regarding technology sources, public extension and mass media sources significantly and positively influenced technology information acquisition [24]. In contrast, social networks and private extension sources did not significantly influence technology information acquisition. Regarding socioeconomic factors, the higher the educational level of the responsible person, the more access to technical information, and the access to credit helps to enhance their access to technical information. The effects of the age of the person in charge, resource endowment, and business scale on access to technical information are insignificant.

The influencing factors and mechanisms of technology adoption in new management agents were analyzed. It was found that among all the influencing factors of adoption intention and adoption decision, regional agro-ecological conditions differences had the most decisive influence on adoption intention and adoption decision. Relative advantage, perceived barriers, and agricultural extension services significantly affected both adoption intention and decision. Moreover, the effect in the adoption intention stage was smaller than in the adoption decision stage. Both management capability and risk response capability did not affect adoption intention, while both significantly positively affected adoption decision. Organization size does not affect adoption intention and adoption decision. Willingness to adopt has a significant positive effect on adoption decision, but the intensity of the effect is not significant.

Technology demands different types of subjects and their influencing factors. The demand for new technologies in different subjects is generally high, but subject differences exist. New management subjects have a higher demand for new technologies than traditional farmers; for example, farming subjects have a higher demand for new technologies than planting subjects, while agricultural enterprises have a higher demand for new technologies than cooperatives and family farms. The most urgent technologies needed by planting and farming subjects are improved equipment and facilities and agricultural information technology [83]. Traditional farmers have a higher demand for traditional improvement technologies such as pest control, soil improvement, and cultivation management. The factors affecting the technology needs of different subjects (farming subjects, planting subjects, and traditional farmers) have significant heterogeneity.

The spatial characteristics and influencing factors of the technology adoption behavior of new management subjects were studied. Both the technology adoption rate and total adoption rate show that new management subjects are higher than traditional farmers, the primary radiation area is higher than the secondary radiation area, and farming technology is higher than planting technology. There are significant differences in the spatial diffusion characteristics of different attribute technologies. Farming technology has a noticeable "proximity effect" and "rank effect" in the process of spatial diffusion. Planting technology is more likely to be affected by the "hierarchical effect". The characteristics of decision makers (decision maker attributes, decision maker perceptions, production and operation characteristics) and diffusion environment characteristics (park extension environment, policy support environment, social network environment) jointly influence the technology adoption decisions and adoption degree of decision makers [24].

A model and simulation study of the park's technology diffusion system (dynamics) was conducted based on the technology adoption behavior of new business entities. The system is dynamic and complex and is formed by the joint action of multiple factors. The synergistic effect of multiple factors can effectively accelerate the technology diffusion process. It promotes the technology adoption and full adoption of new business subjects. The technology adoption curve of new business entities in the simulation period shows an "S"-shaped growth trend. This is consistent with the general rule of innovation diffusion, under the condition that the other parameters remain unchanged; changing a single parameter value will influence the technology adoption of new business entities. Among them, government subsidy policy, credit support policy, informal network influence, technology training intensity, and park publicity have the highest efficiency in improving technology adoption [83].

4. Discussion

Theoretical studies are lagging behind the needs of practical development, and there is an urgent need for corresponding theories to guide them [84]. Based on the research idea of "pattern-structure-process-mechanism", we propose the fundamental theories of agricultural technology diffusion in agricultural parks: growth pole theory (technology zone/technology pole theory), spatial interaction theory, farmer behavior change theory, core-edge theory, and public goods theory.

The process of technology diffusion in ASTPs can be regarded as a complex system. Structurally, it can be divided into five main components: innovator, innovation technology, diffusion channel, adopter, and radiation area. Moreover, each component of the system and the system characteristics and operation mechanism are analyzed. It is believed that various factors influence the innovative technologies generated in the park, in the process of flowing into the radiation zone and eventually being adopted by farmers. These influencing factors can be divided into three major categories. Namely, the factors of the innovative technologies themselves, the factors of farmers, and the factors of the radiation zone, and the influence of each constituent factor of the radiation zone on the technology diffusion process is analyzed individually.

