Abstract: Conservation tillage is an important approach to prevent water loss and soil erosion and promote soil fertility that has been adopted widely throughout the world. However, despite promotion of the benefits of conservation tillage, obstacles are still encountered in some regions. A survey of 385 farmer households in the semi-arid Loess Plateau of China was conducted to assess the adoption of conservation tillage (ACT). This investigation was located in two counties that have run conservation tillage demonstrations with wheat for at least eight years. A binary logistic regression model was used to quantify the factors determining whether or not farmers adopt conservation tillage. Farmer’s education level, the influence of training, and field demonstrations by agricultural departments had significant positive effects on ACT. Although the adoption rate of conservation tillage in this paper was very high (89%), farmers were reluctant to continue practicing conservation tillage based on their experiences, which is contrary to the expectations of the government. The area available for planting winter wheat and the number of arable plots per household also had significant positive effects on ACT. However, the total cultivated area of land per household had a significant negative impact on ACT. Farmer awareness of conservation tillage technology, the distance from a farmer’s house to the nearest agricultural market, and the size of the active labor force in the family had significant negative impacts on ACT. These results will help in the development of more effective and targeted policies to improve the sustainability of farming systems on the semi-arid Loess Plateau.

Keywords: conservation tillage; binary logistic regression; semi-arid Loess Plateau; China; adoption

1. Introduction

Conservation tillage is considered to be an effective way of conserving soil and water and promoting the sustainable use of farmland [1]. However, the implementation of conservation tillage is not uniformly distributed, especially in developing countries in arid and semi-arid areas dominated by smallholders [2]. Conservation tillage is defined as any tillage system that leaves sufficient crop residue on the field after harvest to protect soil from erosion [3]. According to the Conservation Technology Information Center, tillage that leaves a residue cover of at least 30% of the crop is deemed conservation tillage, and there are four categories types of conservation tillage: no tillage, mulch tillage, ridge tillage, and reduced or minimum tillage [4]. Two fundamental components of conservation tillage should be noted: minimal soil disturbance and permanent soil cover [5]. Tillage is usually implemented on farmland before crop sowing to overcome some soil-related constraints to crop production, but this can affect soil structure, reduce infiltration, and increase runoff, erosion, water pollution, and soil degradation [6]. Conventional soil tillage systems, which usually include intensive and continuous soil tillage, are often responsible for severe soil degradation and the loss of crop
productivity [1]. The benefits of conservation tillage include increasing water and nutrient contents in soil [7], improving crop yields [8], and reducing input costs by eliminating a series of conventional tillage operations [9].

There is a very complex terrain on the Loess Plateau of China, and the ground has been cut severely [10]. Farmland in the region is mainly sloping and very infertile. The Loess Plateau in China is one of the most severely degraded areas in the world—more than 60% of its land is subjected to soil and water loss—with an average annual soil loss of 20–25 t/ha [10]. Soil and water loss in this region occurs in association with natural processes as well as with human activity, in particular, vegetative destruction, unsuitable cropping systems, and other related social factors [11]. The level of agricultural production in the Loess Plateau area is low. Poor socio-economic and technical conditions lead to a weak capability of producing a regenerating agricultural development system. Due to the long-term problem of food and clothing, farmers are very focused on food production.

Conventional tillage systems practiced in the Loess Plateau include intensive soil cultivation combined with low fertilizer and manure inputs, and crop residue removal or burning [12]. The severe environmental problems of the Loess Plateau have been recognized by the Central Government of China, and an important large-scale initiative is the ‘Grain-for-Green’ policy to return steep cropland to forest or pasture in order to combat land degradation in ecologically vulnerable regions [13]. The semi-arid Loess Plateau has a long history of crop production, and the farmers who make the most of their living from the land may gain little economic return from the ‘Grain-for-Green’ policy. Therefore, they can be reluctant to convert their cropland to trees and/or pastures [14]. Consequently, there is an urgent need to develop an effective agronomic package to reduce erosion and protect the environment while increasing crop productivity for the highest possible proportion of farmers in this region.

