Pol. J. Environ. Stud. Vol. 31, No. 3 (2022), 2923-2934
DOI: *10.15244/pjoes/144917* ONLINE PUBLICATION DATE: 2022-03-23

Original Research

Factors Influencing Cotton Farmers to Take Measures for Dealing with Greenhouse Gases: Evidence from Xin Jiang, China

Kaidi Yue[1], Yue Song[2], Lijie Zhang[3]*

[1]Department of Economics and Management, Xin Jiang University, China
[2]Xin Jiang Institution of Technology, China
[3]Department of Textile and Clothing Engineering, Xin Jiang University, China

Received: 26 September 2021
Accepted: 14 December 2021

Abstract

Greenhouse gas emissions are influenced by the technologies that farmers use in their agricultural production. Therefore, the purpose of this study is to find out the influencing factors for cotton farmers to adopt low-carbon technology. First of all, this study surveyed the progress of cotton farmers in Xinjiang and finally obtained 383 valid questionnaires. And then, a logistic model was used to analyze the influence on the adoption of key low-carbon technologies in the cotton cultivation process, combined with the theory of planned behavior. The results show that drip irrigation, soil testing, farmyard fertilizer, biodegradable film, and intercropping have different effects on farmers' adoption of low-carbon technologies. Meanwhile, the attitude had no significant effect on cotton farmers' adoption of low-carbon technology, while perceived behavior control and subjective norms had a significant effect on cotton farmers' adoption of low-carbon behavior. In the end, Suggestions are made from the following points. The government can improve farmers' awareness of low-carbon technologies by raising the level of education and expanding the publicity of agricultural low-carbon technologies. Businesses should be encouraged to provide farmers with free information on low-carbon technologies, so that cotton farmers can better understand agricultural low-carbon technologies. At the same time, to increase the enthusiasm of farmers to participate in training and income, farmers should be encouraged to participate in cooperatives. These initiatives will help the government to further promote low-carbon technologies.

Keywords: eco-friendly environment, theory of planned behavior, cotton, logistic model, agricultural low-carbon technologies

*e-mail: zhanglj@xju.edu.cn

Introduction

With the release of a large number of greenhouse gases, the global temperature has been rising. This kind of climate change seriously harms the living environment of human beings, animals, and plants. The continuously rising temperature will lead to disasters, and sometimes a large number of animals and plants will even become extinct, as described by Root et al., [1]. In addition to the spontaneous release of greenhouse gases by nature, greenhouse gases are also produced by People's Daily production activities. Sohail et al., [2] believed that transportation can lead to environmental pollution. About fifty-two percent of the methane produced by human activities is agriculture, and eighty-two percent of the nitrous oxide produced by human activities is also agriculture, as described by Smiths et al., [3]. According to the Food and Agriculture Organization of the United Nations, developing low-carbon agriculture can offset 80% of agricultural greenhouse gases. Therefore, to protect the environment and achieve the goal of sustainable development of humans, animals, and plants, we urgently need to take practical actions to reduce greenhouse gas emissions as far as possible.

According to previous research, there are many ways to produce greenhouse gases, when people engage in agricultural activities. Li et al. [4] calculated the energy efficiency with DEA, realizing that greenhouse gas emissions can be decreased by effectively increasing the energy efficiency of fertilizers, diesel, plastics, chemicals, and water. Snyder et al. [5] believed that increasing the efficiency of ammonia fertilizer used by farmers could protect water resources and reduce greenhouse gas emissions. Zhen et al. [6] discovered organophosphorus pesticides (OPPs) existed in the soil for a long time in the process of studying pesticide pollution, which would increase the emission rate of greenhouse gases in the soil.

To solve this problem, Skeeter et al. [7] studied how to control greenhouse gas emissions from the perspective of agriculture. Sohail et al. [8] explored ways to protect ecosystems from a water perspective. People can improve water quality by taking preventive measures, as described by Sohail et al., [9]. There is an urgent need for government agencies to make sincere efforts to address the plight of water shortages [10] (Sohail et al., 2014). For example, industrial wastewater can be treated for irrigation [11] (Sohail et al., 2021). Islam et al. [12] studied the greenhouse gas emission of rice under different irrigation methods and different fertilizers through comparative analysis. He argued that a combination of whole grass and fertilizer is better at controlling greenhouse gas emissions than single fertilizer and that better water management can also improve the efficiency of nitrogen fertilizer. Qi et al. [13] believed water-saving irrigation can reduce carbon dioxide emissions compared with continuous irrigation. Usually, water-saving irrigation means drip irrigation, as described by Sander et al., [14]. Gibbons et al. [15] studied farmland soil in English counties and believed that the reason for eutrophication was not because farmers used too much fertilizer, but because farmers did not carry out soil testing and the timing of using fertilization was not appropriate. Wuang et al. [16] conducted three years of experiments on farmland and found that using manure instead of fertilizer was an effective strategy to reduce greenhouse gas emissions. Ma et al. [17] believed that farmyard manure could effectively improve soil fertility and speed up nutrient circulation. Lee et al. [18] found that under the same fertilization conditions when farmers planted crops with film, the grain yield of corn was increased by about 45-95% and carbon emission was caused by corn also reduced. Yang et al. [19] believed that plastic mulch can save water when farmers are engaged in agricultural activities. But it leads to environmental pollution. And degradable films can help a lot to solve the problem. Brooker et al. [20] believe that intercropping could achieve the purpose of increasing production capacity without increasing input costs, and could help farmers adopt sustainable and intensive planting patterns.