Based on the understanding of the radiation zone environment—i.e., the complex of all external factors affecting the technology diffusion in the park–the meaning, functions, and components of the radiation zone diffusion environment are analyzed and categorized. The diffusion environment in the radiation zone of the ASTP is defined as the complex of all kinds of external factors affecting the spatial diffusion of agricultural technologies in the park within a specific period, i.e., the integration and synthesis of all factors other than the technology itself. It is considered that diffusion environment evaluation is a necessary part of optimizing and improving its environment in all parts of the radiation zone to improve the accessibility of technologies, and the basic ideas of diffusion environment evaluation in the radiation zone are proposed [85]. Seven aspects, such as spatial proximity, natural ecological environment, agricultural development level, agricultural science and technology policy, information environment, and intermediary service status, are the key aspects affecting the diffusion environment in the radiation zone.

The diffusion process of innovative technologies in the park is analyzed and inquired from the perspectives of dynamic and operational mechanisms. After understanding why diffusion occurs and how it takes place, the spatial effects and modes of diffusion are further examined. Government orientation, collaborative R&D by universities and firms, and commercial activities are the primary mechanisms for generating technological innovation in parks. The reason for technology diffusion originates from the pursuit of self-interest by all parties in the park's diffusion system, and the diffusion process is inevitably subject to both driving and hindering forces. From the perspective of the primary power source of technology diffusion, the operation mechanism of technology innovation diffusion in the park can be divided into three mechanisms: government-driven, market-induced, and joint-driven. The spatial diffusion effect of park technology can be divided into proximity effect, rank effect, axial effect, and agglomeration effect; the spatial diffusion mode includes three types of extended diffusion, rank diffusion, and displacement diffusion. For a specific technology, there is more than one diffusion mode, and it is usually any two or a combination of the above three modes [24,78,79,81,83].

There is still a gap between Chinese research theories and methods on farmers' adoption behavior and international standards, mainly in the following three aspects: First, most of the research is static, with one-time research leading to post hoc analysis, that is, using cross-sectional data to conduct individual research on a specific process of agricultural technology innovation, diffusion and adoption, while foreign countries have moved to the use of panel data to conduct dynamic coupling research on the whole process of agricultural technology innovation, diffusion and adoption. Second, in research on a single technology attribute area, China is biased towards studying a specific technology specialization and lacks the integration of different attribute technologies. Third, most studies on individual farmer behavior focus on whether this is rational, i.e., whether they are pursuing profit maximization and risk avoidance. In terms of research methods, although domestic research has been dramatically improved and has shifted from qualitative research to quantitative research, the research method is single and still predominantly uses logistic models. In terms of research content, domestic research mainly analyzes the characteristics, motives, willingness, and influencing factors of farmers' technology adoption behaviors; with a high repetition rate, a systematic theoretical framework has not yet been formed [18,21]. There are few original studies, especially those with practicality and operability.

As the actors of agricultural technology adoption in China, farmers' willingness, manner, and efficiency to adopt new technologies are essential criteria for evaluating the effectiveness of technological innovation and diffusion in ASTPs. They are also an essential reflection of the balance between the supply and demand of agricultural technologies. At present, according to the bottom-up "adoption" paradigm, we have conducted an in-depth analysis of farmers' technology adoption behavior. The preliminary theoretical framework of farmers' technology adoption is established. It is specified that the interaction between technology demand and technology advantage forms the inducing mechanism of adoption behavior.