In China, modern conservation tillage research commenced in the early 1980s with systematic research starting in the early 1990s [15]. In 1992, research in Shanxi and Shaanxi provinces showed that conservation tillage could help ease environmental problems, improve crop productivity, and increase the sustainability of rainfed agriculture [16]. Yet by 2008–2009, conservation tillage was only practiced on about 1.3 million hectares of farmland in China [15]. The Chinese Government set up national-level demonstration sites to promote conservation tillage technology and experimental research in different regions of the Loess Plateau. Wheat is widely cultivated on the Loess Plateau and primarily used to meet the food needs of farmers and their families [17], and it is an important demonstration crop for the application of conservation technology in this region. Many policies are already in place to promote the adoption of this technology, such as for example, subsidies for purchasing related equipment, herbicides, and pesticides. In addition, studies on conservation tillage have been conducted in this area [18–20], but most have only focused on experimental results to analyze its impact on the environment, soil, and crop yield, without considering the critical role of socio-economic factors in the promotion of the adoption of conservation tillage (ACT). Wang et al. [12] pointed out that in the promotion of conservation tillage technology, attention should be paid to different regional characteristics that are selected in accordance with technical patterns in order to minimize difficulties in promoting the technology. Previous results have shown that in the Loess Plateau, wheat yields improved significantly with conservation tillage practices compared to conventional systems [21]. Chen et al. [18] revealed that conservation tillage combined with residue mulching effectively maintained both soil and environmental sustainability in the Loess Plateau. In addition, the decline in soil fertility, high cost of agricultural production, and relatively low efficiency in agribusiness have become major factors restricting the development of agricultural production in this area. There has been little research conducted on the factors affecting the uptake of ACT by farmers in this area, and there is the need for vigilance and attention.

Elsewhere, studies have been undertaken on farmer uptake of ACT technology. Mazvimavi and Twomlow [22] summarized some key factors influencing the uptake of soil and water management interventions by smallholder farmers, including conservation tillage technology. D’Emden et al. [23]
noted that identifying key biophysical and socio-economic factors influencing no-tillage adoption by grain growers would improve the understanding of conservation tillage adoption decisions in Australian cropping regions. Dalton et al. [24] compiled biophysical and socio-economic factors, farming methods, and a knowledge index of conservation tillage practices in northwestern Ghana. Due to geographical particularities, different crops, and socio-economic conditions, the findings outlined above are not applicable to the Loess Plateau.

Generally, when a good agricultural technology is tested and promoted in a region, farmers understand the technology more deeply, and the likelihood of a farmer’s adoption will be higher. There were three main objectives of this study. (1) We used the case of conservation tillage technology to verify the above-mentioned theoretical assumptions. (2) We investigated key farmer and farm household characteristics, farm biophysical characteristics, and farm financial characteristics and exogenous factors that influence ACT uptake by farmers in the study area, and then used an econometric model to quantify these decision factors. (3) The outcome from this analysis was to provide the channels of communication between the researchers and policymakers and support the development of more effective and targeted policies to improve the sustainability of farming systems in this region.

2. Materials and Methods

2.1. Study Area

The study was undertaken in two counties of Qingyang Prefecture, Gansu Province, China: Xifeng and Zhenyuan counties (Figure 1). Xifeng was identified as a national-level conservation tillage demonstration county in 2002. Initially, Zhenyuan started as a provincial demonstration county in 2006, but was changed to a national-level demonstration county in 2008.

![Figure 1. Location of the two counties of the Loess Plateau surveyed for the study of the adoption of conservation tillage.](image)

Both counties are typical of the hilly and gully semi-arid Loess Plateau. Xifeng County is located at 35°41′ N and 107°38′ E at an altitude 1421 m above sea level. This region is a typical dry farming area with an average annual rainfall of about 527 mm. It is characterized by the interannual and uneven distribution of precipitation during the year. Precipitation from July to September represents 60–70% of the total annual rainfall. The annual average temperature is 10.1 °C with 2550 h of sunshine per year. Zhenyuan County is located at 35°68′ N and 107°2′ E at an altitude 1550 m above sea level. Similarly to Xifeng County, Zhenyuan County is a rainfed agricultural area. Average annual rainfall is
495.5 mm, while annual potential evaporation is 1565.4 mm. The rainfall distribution is similar to that of Xifeng County, with an average temperature of 10.3 °C and 2343 h of sunshine per year.