The differences between us and the previous research literature are in the following areas. i) We have identified a variety of technologies that affect low-carbon cotton production. These factors include drip irrigation, soil testing, farm fertilizer, biodegradable film, and inter-production. ii) Combined with the theory of planned behavior, the questionnaire was designed. iii) To increase the confidence of the questionnaire, questionnaire surveys were conducted from different organizational forms, and factors affecting the use of different low-carbon technologies by cotton farmers were analyzed. To reduce greenhouse gas emissions, cotton farmers take drip irrigation, soil testing, farmyard manure, degradable films, and intercropping to plant cotton. When farmers are faced with the choice of different planting techniques, the factors that affect farmers taking measures are different. So based on previous research, this paper discusses these methods adopted by cotton farmers in Xin Jiang and tries to find the factors influencing them. And it is significant to promote ESC-friendly planting methods for environmentally sustainable development.

Materials and Methods

Area Selected

In China, agriculture plays an important role in the national economy. Xin Jiang is a major cotton-producing region in China. In 2020, Cotton yielded accounted for 87.33% of the country's total cotton yield, and its planting area accounted for 76% of the country's cotton planting area in Xin Jiang. Therefore, this study conducted a questionnaire survey on cotton farmers in Xin Jiang, trying to find out the factors that influence

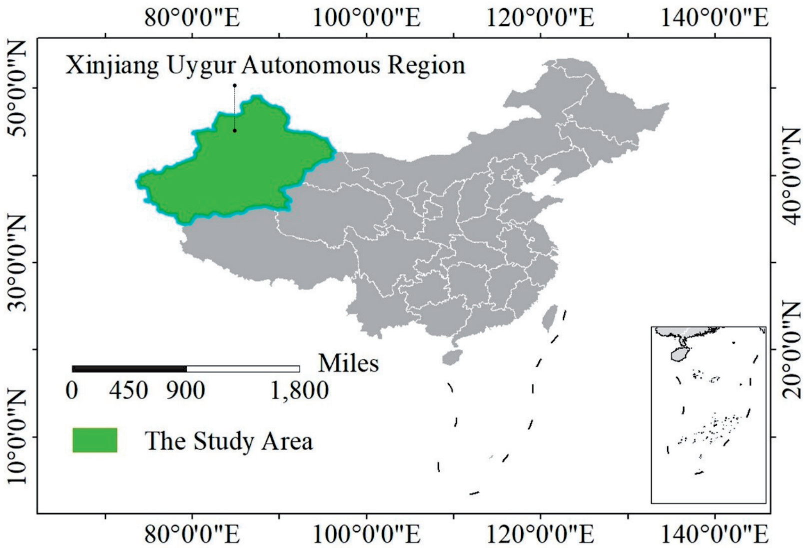

Fig. 1. Location of the study area.

cotton farmers to adopt environmental protection technology for production activities. Fig. 1 shows the map of the study area.

Data Collection

The main body of cotton production and operation in Xinjiang consists of three parts, namely, local government, farm operating enterprise, and production and construction corps (hereinafter referred to as local government, enterprise and corps)."Local" means the people's government of the Xinjiang Uygur Autonomous Region, the governments of Cities, counties and towns. An enterprise refers to an enterprise that uses various factors of production (land, labor force, capital, and technology, etc.) to make profits to engage in economic activities such as production, circulation, and service. It is a comprehensive enterprise with the integrated operation of agriculture, industry, and trade, and has strict production management functions over the areas under its jurisdiction. The corps is a special social organization integrating the party, government, army, and enterprise. It has the function of managing agricultural production, as well as the responsibility of managing and directing farmers' production activities.

Therefore, the locations selected by the questionnaire were also represented by three locations. The representative places of the local government are Yuli County of Korla city with cotton as the leading economy and Manas County of Changji City, an important grain and cotton base. The representative location of the enterprise is selected as Awati County, which is known as "the hometown of Long-staple cotton in China". We selected two enterprises for investigation, namely, Lu Tai Harvest Cotton Co., Ltd. and Xinjiang Tianfeng Seed Co., Ltd. The corps selected two representative sites, the first and eighth Agricultural Construction Division of the Xinjiang Production and Construction Corps, which are the main cotton-producing areas in Xinjiang.

The data needed for the study were obtained through field surveys in the form of questionnaires. A total of 441 questionnaires were obtained from this survey. A total of 141 questionnaires were obtained by the local government, 13 invalid questionnaires were excluded, and 128 valid questionnaires were obtained. And a total of 68 questionnaires were obtained by farm management enterprises, 17 invalid questionnaires were excluded, and 51 valid questionnaires were obtained. A total of 232 questionnaires were obtained from the Corps.28 invalid questionnaires were eliminated, and 204 valid questionnaires were obtained. Finally, a total of 383 valid questionnaires were obtained.

Questionnaire Design

There are many ways to reduce greenhouse gas emissions from agricultural production. These methods include water conservation [21] (Singh et al., 2021), fertilizer conservation [22] (Puspitawati et al., 2021), land conservation [23] (Paul et al., 2020), energy conservation [24] (Sohail et al., 2021) degradable film [25] (Xochitl et al., 2021), recycling of waste from farming and breeding [26] (Renella et al., 2021), recycling of waste from agricultural processing [27] (Yang et al., 2021), and clean energy [28] (Usman et al., 2021). Based on the realistic situation in Xin Jiang, we found that the cotton planting process mainly involved water-saving, fertilizer saving, medicine saving, land saving, and agricultural film substitution technology. Therefore, drip irrigation technology, soil testing technology, farmyard manure technology, degradable films technology, and intercropping technology were selected as the explained variables of the research.

Cotton farmers are asked if they use these techniques. If this technique is used, the value is 1. And if this technique is not used, the value is 0.

The factors affecting the behavior of cotton farmers are mainly considered from the aspects of individual characteristics, family characteristics, land characteristics, and environmental characteristics. Ajzen et al., [29] expanded the theory of rational behavior, believing that people's actions are not only affected by attitudes and subjective norms but also affected by perceived behavior control. Attitude is the attitude formed after an individual evaluates a particular behavior. The subjective norm is that the actions of individuals are influenced by external pressures. Perceptual behavioral control means that past experiences of people and expectations will influence their actions. Therefore, in combination with the theory of planned behavior, attitude and perceived behavior control are added in the analysis of personal characteristics, and subjective norms are added in the analysis of environmental characteristics to determine the final questionnaire design.