In contrast, farmer characteristics and environmental factors work together to form the interference mechanism of adoption behavior. Based on the analysis of the factors influencing the agricultural technology diffusion environment, the evaluation system is constructed by selecting indicators from the levels of natural environmental conditions, agricultural input and output levels, agricultural science and technology information, and farmers' education and artistic quality, respectively, for the quantitative evaluation of the technology diffusion environment. Based on the systematic investigation of agricultural technology diffusion trajectories with different attributes, the behavioral responses of farmers to the existing technology supply model were explored by comprehensively studying their production technology efficiency, technology demand willingness, technology decision and behavior orientation, factors influencing the adoption of new technologies, and behavioral responses to the existing technology supply model, which effectively verified the theoretical hypothesis of farmer subjectivity for technology diffusion and adoption in traditional farming areas. Based on the analysis of the intrinsic mechanism of technology diffusion in ASTPs under demand orientation, a series of countermeasures to improve farmers' enthusiasm to adopt new technologies and improve the agricultural technology diffusion system are proposed in terms of policy support, institutional guarantee, system construction, information network, and environmental optimization.

New agricultural business entities represented by family farms, farmers' cooperatives, and agricultural enterprises are not only the key targets of technology diffusion in the park, but also the main users of innovative technologies in the park. Based on the analysis of industrial association and spatial association, the technology diffusion space of ASTPs is constructed, and the technology adoption behaviors of three types of new agricultural business entities—namely, family farms, farmers' cooperatives, and agricultural enterprises—in the diffusion space are systematically studied. It is of great value to explore the dynamic mechanism and diffusion mode of demand-centered technology diffusion in ASTPs to expand the theory of technology innovation diffusion and enrich the content and field of disciplinary research. The core area of the ASTP is selected as the technology supplier, and three types of new business entities in the diffusion range are the technology receptors to construct the technology diffusion-adoption system. Two types of factors—the intrinsic characteristics of agricultural technology innovation and the regional characteristics of agricultural technology diffusion (diffusion environment)—are selected to analyze and evaluate the factors affecting technology diffusion. Through comprehensive integration, a diversified demand-oriented model of technology diffusion in ASTPs is constructed, and the integrated development path of agricultural areas under the dual drive of innovation diffusion technology adoption in parks is explored [24,83].

5. Conclusions

The process of forming technology poles is essentially a process of spatially agglomerating innovation elements, innovation organizations, and innovation industries, as well as enhancing the “potential energy” of technology poles and the “potential difference” of technology in the surrounding areas. Together, the technology diffusion system in ASTPs constitutes the five elements of technology innovator, technology itself, diffusion channel, and adopter and diffusion environment. Based on the top-down “foundation” paradigm, the study of diffusion stages, diffusion speed, and diffusion breadth of technologies with different attributes confirm the universality of agricultural technology diffusion’s “S” curve characteristics. Regarding the spatial characteristics of technology diffusion, the diffusion patterns and mechanisms of different technologies differ significantly. Overall, agricultural technology diffusion follows the “point-axis” progressive diffusion law. From the bottom-up “adoption” paradigm, the interaction between technology demand and technology advantage forms the inducement mechanism of adoption behavior.

In contrast, the joint action of farmer characteristics and environmental factors forms the interference mechanism of adoption behavior. The technology diffusion environment and attributes significantly affect farmers’ technology adoption behavior. The new agricultural business entities, represented by family farms, farmers’ cooperatives, and agricultural enterprises, have a vital driving role in the technology diffusion and adoption system, which significantly promotes the innovation diffusion of agricultural technologies.

The current research regards the ASTP as a dark box and a technology pole in space. It concentrates on the spatial system consisting of the park-radiation diffusion area. However, as a spatial system, ASTPs are less involved in the inner mechanism of their technological innovation and the impact of the parks’ development on technology diffusion. Therefore, the innovation system of ASTPs and its dynamic mechanism should be given attention in the follow-up studies. ASTPs are one of the main modes of agricultural technology innovation and diffusion in China, where 295 national ASTPs have been established. China has thousands of ASTPs at the provincial, municipal, and county levels; however, researchers have only conducted empirical studies on ASTPs in some regions, and they have not addressed other types of ASTPs. The types, distribution, technological innovation mechanisms, and diffusion patterns of ASTPs in China have apparent spatial and temporal variability. In the long-term context of promoting agriculture through science and technology, studying the patterns and mechanisms of the formation, development, and evolution of ASTPs will be a new field and academic growth point for this discipline in the future.