2.2. Acquisition of Data

Before designing the sampling frame of the households identified, we first learned about the national conservation tillage demonstration area on the semi-arid Loess Plateau in China. Among the many demonstration counties, we randomly selected two counties as the sample for the questionnaire. Xifeng and Zhenyuan counties are national-level demonstration sites for conservation tillage technology. Two towns, Pengyuan and Tunzi, were randomly selected from among the small towns. The data used in this study came from a survey conducted in both counties between January–March 2013. A structured and semi-structured questionnaire was designed to gather data related to farm attributes, farmer characteristics, and other socio-economic factors among farmers. The questionnaire include six parts: (i) the basic information of the farmers; (ii) the livelihood assets of the farmers; (iii) farmers’ farmland use; (iv) farmers’ cognition of conservation tillage technology; (v) the living standard of farmers; and (vi) farmers’ environmental awareness. Items/questions of the questionnaire were based on a large number of previous publications and combined with the actual agricultural production in the study area. Yangao, Caotan, and Tunzi villages were selected for the study, with 385 households randomly selected. Village headmen of the three villages provided us with the list of households. The information collected included farmer and farm household characteristics (population structure, age, education, attitudes towards conservation tillage, awareness of environmental threats), farm biophysical characteristics (total farm size, winter wheat area planted, actual yield of winter wheat), farm financial characteristics (agricultural family labor, source of income), and exogenous factors (availability of obtaining agricultural information attendance at field demonstrations and training). The respondents for this study were the heads of each household, who were assumed to be the sole decision maker in the family. To guide the development of the formal questionnaire, an informal survey was implemented using interviews with key informants including local government officials and other research agencies involved in ACT before the formal investigation.

2.3. Local Farming System and Cultivation Methods for Winter Wheat

A summary of data on farming systems collected from farmer surveys in the two sampled counties is presented in Table 1. Farmers in both counties considered winter wheat as a food crop and spring maize as a cash crop. Other cash crops in Xifeng County included potatoes, millet, flax, peaches, apples, and vegetables, while lentils, millet, forage sorghum, rapeseed, and potatoes are grown in Zhenyuan County.

| Table 1. Summary of data on farming systems in two counties of the Loess Plateau. |
|---------------------------------|----------------|----------------|
| Xifeng County (n = 203)         | Zhenyuan County (n = 182) |
| **Crop for food**               | **Area per household** | **Area per household** |
| Winter wheat, one crop/year     | 0.32 ha            | Winter wheat, one crop/year | 0.31 ha |
| **Main cash crop**              |                  |                  |
| Spring maize                    | 0.27 ha            | Spring maize     | 0.12 ha |
| **Other cash crops**            |                  |                  |
| Potatoes, millet, flax, peaches, apples, vegetables | very small          | Lentils, millet, forage sorghum, rapeseed, potatoes | very small |
| **Average population per household** | 4.1 people        | 3.4 people      |

Note: number of responses of villages, Caotan (n = 100) and Yangao villages (n = 103) in Xifeng county; and Tunzi village (n = 182) in Zhenyuan county. Farmed-land included the adoption of conservation tillage (ACT) and traditional tillage systems.
Winter wheat has been produced locally for a long time using traditional farming methods with moldboard plow deep tilling and intensive farming. Generally, soil is plowed three times and harrowed twice between harvest and autumn sowing. All stubble and residues are removed from fields at crop harvest for heating or cooking [15]. With the central government promoting conservation tillage, local farmers have started to use this technology to grow winter wheat, particularly in demonstration areas. The two main methods for planting winter wheat for ACT in the local agriculture sector are (1) a sub-soiling covering of crushed stalks of wheat process, and (2) a reduced-tillage crushed stalk mulching process.