The variables of individual characteristics include gender, age, educational level, attitude, and perceived behavior control. In general, different individual characteristics of farmers will have an impact on their behavioral decisions. Li et al. [30] found that men are more willing to adopt agricultural low-carbon technologies. The older people are, the slower they are at learning new things, and the more likely they are to adopt old techniques, influenced by old habits. The more educated people are, the more likely they are to accept new things and take control of them. Cotton farmers who are willing to actively try new technologies should be more likely to adopt low-carbon technologies than those who are not willing to actively try new technologies. Cotton farmers who know these techniques are more likely to adopt them than those who do not. Therefore, it is expected that male cotton growers are more inclined to adopt low-carbon technology. The older cotton farmers are, the less likely they are to adopt low-carbon technologies. Cotton farmers with a higher education level, a more positive attitude towards new technologies and more understanding of new technologies are more inclined to adopt low-carbon technologies.

Household characteristic variables include the number of people engaged in cotton cultivation, the proportion of cotton income, and whether they join the cooperative. Xin et al. [31] conducted a study on cotton farmers in Xinjiang and found that the quantity of labor force and land type were the main factors affecting whether cotton farmers in Xinjiang adopted machine-picked cotton technology. Considering that different types of low-carbon technologies will have different demands on labor, labor-intensive low-carbon technologies and large labor force have advantages, the relationship between the number of people engaged in cotton cultivation and the adoption of low-carbon technologies still needs to be tested. In terms of the proportion of cotton income, the larger the proportion of cotton income in the total household income, the more attention the cotton-planting households pay to the improvement of cotton production technology, and the more inclined they are to adopt low-carbon technology. Cooperatives can provide their members with relevant technical information and other services, and members of cooperatives have more opportunities to learn about low-carbon technologies and the benefits they bring than those who do not join. Therefore, this study expects that the higher the proportion of cotton income and the participation in the cooperative will have a positive impact on the adoption of low-carbon technologies by cotton growers. The relationship between the number of people engaged in cotton cultivation and the adoption of low-carbon technologies has not yet been established.

Land characteristic variables include 3 parts. They are planting scale, land ownership type, and distance from the nearest market. The larger the planting scale, the more convenient the technology adoption and the lower the average adoption cost. From the perspective of land ownership types, compared with land leaseholders, landowners pay more attention to soil improvement and sustainable land use and are more inclined to choose production technologies with low harm to soil. Cooperatives can provide their members with relevant technical information and other services, and members of cooperatives have more opportunities to learn about low-carbon technologies and the benefits they bring than those who do not join. Therefore, this study predicts that cotton farmers with a large cotton planting scale, high land ownership, and cooperative participation are more likely to adopt low-carbon technologies.

The characteristic variables of the technological environment include government promotion, government regulations, technical guidance for agricultural technicians, and technical training organized by the government. Government promotion, government regulations, technical guidance of agricultural technicians, and technical training organized by the government will help cotton-growers to have a comprehensive and correct understanding of low-carbon technology and its economic benefits, help cotton-growers to adopt low-carbon technology correctly, reduce the cost and risk of low-carbon technology adoption, and make cotton-growers more inclined to adopt low-carbon technology. Technical popularization, technical guidance of agricultural technicians, and technical training can promote farmers to adopt new technologies. Therefore, this study expects that government promotion, government regulations, technical guidance for agricultural technicians, and technical training organized by the government will have a positive impact on cotton growers to adopt low-carbon technologies.

Table 1. Planting technique adoption rate of cotton farmers.

Technology item	Amount	Rate	Code	Assignment
Drip irrigation	381	99.48%	y_1	Adopt = 1, Not = 0
Soil testing	209	54.57%	y_2	Adopt = 1, Not = 0
Farmyard fertilizer	138	36.03%	y_3	Adopt = 1, Not = 0
Biodegradable film	46	12.01%	y_4	Adopt = 1, Not = 0
Intercropping	77	20.10%	y_5	Adopt = 1, Not = 0

Model Construction and Variable Description

The Logistic regression model is a probabilistic nonlinear regression model, which is suitable for the analysis of explained variables as dichotomous variables. The explained variable is a typical binary variable. Therefore, a binary Logistic regression model is selected to analyze the influencing factors of the low-carbon technology adoption behavior of cotton growers. The specific model is as follows.

$$P_i = F(y) = \frac{e^{a+\sum_{i=1}^{n} b_i x_i}}{1+e^{a+\sum_{i=1}^{n} b_i x_i}} \quad (1)$$

The Logit transformation of Equation (1) can be obtained as follows.

$$\ln\frac{P_i}{1-P_i} = a + \sum_{i=1}^{n} b_i x_i \quad (2)$$

p_i represents the probability of cotton growers adopting low-carbon technology. y is the explained variable, which represents the adoption behavior of cotton growers to low-carbon technology (adopt = 1, not adopt = 0). x_i is the explanatory variable, which represents the possible influencing factors for cotton growers to adopt low-carbon technology. a is the constant term, b_i is the regression coefficient, and n represents the order of possible influencing factors.

Results and Discussion

Planting Technology

Among 383 cotton-planting households, the samples of drip irrigation used by farmers accounted for 99.48% of the total samples. And 54.57% of the total samples adopted soil testing technology. The ratio of cotton farmers using farmyard manure technology accounted for 36.03% of the total samples. Cotton farmers using biodegradable film accounted for 12.01% of the total samples. Cotton farmers using intercropping accounted for 20.10% of the total samples. It can be seen that there are huge differences in the adoption of the five types of low-carbon technologies (Table 1). Except that most farmers adopt drip irrigation, the overall adoption level of other technologies is not high.