The content of “research on a technology diffusion model of ASTPs oriented by farmers’ needs” proposes a basic framework of ASTPs oriented by the needs of the farmers. However, the question of the rationality and feasibility of the information feedback using farmers’ participation-organizational adoption diffusion model with ASTPs as the diffusion pole has not been thoroughly studied. However, no in-depth research has been conducted on the rationality and feasibility of the diffusion model of “information feedback-farmer participation-organization adoption” with the ASTP as the diffusion pole. Meanwhile, related studies have mainly focused on the diffusion and adoption of technological innovation. The diffusion of innovation in ASTPs includes multiple dimensions such as technology diffusion, organizational diffusion, concept diffusion, and the integrated landing of diffusion in ASTPs (urban–rural integration). Follow-up research needs to establish a multidimensional diffusion model from the interdisciplinary perspective (geography, management, and communication) to comprehensively study the diffusion and adoption of innovation in parks.

Author Contributions: X.C.: conceptualization, and contributing to the data collection, data summary, and writing of the manuscript. T.L.: conceptualizing the framework of this study and revising the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Natural Science Foundation of China (41771129).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We thank to Jiayin Lv, Bingchen Zhu for their assistance in collecting this research data and revising the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lybæk, R.; Christensen, T.B.; Kjær, T. Governing innovation for sustainable development in the Danish biogas sector–a historical overview and analysis of innovation. *Sustain. Dev.* **2013**, *21*, 171–182. [CrossRef]
2. Li, T.; Luo, Y. Technology diffusion of agricultural science and technology park. *Geogr. Res.* **2016**, *35*, 419–430.
3. Skiadas, C.H. Innovation diffusion models expressing asymmetry and/or positively or negatively influencing forces. *Technol. Forecast. Soc.* **1986**, *30*, 313–330. [CrossRef]
4. Sharif, M.N.; Ramanathan, K. Binomial innovation diffusion models with dynamic potential adopter population. *Technol. Forecast. Soc.* **1981**, *20*, 63–87. [CrossRef]
5. Kelley, M.R.; Brooks, H. External learning opportunities and the diffusion of process innovations to small firms: The case of programmable automation. In *Diffusion of Technologies and Social Behavior*; Nakićenović, N., Grübler, A., Eds.; Springer: Berlin/Heidelberg, Germany, 1991; pp. 341–381.
6. Chatterjee, R.A.; Eliashberg, J. The innovation diffusion process in a heterogeneous population: A micromodeling approach. *Manag. Sci.* **1990**, *36*, 1057–1079. [CrossRef]
7. Karshenas, M.; Stoneman, P.L. Rank, stock, order, and epidemic effects in the diffusion of new process technologies: An empirical model. *RAND J. Econ.* **1993**, *24*, 503–528. [CrossRef]
8. Mahajan, V.; Muller, E.; Srivastava, R.K. Determination of adopter categories by using innovation diffusion models. *J. Mark. Res.* **1990**, *27*, 37–50. [CrossRef]
9. Rrgan, J. Classifying adopters and nonadopters for technologies using political activity, media use and demographic variables. *Telemat. Inform.* **1987**, *4*, 3–16. [CrossRef]