In the first method, farmers initially leave high stubble after harvesting winter wheat with a combine harvester, and sub-soiling to ~20–40 cm deep. The straw is then used to cover the ground in summer. By autumn, farmers flatten the farmland with a light harrow to create a good seed bed and eliminate weeds before sowing winter wheat with a no-tillage planter. This system is used in areas with relatively poor soil. In the second method, farmers cover the ground with high post-harvest stubble in summer. If the ground is uneven or has more weeds, farmers treat it with shallow loose seed beds and weeding. After that, wheat is planted with a no-till planter. This method is used in areas with more fertile, loose soil. In the present study, farmers who have willingly adopted either of these two methods were considered to have adopted conservation tillage.

2.4. Conceptual and Analytical Framework

The conceptual framework of this study is based on a consumer theory approach developed by Lancaster [25] which assumed that adoption is an activity in which single or combined technologies are inputs, and the output is a collection of characteristics [26]. Standard neo-classical economic theory emphasizes that risk, financial, and scale factors are usually considered the most critical issues in technology adoption decisions for profit-maximizing producers [25]. If its benefits exceed its costs, a producer will adopt the technology. When capital investment is required, producers with larger operations are willing to gain higher benefits from a given technology adoption decision. Thus, if rational producers maximize their profits, a technology or production practice that has been demonstrated to be profitable would probably be widely adopted by producers [25]. To adequately represent a range of possible effects (positive and negative) within the farming system, short and long-term advantages should be considered. Individual farmers tend to adopt conservation tillage if the benefit of adoption is greater than the benefit of traditional farming. The probability \( P \) of a farmer adopting ACT is:

\[
P = f(h, b, c, x) \tag{1}
\]

where \( f \) is a function of four factors: \( h \), farmer and farm household characteristics; \( b \), farm biophysical characteristics; \( c \), farm financial characteristics; and \( x \), exogenous factors.

The analysis used a binary logistic regression model that considers a set of explanatory variables; it is a popular statistical technique applied in adoption studies [17,27–30]. Logistic regression assumes a cumulative logistic probability function, so the model can be described as:

\[
P_i(\mathbf{Y}_i = 1) = \frac{e^{f(h_i,b_i,c_i,x_i)}}{1 + e^{f(h_i,b_i,c_i,x_i)}} \tag{2}
\]

where \( P_i \) denotes the probability of the \( i \)th farmer’s adoption decision, and \( \mathbf{Y} \) is a qualitative dependent variable representing whether the farmer adopted conservation tillage or not. If \( \mathbf{Y}_i = 1 \), then the \( i \)th farmer adopted conservation tillage, but if \( \mathbf{Y}_i = 0 \), then no adoption occurred. The coefficients of the binary logistic regression model were estimated by maximum likelihood methods using SPSS 17.0.
2.5. Variable Selection and Hypotheses

2.5.1. Dependent Variable

The variables used in this study are presented in Table 2. The dependent variable for this study is the farmers’ choice behavior in terms of utilizing the tillage practice or not (T). This is a binary variable with a value of 1 for farmers who adopted conservation tillage, and 0 for those who did not.

Table 2. Definition of variables used in the analysis of ACT.