Descriptive Statistical Analysis of Features

Table 2 shows the descriptive statistical analysis of individual characteristics. In terms of gender, the respondents were mainly male, accounting for 76.5% of the total number of respondents. The majority of people are 41 to 50 years old. The proportion of those

Table 2. Descriptive statistical analysis of individual characteristics.

Variables	Code	Assignment	Mean	Se.
Gender	x_{11}	Male = 1, Female = 0	0.77	0.43
Age	x_{12}	Calculate according to the actual age of the respondent	44.49	9.07
Education	x_{13}	Primary and below = 1, Junior high school = 2; High school or technical secondary school = 3; Junior College and above = 4	2.19	0.75
Attitude	x_{14}	Most people adopt then adopt = 1; See how it works then use = 2; Active try = 3	2.12	0.66
Perceive behavior control	x_{151}	Drip irrigation,not understanding = 0;Understanding = 1	0.99	0.07
	x_{152}	Soil testing, not understanding = 0; Understanding = 1	0.71	0.46
	x_{153}	Farmyard fertilize, not understanding = 0; Understanding = 1	0.61	0.49
	x_{154}	Biodegradable film, not understanding = 0, Understanding = 1	0.28	0.45
	x_{155}	Intercropping, not understanding = 0; Understanding = 1	0.33	0.47

Table 3. Descriptive statistical analysis of family characteristics.

Variables	Code	Assignment	Mean	Se.
The number of people	x_{21}	Calculate according to the actual number of people engaged in cotton farming	1.95	0.68
Income	x_{22}	The ratio of cotton income to total income is less than 50% = 0, More than 50% = 1	0.85	0.35
Cooperative	x_{23}	Join = 1, Not = 0	0.15	0.35

Table 4. Descriptive statistical analysis of land features.

Variables	Code	Assignment	Mean	Se.
Scale	x_{31}	Calculated by actual planting area	157.62	190.69
Ownership type	x_{31}	The leaseholder of free land (private land) =1, Land contractor = 2, Owner of private land = 3	2.09	0.38
Distance	x_{31}	Distance from location to nearest market (km)	11.69	14.31

with junior secondary education reached 86.9 percent. And 55.4% of cotton farmers will adopt the new technology after seeing the effects of others using it. More than 60% of cotton farmers know drip irrigation, soil measurement, and farm manure, and less than 33.3% of them know biodegradable film and inter-row farmers.

Table 3 shows the descriptive statistical analysis of family characteristics. From the perspective of the number of growers, two people in the surveyed family were mainly engaged in planting activities, accounting for 72.1% of the total number of respondents. And 85.4% of households rely on cotton to earn more than 50% of total household income. In addition, the majority of families did not choose to join the cooperative, that's 85.4 percent.

Table 4 shows the descriptive statistical analysis of land features. 54% of the households surveyed have a planting scale of between 40 mu and 100 mu. 84.6 percent of the land planted by cotton farmers is contracted; Farmers whose land is within 10 kilometers of the market account for 68% of all farmers.

Table 5. Descriptive statistical analysis of the technological environment.

Variables	Code	Assignment	Mean	Se.
Government promotion	x_{411}	Soil testing, not promoting = 0; Promoting = 1	0.41	0.49
	x_{412}	Farmyard fertilize, not promoting = 0; Promoting = 1	0.21	0.41
	x_{413}	Biodegradable film, not promoting = 0; Promoting = 1	0.11	0.32
	x_{414}	Intercropping, not promoting = 0; promoting = 1	0.10	0.30
Government regulation	x_{421}	Soil testing, without regulation = 0; regulation = 1	0.07	0.25
	x_{422}	Farmyard fertilize, without regulation = 0; regulation = 1	0.06	0.24
	x_{423}	Biodegradable film, without regulation = 0; regulation = 1	0.02	0.13
	x_{424}	Intercropping, without regulation = 0; regulation = 1	0.03	0.18
Government guidance	x_{431}	Soil testing, without guidance = 0; guidance = 1	0.43	0.50
	x_{432}	Farmyard fertilize, without guidance = 0; guidance = 1	0.21	0.41
	x_{433}	Biodegradable film, without guidance = 0; guidance = 1	0.07	0.25
	x_{434}	Intercropping, without guidance = 0; guidance = 1	0.09	0.28
Government training	x_{441}	Soil testing, without training = 0; training = 1	0.33	0.47
	x_{442}	Farmyard fertilize, without training = 0; training = 1	0.20	0.40
	x_{443}	Biodegradable film, without training = 0; training = 1	0.07	0.26
	x_{444}	Intercropping, without training = 0; training = 1	0.09	0.29

Table 5 shows the descriptive statistical analysis of the technological environment. From the cotton farmers surveyed, 65.4 percent received a signal from the government to promote irrigation technology, only 22.5 percent received subsidies, and the number of farmers receiving technical guidance and government training was close to 50 percent of the total. It can be seen that the government attaches great importance to the promotion of drip irrigation technology. Drip irrigation has many advantages, such as saving labor, saving irrigation water, saving digging ditches, and so on. As drip irrigation technology brings cost-saving advantages, farmers can more easily accept and adopt this technology after the government promotes drip irrigation technology and provides farmers with technology and training.

The government's popularization rate of soil measurement technology reached 47.73%. The number of cotton growers receiving government subsidies accounted for 6.79% of all the surveyed cotton farmers. The technical personnel's guidance rate of soil measurement technology accounted for 42.56% of all the surveyed cotton farmers. And 32% of the surveyed cotton farmers received training organized by the government.

Among the surveyed cotton farmers, only 20.89% of them were promoted by the government, 6.27% of them received government subsidies, 21.15% of them received guidance from technicians, and 18.58% of them received training on-farm manure.