10. Hagerstrand, T. *Innovation Diffusion as a Spatial Process*; University Chicago of Press: Chicago, IL, USA, 1967; pp. 68–75.
11. Hu, W. Research on agricultural technology innovation and agricultural technology diffusion. *Sci. Technol. Prog. Policy* **2003**, *5*, 73–75.
12. Xu, J. The Diffusion Model Analysis of Rises Rice Seedling on Land. *J. Ind. Eng. Eng. Manag.* **2001**, *1*, 21–27.
13. Fang, W.; Li, T. Analysis and evaluation of the agricultural technology diffusion environment. *Sci. Technol. Prog. Policy* **2006**, *11*, 49–50.
14. Li, X. The Role of Rural Household Behavior in Economic Development of Less Developed Rural Area:a Case Study of Western Henan Mountainous and Hilly Region, China. *Acta Geogr. Sin.* **2002**, *4*, 459–468.
15. Li, X. Rural development in the less developed pegion of Chian: A household perspective. *Hum. Geogr.* **2008**, *1*, 1–6.
16. Lv, R.; Kang, K.; Ren, Y. A Study on the influence of Transition of Agricultural Operating System on Diffuse of Crossbreed Maize Technology. *J. Hebei Univ. Technol.* **1999**, *3*, 25–27.
17. King, R.N.; Rollins, T. Factors influencing the adoption decision: An analysis of adopters and nonadopters. *J. Agric. Educ. Ext.* **1995**, *36*, 39–47.
18. Liu, X.; Li, T. A research on the international experiences and domestic trend for the diffusion study of agriculture technique innovation. *Econ. Geogr.* **2006**, *6*, 931–935.
19. Shi, Z.; Fu, Y. Contradiction Between Green Production Intention and Farmers' Behavior from the Perspective of Technology Diffusion Conditions:Taking Adoption of Pollution-Free Pesticide Technology as An Example. *J. Agro For. Econ. Manag.* **2022**, *21*, 29–39.
20. Yu, D.; Peng, J.; Liu, Y.; Xiao, H.; Zhou, R. The Trend and Hotspots of Agricultural Technology Diffusion in Domestic and Foreign Areas. *J. Libr. Inf. Sci. Agric.* **2018**, *30*, 6–17.
21. Chu, X.; Yao, F.; Wu, J.; Huang, X.; Mao, S.; Ma, L.; Yang, Y.; Zhang, L. Mapping knowledge domains of China's agricultural technology diffusion research based on CiteSpace. *Guangdong Agric. Sci.* **2017**, *44*, 129–138.
22. Bunnell, T.G.; Coe, N.M. Spaces and scales of innovation. *Prog. Hum. Geog.* **2001**, *25*, 569–589. [CrossRef]
23. Scott, A.; Storper, M. Regions, globalization, development. *CUERS Rep.* **2003**, *37*, 579–593. [CrossRef]
24. Wang, Z.; Liu, J.; Li, T. Spatial heterogeneity of agricultural science and technology parks technology diffusion: A case study of Yangling ASTP. *Chin. Geogr. Sci.* **2021**, *31*, 629–645. [CrossRef]
25. Ragers, E.M. *Diffusion of Innovations*, 3rd ed.; Free Press: New York, NY, USA, 1983; pp. 1–3.
26. Xie, L.; Lv, K.; Xia, Y. Research Progress and Prospect of China Agricultural Science and Technology Parks. *Sci. Technol. Manag. Res.* **2019**, *39*, 201–206.
27. Man, M.; Li, T. A review of research on agricultural technology adoption. *Res. Dev.* **2010**, *1*, 80–85.
28. Haverkort, B. Farmers' Experiments and Participatory Technology Development. In *Joining Farmers' Experiments*; Haverkort, B., van der Kamp, J., Waters-Bayer, A., Eds.; Intermediate Technology Publications: London, UK, 1991; pp. 3–17.
29. Chambers, R.; Thrupp, L.A. *Farmer First: Farmer Innovation and Agricultural Research*; Karthala Editions: Paris, France, 1994.
30. Paulson, N.D.; Schnitkey, G.D. Policy concerns of midwestern grain producers for the 2012 farm bill. *Am. J. Agric. Econ.* **2012**, *94*, 515–521. [CrossRef]