| Variable | Definition | Variable Types | Type of Measure |
|----------|------------|----------------|-----------------|
| T        | Whether a farmer has adopted or not | Dummy | 1 if yes, 0 if no |
| PEO      | Number of family members | Numeric | Number |
| AGE      | Age of the head of the family | Numeric | Number |
| EDU      | Educational background of the household head | Dummy | 1. no formal education 2. primary school 3. junior secondary school 4. senior secondary school 5. college and above |
| NFL      | Number of family laborers | Numeric | Number |
| LIND     | Understanding of conservation tillage by farmers | Dummy | 1. completely unknown 2. only known 3. general understanding 4. good understanding |
| AWA      | Head of household’s awareness of ecological environmental threats in recent years | Dummy | 1. deterioration 2. unchanged 3. improving |
| DIS      | Distance of farmers’ house to the nearest agricultural market | Dummy | 1. very near 2. near 3. far 4. very far |
| FARM     | Total area farm land owned | Numeric | Hectare |
| WWA      | Actual planting area of winter wheat | Numeric | Hectare |
| NUM      | Number of arable plots per household | Numeric | Number |
| INC      | Total income/year in the family | Dummy | 1. <10,000 Yuan 2. 10,001–20,000 Yuan 3. 20,001–30,000 Yuan 4. 30,001–40,000 Yuan 5. 40,001–50,000 Yuan 6. >50,000 Yuan |
| PRO      | Percentage of off-farm income within total household income | Numeric | Number |
| YIE      | Average yield per hectare of winter wheat | Numeric | kg |
| TRAI     | Has head of household received training for conservation tillage? | Dummy | 1 if yes, 0 if no |
| DEM      | Has head of household participated in conservation tillage field demonstration? | Dummy | 1 if yes, 0 if no |

Note: Chinese monetary unit (Yuan): 1 US dollar equal to 6.23 Chinese Yuan during the study period.
2.5.2. Explanatory Variables and Relationship to ACT

Farmer and Farm Household Variables

PEO measures the number of members within a household. Most of the literature on agricultural technology adoption considers that the decision to adopt technologies, including conservation tillage, is affected by the number of people in a household \([31,32]\). Households that are large in their size are more likely to adopt conservation tillage because conservation tillage is not labor-intensive. In this case, there are extra persons to give serious consideration to conservation tillage technology. As household size continues to increase, the likelihood of adoption of conservation tillage is expected to be high. Meanwhile, a larger family size is generally associated with a larger labor force to perform off-farm work and get more economic benefits through other channels. For this reason, households prefer conservation tillage. Therefore, we assumed that the variable PEO is positively related to ACT.

AGE measures the age of the head of a household. According to the theory of human capital, young members of a household are more likely to absorb and apply new knowledge \([33]\). Therefore, it is expected that AGE will have a negative impact on the ACT.

EDU refers to the level of education of the household head. Higher education enhances the capacity for creativity and innovation. Most adoption studies have indicated that farmers with higher levels of education are more likely to adopt new technologies or practices than less-educated farmers \([34,35]\). It is expected that EDU will have a positive influence on the ACT.

NFL reflects the size of the active labor force in the family. A household’s labor availability will affect the farm household’s decision to ACT \([36,37]\). Although labor constraints do not often limit a farmer’s use of conventional tillage, they rarely consider the opportunity cost of the labor force. Thus, a negative influence on the ACT is expected with the presence of a larger, active labor force.

UND is used to measure the understanding of conservation tillage by farmers. The farmer’s level of understanding of conservation tillage directly affects their decision-making behavior. There is no obvious causal relationship between the level of understanding and choice of ACT, so it is difficult to predict the impact of this variable.

AWA measures the household head’s awareness of ecological environmental threats in recent years. The awareness of such environmental threats supports the use of conservation tillage. One study revealed that AWA is positively related to ACT \([38]\), which is also expected for this study.

DIS represents the distance of a farmer’s house to the nearest agricultural markets, where farmers buy agricultural equipment and materials and sell their products. Closer proximity to agricultural markets implies less cost and time related to ACT. It is hypothesized that the closer a farmer’s house is to the agricultural markets, the more likely a farmer will adopt conservation tillage.

Farm Biophysical Variables

FARM measures the total area of farmland owned by the respondents. FARM is a common factor in studies on ACT and similar soil conserving practices \([39,40]\). Farmers with large farms are more likely to benefit from agricultural production than those with smaller farms. Generally, farmers with large areas of arable land are more likely to make upfront technical investments such as the need for conservation tillage, which is why FARM usually positively affects ACT.

WWA represents the actual planting area of winter wheat in the respondent’s family. Naturally, large areas contribute to higher total yields. ACT saves labor due to the wide use of machinery. Therefore, WWA is expected to positively affect the ACT.