Government promote the rate of degradation of the membrane is only 11.2%, enjoy the government subsidy rate was 1.83%, the technical personnel to guide the ratio of 6.79% biodegradable film, the government for biodegradable film training rate of 7.05% compared with the dropper soil testing technology of farm technology, farmers surveyed in terms of the use of biodegradable film, facing the subjective norms are relatively weak, affected by the outside world is relatively small.

For intercropping seeding technology, the government promotion rate accounted for 10.18% of all respondents, the proportion of cotton farmers who received government subsidies accounted for 3.39% of all respondents, the guidance rate of technical personnel for inter-row seeding was 8.62%, and the proportion of cotton farmers who received training from the government accounted for 8.88% of all respondents. The purpose of interrow seeding technology is to improve the efficiency of soil use and increase land income. Because of the unique nature of intercropping, cotton farmers use intercropping to achieve higher incomes, even with less government intervention.

Validity Analysis

The validity analysis of this questionnaire was carried out using the SPSS25 version and the exploratory factor molecule method. According to the results of the exploratory factor analysis above (Table 6), it can be seen that the coefficient results of the KMO test are between 0.63 and 0.71, and the coefficient values of the KMO test range from 0 to 1. The closer to 1, the better the validity of the questionnaire. According to the significance of the spherical test, we can also see that the significance of this test is infinitely close to 0. Reject the null hypothesis, so the questionnaire has a good effect.

In our study, a total of 383 valid questionnaires were collected. We found that the number of people using drip irrigation technology for cotton irrigation has accounted for 99.48% of the total sample. So when we did the regression analysis, we eliminated this explained variable. The correlation test of the sample was carried out using the Pearson analysis method, and the results are shown in Tables 8, 9, 10, and 11. To further analyze the influence factors of low-carbon technology, we use a binary Logistic regression model to test the influence of variables on cotton farmers' low-carbon technology adoption behavior, and the results are shown in Table 12.

By analyzing the regression results, we find that the fitting results of the adoption behavior model of the four types of low-carbon technologies can be significant at the 1% level. In other words, the model fits well. Personal characteristics, family characteristics, land characteristics, technical and environmental characteristics have different degrees of influence on the adoption of four types of low-carbon technologies by cotton farmers.

Table 6. KMO and Bartlett tests.

Variables	Soil testing	Fertilizer farmyard	Biodegradable film	Intercropping
KMO measure	0.63	0.71	0.71	0.69
Bartlett sphericity test				
The approximate chi-square	644.27	812.79	882.44	815.97
Degree of freedom	105.00	105.00	105.00	105.00
Significance	0.00	0.00	0.00	0.00

Table 8. Correlation between the relevant variables of soil measurement.

Variables	1	2	3	4	5	6	7
Soil testing	1						
Perceiving	0.61***	1					
Ownership	-0.04	-0.02	1				
Promotion	0.56***	0.45***	-0.12**	1			
Regulations	0.25***	0.13**	-0.03	0.26***	1		
Guidance	0.55***	0.47***	-0.04	0.56***	0.23***	1	
Training	0.47***	0.40***	-0.07	0.61***	0.32***	0.65***	1

Table 9. Correlation between the relevant variables of farmyard manure.

Variables	1	2	3	4	5	6	7
Farmyard manure	1						
Perceiving	0.56***	1					
Ownership	0.03	0.03	1				
Promotion	0.46***	0.36***	-0.10*	1			
Regulations	0.32***	0.19***	-0.09*	0.37***	1		
Guidance	0.46***	0.33***	-0.08	0.60***	0.34***	1	
Training	0.45***	0.33***	-0.06	0.620***	0.39***	0.73***	1

Table 10. Correlation between the relevant variables of degradable films.

Variables	1	2	3	4	5	6	7
Degradable films	1						
Perceiving	0.58***	1					
Ownership	0.21***	0.12**	1				
Promotion	0.63***	0.45***	0.11**	1			
Regulations	0.37***	0.22***	0.07	0.38***	1		
Guidance	0.44***	0.37***	0.10**	0.53***	0.27***	1	
Training	0.40***	0.35***	0.10*	0.48***	0.34***	0.70***	1

Table 11. Correlation between the relevant variables of intercropping.

Variable	1	2	3	4	5	6	7
Intercropping	1						
Perceiving	0.66***	1					
Ownership	0.02	0.04	1				
Promotion	0.50***	0.41***	0.11**	1			
Regulations	0.34***	0.27***	0.07	0.38***	1		
Guidance	0.40***	0.36***	0.10**	0.53***	0.27***	1	
Training	0.46***	0.37***	0.10*	0.48***	0.34***	0.70***	1

Table 12. Model estimation results.

Variables	Soil testing	Fertilizer farmyard	Degradable film	Intercropping
Gender	-0.01	0.79*	0.76	0.84
Age	-0.02	-0.04	-0.01	0.02
Education	-0.59*	0.13	0.13	-0.29
Attitude	-0.23	-0.29	-0.25	-0.17
Perceive behavior control	3.01***	3.60***	4.90***	4.30***
The number of people	-0.01	0.32	0.05	0.52
Income	0.23	-0.05	2.12	0.65
Join the cooperative	0.95*	0.26	2.08*	-0.24
Planting scale	0.01	-0.01	0.01	0.01
Land ownership	0.17	0.49	1.93**	-0.05
Distance	0.02*	-0.01	0.01	0.01
Government promotion	1.90***	0.77	3.03***	1.72**
Government regulations	17.02	2.73*	17.49	1.48
Technical guidance	1.45***	1.02*	-0.40	-0.15
Technical training	-0.02	0.68	0.44	1.33
_cons	-1.68	-4.23**	-13.66***	-6.65**

The Impact of Individual Characteristics on the Adoption of Four Types of Low-Carbon Technologies

Gender had a significant positive effect on the adoption of farmyard fertilizer technology by cotton farmers, and it was significant at the level of 5%. In other words, male cotton farmers are more inclined to adopt farmyard fertilizer technology under the condition that other factors remain unchanged. However, gender had no significant impact on soil formulation technology, biodegradable membrane technology, and intercropping technology, which may be due to the lack of sufficient understanding of these low-carbon technologies by current cotton farmers or the fact that they do not think these three low-carbon technologies can bring expected benefits.