31. Atari, D.O.A.; Yiridoe, E.K.; Smale, S. What motivates farmers to participate in the Nova Scotia environmental farm plan program? Evidence and environmental policy implications. *J. Environ. Manag.* **2009**, *90*, 1269–1279. [CrossRef]
32. Ruto, E.; Garrod, G. Investigating farmers' preferences for the design of agri-environment schemes: A choice experiment approach. *J. Environ. Plan. Man.* **2009**, *52*, 631–647. [CrossRef]
33. FiBL, A. *Swiss Association for the Development of Rural Areas and Research Institute for Organic Agriculture*; Deckungsbeiträge: Aargau, Switzerland, 2010.
34. Kaiser, T.; Rohner, M.S.; Matzdorf, B. Validation of grassland indicator species selected for result-oriented agri-environmental schemes. *Biodivers. Conserv.* **2010**, *19*, 1297–1314. [CrossRef]
35. Matzdorf, B.; Lorenz, J. How cost-effective are result-oriented agri-environmental measures?—An empirical analysis in Germany. *Land Use Policy* **2010**, *27*, 535–544. [CrossRef]
36. Osterburg, B.; Techen, A.K. Verifiability of result oriented policy measures to reduce N emissions from German agriculture. *Nitrogen Glob. Change Key Find. Future Chall.* **2011**, *4*, 11–15.
37. Burton, R.J.F.; Schwarz, G. Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change. *Land Use Policy* **2013**, *30*, 628–641. [CrossRef]
38. Asfaw, S.; Shiferaw, B.; Simtowe, F. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy* **2012**, *37*, 283–295. [CrossRef]
39. Bezu, S.; Kassie, G.T.; Shiferaw, B. Impact of improved maize adoption on welfare of farm households in Malawi: A panel data analysis. *World Dev.* **2014**, *59*, 120–131. [CrossRef]
40. Awotide, B.A.; Alene, A.D.; Abdoulaye, T. Impact of agricultural technology adoption on asset ownership: The case of improved cassava varieties in Nigeria. *Food Secur.* **2015**, *7*, 1239–1258. [CrossRef]
41. Dadi, L.; Burton, M.; Ozanne, A. Duration analysis of technological adoption in Ethiopian agriculture. *J. Agric. Econ.* **2004**, *55*, 613–631. [CrossRef]
42. Alcon, F.; Miguel, M.D.; Burton, M. Duration analysis of adoption of drip irrigation technology in southeastern Spain. *Technol. Forecast. Soc.* **2011**, *78*, 991–1001. [CrossRef]
43. Lambrecht, I.; Vanlauwe, B.; Merckx, R. Understanding the process of agricultural technology adoption: Mineral fertilizer in eastern DR Congo. *World Dev.* **2014**, *59*, 132–146. [CrossRef]
44. Mackrell, D.; Kerr, D.; Von Hellens, L. A qualitative case study of the adoption and use of an agricultural decision support system in the Australian cotton industry: The socio-technical view. *Decis. Support Syst.* **2009**, *47*, 143–153. [CrossRef]