NUM is a numeric variable that measures the number of plots of arable land per household. ACT relies on the extensive use of machinery and appliances. More plots imply that the arable land is more dispersed, which is not conducive to the operation of machinery and appliances. Therefore, NUM should have a negative effect on the ACT.
Farm Financial Variables

$\text{INC}$ measures the total income per year in the family. Relevant analyses of ACT have indicated that $\text{INC}$ is an important variable \cite{41}. ACT requires sufficient financial well-being, especially if new equipment is hired or purchased and expensive herbicides are needed. A well-off farmer is more likely to withstand a higher risk of failure of ACT. In general, ACT is enhanced by a higher $\text{INC}$.

$\text{PRO}$ refers to the proportion of total household income accounted for by off-farm income. The availability of off-farm income or income received by the household as in-kind may also affect the decision to adopt agricultural technologies such as conservation tillage \cite{31}. A higher $\text{PRO}$ indicates that farmers do not rely on agriculture for their livelihood; they may ignore innovations in farming as they have other sources of income off-farm. Meanwhile, access to and reliance on off-farm income can influence the adoption of practices by decreasing the tendency to adopt some practices that would increase profitability but involve greater management demands. A higher value of $\text{PRO}$ means less interest in ACT, which will have a negative effect.

$\text{YIE}$ measures the average hectare yield of winter wheat. Regardless of farming method, yield remains the fundamental issue for farmers. $\text{YIE}$ is expected to have a positive influence on the ACT.

Exogenous Variables

$\text{TRAI}$ is a dummy variable representing training services obtained by respondents, and takes the value of 1 or 0 depending on whether the respondent attends or misses such training sessions. Participation in training helps farmers better understand conservation tillage technology and regularly update their knowledge. In this study, we expect a positive influence of $\text{TRAI}$ on ACT.

$\text{DEM}$ is a dummy variable reflecting participation in conservation tillage field demonstrations. It takes a value of 1 if the farmer participates in a field demonstration and 0 if not. Through field demonstrations, farmers can directly, and in a timely manner, resolve problems that they face in their work. Attending such field demonstrations is positively related to ACT.

3. Results

3.1. Descriptive Statistics and Survey Results

Descriptive statistics for all of the dependent ($Y$) and explanatory variables ($h$, $b$, $c$, and $x$) in the empirical model are given in Table 3. Within these columns are the variable minima, maxima, means, and standard deviations for the total sample. Table 4 shows the structure and income of farmers’ crop production. Farmers allocated more land (59.1%) to spring maize, which yielded more than twice that of winter wheat. The yield of spring maize per hectare is more than twice that of winter wheat. Under the conditions of the close price, farmers who plant more spring maize have larger economic returns. This means that if there is more farmland, farmers prefer to grow spring maize. Government demonstrations were the key reason why farmers adopted conservation tillage (Table 5). The influence of surrounding farmers, demonstration farmland, and government subsidies are also important factors that contributing to the adoption of conservation tillage for farmers (Table 5). We could conclude that government policy is very significant in effectively promoting ACT. Technology complexity, fewer government subsidies, and unstable winter wheat yields after using conservation tillage were the main reasons that farmers did not adopt conservation tillage (Table 6). Among them, technical complexity is the most important reason for most farmers being reluctant to adopt conservation tillage. Conservation tillage technology is a set of technologies. Some of these technologies include conservation tillage modes, control on weeds, disease, and pest control, and the matching implements. The low education level of the local farmers makes it difficult to grasp the conservation tillage technology system.
Table 3. Summary of response variables used in the analysis (n = 385).