We found that the impact of education level on cotton farmers' adoption of soil testing formula technology was not as expected, showing a significant negative impact. The reason may be that the cotton planting area in Xinjiang is large and the soil is rich. If the soil testing formula is adopted, it will lead to an increase in production input costs for cotton farmers. The more educated the cotton growers, the better their understanding of the land, and the more techniques they have to improve soil fertility. Therefore, when using soil improvement technology, these people will combine the actual situation of the land and consider the production cost, so they are reluctant to use soil testing formula technology. Education level had no significant effect on the adoption of biodegradable film technology and intercropping technology by cotton farmers. The application process of degradable agricultural film technology and intercropping technology is simple and easy to be mastered. If people adopt these technologies, they don't need to be highly educated to apply them.

Perceptual behavior control had significant positive effects on cotton farmers' adoption of the four techniques. Perceptual behavioral control refers to the influence of experience and expectation on human behavior. The more cotton farmers know about the effects of low-carbon technologies, the more likely they are to adopt them.

Age attitudes to new technologies had no significant effect on cotton farmers' adoption of the four types of low-carbon technologies.

The Impact of Household Characteristics on the Adoption of Four Types of Low-Carbon Technologies

The number of people engaged in cotton production has no significant influence on cotton farmers' adoption of soil measurement formula technology biodegradable agricultural film technology and intercropping technology.

The results show that the ratio of cotton income to cotton income has a significant and positive impact on the adoption of degradable agricultural film technology. The reason may be that the price of biodegradable agricultural film is 1.6 times that of ordinary agricultural film. If people use biodegradable film, soil pollution will be reduced, but it will also increase the cost of cotton production. The lower the percentage of income from cotton, the fewer attention farmers pay to the benefits of cotton and the less they are willing to invest in managing cotton and protecting the soil. For cotton farmers with a higher proportion of cotton income, pay more attention to cotton production, invest more energy, and are more willing to invest more cost to protect the soil. The cotton income ratio had no significant effect on soil test formula technology and intercropping technology.

There was a significant positive correlation between soil testing formula technology and degradable film technology for cotton farmers after joining the cooperative, which was consistent with the expectation. Cooperatives can provide their members with required technical information services and technical guidance and demonstration. And the probability that the cotton farmers who participated in the cooperative adopted the soil testing technology was 2.5 times higher than that of the cotton farmers who did not participate in the cooperative. Among cotton farmers who participated in cooperatives, they were 5.7 times more likely to adopt biodegradable film technology than those who did not. The incorporation of cotton farmers into cooperatives had no significant effect on the adoption of farm manure technology and intercropping technology.

The Impact of Land Characteristics on the Adoption Behavior of Four Types of Low-Carbon Technologies

In the course of the investigation, we found that the cotton planting area of the survey subjects was more than 2.67 hectares. In addition, cotton is widely grown on a large scale in Xinjiang. Therefore, the planting scale has no significant impact on the adoption of the four types of low-carbon technologies.

Land ownership type had a significant positive effect on cotton growers' adoption of degradable film technology, which was consistent with the expectation. Biodegradable agricultural film technology has the characteristics of protecting the environment and reducing the damage to the soil but if people use it, they need to spend more money. If people grow land that is leased, they focus more on the short term to get more revenue. And they will be reluctant to invest more in reducing the damage to soil caused by ordinary mulch. Cotton farmers are more interested in the long term if they own the land. While they get the benefits from the land, they also pay attention to the protection and sustainable use of the land. And they tend to use biodegradable film technology to reduce the damage to the soil. The effect of land ownership type on soil test formula technology and intercropping technology was not significant.

The distance from the nearest market to the home location is significantly positively correlated with soil testing formulation techniques. In other words, the farther away from the market, the more cotton farmers tend to use soil testing formula technology. It was not in line with expectations. The reason for this phenomenon is that Xin Jiang cotton farmers' access to low-carbon technology information is relatively simple. In general, the closer you are to the market, the faster, more comprehensive, and more comprehensive you will get information about low-carbon technologies. According to the survey, we found that 65.27 percent of cotton farmers' access to low-carbon technology information comes from the government's technology promotion department, and 29.50 percent of cotton farmers' access to low-carbon technology information comes from television networks and other media, which makes access to low-carbon technology information break through the distance limit.

The Impact of Technology Environment on the Adoption Behavior of Four Low-Carbon Technologies

For cotton farmers, government promotion will have a significant and beneficial impact on the use of three technologies: soil measurement, biodegradable film, and intercropping. This conclusion is in line with expectations. This suggests that when government takes measures to promote technology, farmers will have a better understanding of them. And then, these cotton farmers are more likely to use them. However, the impact of government promotion on the use of farm fertilizer technology by cotton farmers is not significant The reason explaining the phenomenon is that cotton farmers already have known about farmyard fertilizer. Whether the government promotes this technology or not, it will not deepen farmers' understanding of this technology.

Government regulation is an important factor affecting cotton farmers' use of farm fertilizer, which is in line with expectations. However, it has little effect on cotton farmers using soil testing formula technology, biodegradable agricultural film technology, and inter-seeding technology. This shows that in the process of technology promotion, ignoring the will of cotton farmers themselves to force cotton farmers to adopt low-carbon technology is not very effective. Cotton farmers will be more willing to adopt low-carbon technologies if the government should adopt a guided approach.