45. Vom Brocke, K.; Trouche, G.; Weltzien, E. Participatory variety development for sorghum in Burkina Faso: Farmers' selection and farmers' criteria. *Field Crop Res.* **2010**, *119*, 183–194. [CrossRef]
46. Balmann, A. Farm-based modelling of regional structural change: A cellular automata approach. *Eur. Rev. Agric. Econ.* **1997**, *24*, 85–108. [CrossRef]
47. Berger, T. Agent-based spatial models applied to agriculture: A simulation tool for technology diffusion, resource use changes and policy analysis. *J. Agric. Econ.* **2001**, *25*, 245–260. [CrossRef]
48. Davis, F.D.; Bagozzi, R.P.; Warshaw, P.R. User acceptance of computer technology: A comparison of two theoretical models. *Manag. Sci.* **1989**, *35*, 982–1003. [CrossRef]
49. Venkatesh, V.; Davis, F.D. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Manag. Sci.* **2000**, *46*, 186–204. [CrossRef]
50. Lee, Y.; Kozar, K.A.; Larsen, K.R.T. The technology acceptance model: Past, present, and future. *Commun. Assoc. Inf. Sys.* **2003**, *12*, 752–780. [CrossRef]
51. Zeweld, W.; Van Huylenbroeck, G.; Tesfay, G. Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *J. Environ. Manag.* **2017**, *187*, 71–81. [CrossRef] [PubMed]
52. Case, S.D.C.; Oelofse, M.; Hou, Y. Farmer perceptions and use of organic waste products as fertilisers–A survey study of potential benefits and barriers. *Agric. Syst.* **2017**, *151*, 84–95. [CrossRef]
53. Ramirez, A. The influence of social networks on agricultural technology adoption. *Procedia Soc. Behav. Sci.* **2013**, *79*, 101–116. [CrossRef]
54. Maertens, A.; Barrett, C.B. Measuring social networks' effects on agricultural technology adoption. *Am. J. Agric. Econ.* **2013**, *95*, 353–359. [CrossRef]
55. Sattler, C.; Nagel, U.J. Factors affecting farmers' acceptance of conservation measures—A case study from north-eastern Germany. *Land Use Policy* **2010**, *27*, 70–77. [CrossRef]
56. Larson, N.; Sekhri, S.; Sidhu, R. Adoption of water-saving technology in agriculture: The case of laser levelers. *Water Resour. Econ.* **2016**, *14*, 44–64. [CrossRef]
57. Abate, G.T.; Rashid, S.; Borzaga, C. Rural finance and agricultural technology adoption in Ethiopia: Does the institutional design of lending organizations matter? *World Dev.* **2016**, *84*, 235–253. [CrossRef]
58. Carter, M.R.; Cheng, L.; Sarris, A. Where and how index insurance can boost the adoption of improved agricultural technologies. *J. Dev. Econ.* **2016**, *118*, 59–71. [CrossRef]
59. He, Y.; Zhou, Z. New Advances in the Internal Research on the Models for New Product Diffusion. *Chin. J. Manag.* **2007**, *4*, 529–536.