|        | Minimum | Maximum | Mean   | Std. Deviation |
|--------|---------|---------|--------|----------------|
| T      | 0       | 1       | 0.89   | 0.32           |
| PEO    | 1       | 8       | 3.79   | 1.35           |
| AGE    | 26      | 83      | 50.16  | 10.81          |
| EDU    | 1       | 5       | 2.94   | 0.75           |
| NFL    | 1       | 6       | 2.35   | 0.90           |
| UND    | 1       | 4       | 1.87   | 0.73           |
| AWA    | 1       | 3       | 2.07   | 0.70           |
| DIS    | 1       | 4       | 3.01   | 1.10           |
| FARM   | 0.13    | 1.6     | 0.54   | 0.25           |
| WWA    | 0       | 1.3     | 0.30   | 0.13           |
| NUM    | 1       | 5       | 2.04   | 0.82           |
| INC    | 1       | 6       | 2.34   | 1.78           |
| PRO    | 0       | 1       | 0.65   | 0.22           |
| YIE    | 0       | 5192.3  | 3604.5 | 533.7          |
| TRAI   | 0       | 1       | 0.83   | 0.38           |
| DEM    | 0       | 1       | 0.79   | 0.40           |

Note: Italic abbreviations represented the variables used in the model (see Table 2) and response variables were the dependent variable and explanatory variables in the model.

Table 4. Structure and income of farmers’ crop production for farmers who participated in the questionnaire.

| Name              | Percent (%) | Average Yield (kg/ha) | Price (Yuan/kg) | Average Cost (Yuan/ha) | Net Average Income (Yuan/ha) |
|-------------------|-------------|-----------------------|-----------------|------------------------|-----------------------------|
| Winter wheat      | 37.9        | 3604.5                | 1.9             | 3000                   | 3849                        |
| Spring maize      | 59.1        | 8499                  | 2.0             | 6450                   | 10,548                      |
| Others            | 3           | –                     | –               | –                      | –                           |

Note: Chinese monetary unit (Yuan): 1 US dollar equal to 6.23 Chinese Yuan during the study period.

Table 5. Reasons why farmers who participated in the questionnaire adopted conservation tillage (n = 344).

| Reason                                      | Frequency | Percent (%) |
|---------------------------------------------|-----------|-------------|
| Government demonstration                    | 310       | 24.7        |
| Influence of surrounding farmers            | 278       | 22.2        |
| Demonstration farmland around               | 270       | 21.5        |
| Government subsidies                        | 201       | 16.0        |
| Experimental demonstration in the village   | 180       | 14.4        |
| Farmland owned by themselves as demonstration farmland | 14 | 1.1 |

Table 6. Reasons why farmers did not adopt conservation tillage (n = 44).

| Reason                                      | Frequency | Percent (%) |
|---------------------------------------------|-----------|-------------|
| Technology complexity                       | 38        | 86.3        |
| Less government subsidies                   | 35        | 79.5        |
| Unstable yield                              | 31        | 70.1        |
| Too many weeds in the fallow period         | 8         | 18.1        |
| Few suitable machines                       | 6         | 13.6        |

From the survey, we found that the adoption rate of conservation tillage was up to 89% (Table 3). However, farmers who had adopted conservation tillage during the government incentive program were unlikely to continue to do so once the program was completed (Table 7). Indeed, the modeling analysis indicated that UND had a significant negative impact on adoption ($p < 0.01$), i.e., ACT was
higher among farmers with less understanding of the technology than for farmers who understood it well.

Table 7. Responses of farmers who participated in the questionnaire to the question, “Do you want to continue adopting conservation tillage techniques after the completion of the national-level conservation tillage demonstration project?” (n = 341).

| Choices of the Conservation Tillage Actual Users | Frequency | Percent (%) |
|-------------------------------------------------|-----------|-------------|
| I will continue adopt conservation tillage      | 5         | 1.5         |
| I will not adopt conservation tillage any longer| 334       | 97.9        |
| Depending on the situation before making a decision | 2         | 0.6         |

3.2. Modeling the Survey Data

The binary logistic regression model produced a good fit to the survey data; nine of the 15 explanatory variables in the model had coefficients significant at \( p < 0.1 \). The model was reliable and consistent according to the signs, magnitudes, and statistical significance of the estimated parameters in the model (Table 8).