The technical guidance provided by agricultural technicians is an important factor affecting the adoption of soil testing formula technology and farm-house fertilizer technology by cotton-planting households, which is positively correlated and consistent with the expectation. The technical requirements of soil testing formula and manure are high. Technical guidance from agricultural technicians can help cotton farmers use low-carbon technologies correctly. By doing so, they reduce the risk that cotton farmers will lose money because of operational errors. The effect of technical guidance provided by agrotechnologists on cotton farmers' adoption of degradable film technology and intercropping technology was not significant and was negative. The reason for this result may be that the biodegradable agricultural film technology and inter-seeding technology are simple to operate. Therefore, cotton farmers do not need to be guided by a technician.

The technical training organized by the government has a significant positive effect on cotton growers using intercropping technology. This conclusion is in line with expectations. Technical training organized by the government is helpful for cotton farmers to master intercropping technology correctly. And it will reduce the risk of loss to cotton farmers due to operational errors. But technical training organized by the government has no significant effect on the adoption of soil testing formula technology, manure technology, and degradable agricultural film technology by cotton planters. Through our survey, we found that most of the farmers interviewed knew that the government organized technical training. However, some cotton growers did not participate in the technical training organized by the government. Some cotton farmers attend technical training not seriously, the harvest after training is not much.

Conclusion

In addition to drip irrigation, cotton farmers in Xinjiang have a low adoption rate of low carbon technologies such as soil formula technology, biodegradable agricultural film technology, and intercropping interplanting technology. The adoption rate of soil measurement technology is 54.57%, and the adoption rate of other technologies is not even up to 50%. Individual characteristics, family characteristics, land characteristics, and technological environment have different impacts on the adoption of four types of low-carbon technologies by cotton farmers in Xin Jiang. The significant factors influencing cotton farmers' soil measurement are the level of education, the level of knowledge of the technology itself, participation in cooperatives, government promotion, and guidance from technical personnel. The significant factors affecting the adoption of farm fertilizer technology by cotton farmers are gender, the degree of understanding of the technology itself, government regulation, and technical personnel guidance. Significant factors affecting the adoption of biodegradable thin-film technology by cotton farmers are the level of understanding of the technology itself, the share of cotton income in all income, participation in cooperatives, and government promotion. The significant factor affecting the inter-line technology adopted by cotton farmers is the degree of understanding of the technology itself and the government's promotion.

In order to better promote the development of low-carbon agriculture, we can start from the following aspects. i) The government education sector may reduce tuition fees and incidental fees for education in poor areas and promote vocational and technical education in agriculture. ii) The government should further promote the exchange of agricultural cooperatives and enhance exchanges and learning among cotton farmers. This is conducive to improving the management level of farmers on the land. iii) Governments can increase investment in secondary and tertiary industries in economically underdeveloped regions. This could help agricultural workers increase their incomes through a second job and increase funding for low-carbon production technologies.

Although this study has made a relevant and regressive analysis of the factors affecting the use of various low-carbon technologies by cotton farmers, we also put forward some suggestions for promoting low-carbon technologies in agriculture based on the results. However, in addition to the effects of growing crops on greenhouse gas emissions, people living in rural areas also produce greenhouse gases during their daily heating. In the future, we may consider studying the effects of urban-rural integration on greenhouse gases.

Acknowledgments

Thanks to the reviewers of the article. The article is supported by the Social Science Fund of Xinjiang Uygur Autonomous Region (No. 20AZD004).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

1. ROOT T., PRICE J., HALL K., SCHNEIDER S., ROSENZWEIG C. Fingerprints of global warming on wild animals and plants. Nature, **421** (6918), 57, **2003**.
2. SOHAIL M. T., ULLAH S., MAJJEED M. T., USMAN A. Pakistan management of green transportation and environmental pollution: a nonlinear ARDL analysis. Environmental Science and Pollution Research, **3**, 1, **2021**.
3. SMITHS P., MARTINO D., CAI Z., GWAY D., JANZEN H., KUMAR R., MCCARL B., OGLE S.,HOWDEN M., MCALLISTER T., PAN G., ROMANENKOVV.,SCHNEIDER U.,TOWPRAYOON S.,WATTENBACH M., SMITH J. Greenhouse gas mitigation in agriculture. Philosophical transactions of the royal Society B: Biological Sciences, **363** (1492), 789, **2008**.
4. LI Q., KHAN M., ASHFAQ M. Greenhouse Gas Reduction in Off-Season Cucumber Production by Improving Energy Efficiency: A Case Study from Punjab, Pakistan. Polish Journal of Environmental Studies, **26** (4), 1453, **2017**.