60. Chang, X.; Han, Y. Research about Effects of Agricultural Technology Diffusion Power and Channel Operation on Farmers' Production Efficiency—Based on the Data of Henan Wheat Planting Area. *China Rural. Surv.* **2014**, *35*, 63–70.
61. Long, D.; Li, T.; Yu, Z. Research on Behavior of Farmers' Adoption under Technology Diffusion of Agriculture: Abroad Progress and Domestic Trends. *Areal Res. Dev.* **2014**, *33*, 132–139.
62. Zhu, M.; Qi, Z.; Wu, L. Empirical Analysis on Factors of New Agricultural Business Entities' Agricultural Technology Needs: Taking 395 Scaled Rice Farmers in Southern Jiangsu Province as the Example. *China Rural. Surv.* **2015**, *36*, 30–38.
63. Li, Q.; Zhang, H.; Liu, W. Analysis of Farmers' Acceptance and Response to Agricultural Technologies in Main Grain Production District—A Case from Yushu County in Jilin. *Sci. Agric. Sin.* **2008**, *41*, 1963–1968.
64. Shi, S.; Shao, W. Analysis of demand characteristics of agricultural science and technology services and farmers' willingness to pay. *Stat. Decis.* **2013**, *29*, 83–86.
65. Huang, M.; Li, X.; Yuan, M. Differences between farmers' perception and behavior decisions on crop planting: An empirical study of Jianghan Plain. *Res. Agric. Mod.* **2016**, *37*, 892–901.
66. Yu, Y.; Zhang, J. Farmers' willingness to adopt rice IPM technology and its influencing factors. *Chin. Rural. Econ.* **2009**, *11*, 77–86.
67. Zhu, H.; Zhou, S. Factors Influencing Southern Rice Farmers Adapting to Climate Change Behavior—Based on 346 Household Survey Data of 36 Counties in Jiangxi Province. *J. Nat. Resour.* **2011**, *26*, 1119–1128.
68. Zhu, L.; Xiang, H. Analysis of farmers' willingness to adopt water-saving irrigation in major grain producing areas. *Chin. J. Agric. Resour. Reg. Plan.* **2011**, *32*, 17–21.
69. Liu, Q.; He, Z.; Zheng, Y. Study on the impact of farmers' straw returning to the field adoption behavior. *Chin. J. Agric. Resour. Reg. Plan.* **2014**, *35*, 25–29.
70. Jiang, T.; Zhao, N. Influencing Factors of Famers' Behavior of Adopting Cleaner Production Technology—Taking Rice Farmers in Jilin Province as Case. *J. Jilin Agric. Univ.* **2015**, *37*, 746–750.
71. Chu, C.; Feng, S.; Zhang, W. An Empirical Analysis of Farmers' Behavior in Adopting Environmentally Friendly Agricultural Technologies. *Chin. Rural. Econ.* **2012**, *33*, 68–77.
72. Man, M.; Zhou, M.; Li, T. Analysis of differences in farmers' behavior in adopting different attribute technologies. *Chin. Rural. Econ.* **2010**, *2*, 68–78.
73. Zhou, R.; Tu, G.; Yu, D. Mechanism model of farmers' behaviors on adopting sci-tech achievements in agriculture based on TPB and SN. *Guangdong Agric. Sci.* **2014**, *17*, 185–190.
74. Barbera, F.; Fassero, S. The place-based nature of technological innovation: The case of Sophia Antipolis. *J. Technol. Transfer* **2013**, *38*, 216–234. [CrossRef]
75. Li, W.; Li, X.; Ou, Q. Informal ties in industrial cluster and its impact on technological innovation: A case study of household appliance cluster in Shunde. *Econ. Geogr.* **2013**, *32*, 518–530.
76. Dandan, L.; Tao, W.; Yehua, W. Spatial and temporal complexity of scientific knowledge network and technological knowledge network on China's urban scale. *Geogr. Res.* **2015**, *34*, 525–540.
77. Han, H. The Reference of China's Regional Cooperation and Development Experience to the Cooperation of Huaihai Economic Zone. *Acad. J. Humanit. Soc. Sci.* **2019**, *2*, 55–66.
78. Li, S.; Li, T. A quantitative evaluation and study of diffusion environment of agri-technique at country level in the Northwestern China. *Arid. Land Geogr.* **2011**, *34*, 179–186.
79. Liu, X.; Li, T.; Zhang, J. An empirical study on the spatial diffusion of agricultural technology innovation-a case of wheat-seed. *Syst. Sci. Compr. Stud. Agric.* **2011**, *2*, 148–153.
80. Li, J.; Li, T.; Li, S. Analysis of farmer's technology adoption behavior in different environments of agritechnique diffusion—A case study of water-saving irrigation technology in the arid and semiarid area of northwest China. *Bull. Soil Water Conserv.* **2010**, *30*, 201–205.
81. Wang, W.; Li, T.; Liu, X. Research on spatial diffusion of agricultural technology—A Case Study of Diffusion of Fruit Cultivation Technique. *Hum. Geogr.* **2009**, *1*, 76–80.
82. Man, M.; Li, T.; Li, S. Analysis of the technology environment's impact on the farmer's adoption of new technology in northwest traditional agricultural areas: Based on the survey in three type of agricultural technology with different attributes. *Scientia Geogr. Sin.* **2010**, *30*, 66–74.
83. Wang, Z.; Liu, J.; Li, T.; Chao, J.; Gao, X. Factors Affecting New Agricultural Business Entities' Adoption of Sustainable Intensification Practices in China: Evidence from the Main Apple-Producing Areas in the Loess Plateau. *Agronomy* **2021**, *11*, 2435. [CrossRef]
84. Hargreaves, T. Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. *J. Consum. Cult.* **2011**, *11*, 79–99. [CrossRef]
85. Fu, Y.; Shi, X.; He, J. Identification and optimization strategy of county ecological security pattern: A case study in the Loess Plateau, China. *Ecol. Indic.* **2020**, *112*, 106–130. [CrossRef]