5. SNYDER C., BRUULSEMA T., JENSEN T., FIXEN P. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems & Environment, **133** (3), 247, **2009**.
6. ZHEN M., BENRU S., XIAOMEI L., RADHIKA C., JINGCHUN T. Biochar-mediated regulation of greenhouse gas emission and toxicity reduction in bioremediation of organophosphorus pesticide-contaminated soils. Chinese Journal of Chemical Engineering, **26** (12), 2592, **2018**.
7. SKEETER J., CHRISTEN A., LAFORCE A.,HUMPHREYS E.,HENRY G. Vegetation influence and environmental controls on greenhouse gas fluxes from a drained thermokarst lake in the western Canadian Arctic. Biogeosciences, **17** (17), 4421, **2020**.
8. SOHAIL M.T., MAHFOOZ Y., AZAM A. K., YAT Y., FAHAD S. Impacts of urbanization and land cover dynamics on underground water in Islamabad, Pakistan. Desalination and Water Treatment, **159**, 402, **2019**.
9. SOHAIL M.T., AFRAB R., MAHFOOZ Y., YASAR A., YAT Y., SHAIKH S.A., IRSHAD S.J. Estimation of water quality, management and risk assessment in Khyber Pakhtunkhwa and Gilgit-Baltistan, Pakistan. Desalination and Water Treatment, **171**, 105, **2019**.
10. SOHAIL M.T., DELIN H., SIDDIQ A. Indus Basin Waters A Main Resource of Water in Pakistan: An Analytical Approach. Current World Environment, **9** (3), 670, **2014**.
11. SOHAIL M.T., LIN X., LIIZHI, L., RIZWANULLAH M., NASRULLAH M., XIUYUAN Y., ELIS R.J. Farmers' Awareness about Impacts of Reusing Wastewater, Risk Perception and Adaptation to Climate Change in Faisalabad District, Pakistan. Polish Journal of Environmental Studies, **30**(5), 4663, **2021**.
12. ISLAM S.F., SANDER B.O., QUILTY J.R., NEERGAARD A., GROENIGEN J.W.,JENSEN L.S. Mitigation of greenhouse gas emissions and reduced irrigation water use in rice production through water-saving irrigation scheduling, reduced tillage and fertilizer application strategies. Science of the Total Environment, **739**, 140215, **2020**.
13. QI L., NIU H.D., ZHOU P., JIA R.J., GAO M. Effects of biochar on the net greenhouse gas emissions under continuous flooding and water-saving irrigation conditions in paddy soils. Sustainability, **10** (5), 1403. **2018**.
14. SANDER B.O., WASSMANN R., SIOPONGCO J.D., HOANH C.T., JOHNSTON R., STMAKTHIN V. Mitigating greenhouse gas emissions from rice production through water-saving techniques: potential, adoption and empirical evidence. Climate Change and Agricultural Water Management in Developing Countries, **8**, 193, **2015**.
15. GIBBONS J.M., WILLIAMSON J.C., WILLIAMS A.P., WITHERS P.J., HOCKLEY N., HARRIS I. M., HEALEY J.R. Sustainable nutrient management at field, farm, and regional level: Soil testing, nutrient budgets and the trade-off between lime application and greenhouse gas emissions. Agriculture, ecosystems & environment, **188**, 48, **2014**.
16. WUANG S.C., KHIN M.C., CHUA P.Q., LUO Y.D. Use of Spirulina biomass produced from treatment of aquaculture wastewater as agricultural fertilizers. Algal research, **15**, 59, **2016**.
17. MA Q., WEN Y., WANG D., SUN X., HILL P. W., MACDONALD A.,JONES D.L. Farmyard manure applications stimulate soil carbon and nitrogen cycling by boosting microbial biomass rather than changing its community composition. Soil Biology and Biochemistry, **144**, 107760, **2020**.
18. LEE J.G., CHO S.R., JEONG S.T., HWANG H.Y., KIM P.J. Different response of plastic film mulching on greenhouse gas intensity (GHGI) between chemical and organic fertilization in maize upland soil. Science of The Total Environment, **696**, 133827, **2019**.
19. YANG N., SUN Z.X., FENG L.S., ZHENG, M.Z., CHI D.C., MENG W.Z., LI K.Y. Plastic film mulching for water-efficient agricultural applications and degradable films materials development research. Materials and Manufacturing Processes, **30** (2), 14, **2015**.
20. BROOKER R.W., BENNETT A.E., CONG W.F., DANIELL T.J., GEORGE, T.S., HALLETT P.D., LI L. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. New Phytologist, **206** (1), 107. **2015**.
21. SINGH T., SINGH N.D. Farmer's perception regarding on-farm water conservation in Punjab agriculture. Indian Journal of Economics and Development, **17** (2), 273, **2021**.
22. PUSPITAWATI M.D., SUMIASIH I.H. Organic Fertilizer from Starfruit Waste Sustainable Agriculture Solution. In IOP Conference Series: Earth and Environmental Science, **709** (1), 012069, **2021**.
23. PAUL S.S., DOWELL L., COOPS N.C., JOHNSON M.S., KRZIC M., GEESING D., SMUKLER S.M. Tracking changes in soil organic carbon across the heterogeneous agricultural landscape of the Lower Fraser Valley of British Columbia. Science of The Total Environment, **732**, 138994, **2020**.
24. SOHAIL M.T., ULLAH S., MAJEED M.T., USMAN A., ANDLIB Z. The shadow economy in South Asia: dynamic effects on clean energy consumption and environmental pollution. Environmental Science and Pollution Research, **28**, 29265, **2021**.
25. XOCHITL Q.P., MARIA H.B., MARIA M.S., ROSA E.V., ALETHIA V.M. Degradation of Plastics in Simulated Landfill Conditions. Polymers, **13** (7), 1014, **2021**.
26. YANG L., XIAN X., GU K. Agricultural Waste Recycling Optimization of Family Farms Based on Environmental Management Accounting in Rural China. Sustainability, **13** (10), 5515, **2021**.
27. RENELLA G. Recycling and Reuse of Sediments in Agriculture: Where Is the Problem?. Sustainability, **13** (4), 1648, **2021**.
28. USMAN M., MA Z., ZAFAR M.W., WAHEED A., LI M. Analyzing the determinants of clean energy consumption in a sustainability strategy: evidence from EU-28 countries. Environmental Science and Pollution Research, **28**(39), 1, 2021.
29. AJZEN I. Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. Journal of applied social psychology, **32** (4), 665, **2002**.
30. LI W., RUIZMENJIVAR J., ZHANG L., ZHANG J. Climate change perceptions and the adoption of low-carbon agricultural technologies: Evidence from rice production systems in the Yangtze River Basin. Science of the Total Environment, **759**, 143554, **2021**.
31. XIN M.H., WANG Z.B., HAN Y.C., FAN Z.Y., FENG L., YANG B.F., LI X.F., WANG G.P., LEI Y.P., XING F.F., XIONG S.W., LI Y.B. Review, Status and Measures of Xinjiang Machine-picked Cotton. Journal of Agricultural Science and Technology, **23** (7), 11, **2021**.