Table 8. Econometric model results of factors affecting farmers’ adoption of conservation tillage.

| Coefficient | S.E. | Wald Statistics | p-Value |
|-------------|------|-----------------|---------|
| PEO         | -0.329 | 0.471 | 0.487 | 0.485 |
| AGE         | -0.042 | 0.052 | 0.656 | 0.418 |
| EDU         | 1.524  | 0.776 | 3.860 | 0.049 **|
| NFL         | -1.411 | 0.824 | 2.935 | 0.087 *|
| UND         | -2.430 | 0.937 | 6.733 | 0.009 ***|
| AWA         | -0.853 | 0.828 | 1.060 | 0.303 |
| DIS         | 2.273  | 0.893 | 6.483 | 0.011 **|
| FARM        | -0.770 | 0.368 | 4.377 | 0.036 **|
| WWA         | 27.890 | 9.931 | 8.821 | 0.003 ***|
| NUM         | 3.968  | 1.128 | 12.374 | 0.000 ***|
| INC         | 1.597  | 1.381 | 1.336 | 0.248 |
| PRO         | -2.127 | 1.975 | 1.160 | 0.281 |
| YIE         | 0.000  | 0.001 | 0.085 | 0.770 |
| TRAI        | 2.656  | 1.142 | 3.498 | 0.061 *|
| DEM         | 8.269  | 2.353 | 12.354 | 0.000 ***|
| Constant    | -9.579 | 7.923 | 1.462 | 0.227 |

Chi square: 231.84; d.f.: 15; Sig.: \( p < 0.001 \); \(-2\) Log likelihood: 41.805; Cox and Snell \( R^2 = 0.452 \); Nagelkerke \( R^2 = 0.889 \); ** Significance at \( p < 0.01 \); * Significant at \( p < 0.05 \); Overall percentage of correct predictions: 97.7%; No collinearity between variables (all variance inflation factors (VIF) < 4).

PEO, AGE, and AWA were not significantly related to ACT. As expected, ACT was positively and significantly related to EDU (\( p < 0.05 \)). NFL had the expected negative impact on the ACT, and was significant (\( p < 0.1 \)). The coefficient of DIS was positive and significant (\( p < 0.05 \)), suggesting that farmers who were further from the nearest agricultural market were more likely to adopt conservation tillage.

Contrary to our expectations, FARM was negatively and significantly (\( p < 0.05 \)) related to ACT. As anticipated, WWA was significantly positively related to adoption (\( p < 0.01 \)). Surprisingly, NUM was significantly positively related to adoption (\( p < 0.01 \)), implying that households with more plots of cultivated land were more likely to adopt.

INC, PRO, and YIE had no significant effect on ACT. As expected, TRAI was positively related to adoption and significant (\( p < 0.1 \)). In our study, DEM was significantly positively related with ACT (\( p < 0.01 \)), which indicates that the government training and demonstrations were helpful for ACT.
4. Discussion

Factors that affect farmers’ ACT will differ according to different social and economic context, as well as resource endowment. Our research revealed the scientific problem. In addition, we verified the impact of farmers’ cognition on the adoption of conservation tillage. These factors should be considered by researchers, policymakers, and others who are interested in improving the sustainability of farming systems on the semi-arid Loess Plateau.

4.1. Education and Perception of Farmers

The positive impact of EDU on ACT (adoption of conservation tillage) is similar to that in other relevant studies [37,42]. Improving the education level of local farmers would help ACT, and the governments should pay more attention to it. Our results suggest that conservation tillage is unsuitable for this region (i.e., a negative relationship between ACT and both UND and FARM). However, the negative relationship for UND is not consistent with previous case studies. For example, Goswami et al. [28] revealed that farmers’ perceptions had a significant positive impact on the adoption of slash and burn agriculture.

The investigated region is a national-level demonstration area that the government designated. In this district example, the government has given a great deal of support. On one hand, initially, agricultural technology extension technicians persuaded farmers to start utilizing conservation tillage farmers. On the other hand, the farmer group leaders also had the responsibility to extend the task to the lowest socio-economic areas and household numbers. The local farmers had to follow the group leaders to take the task of extension. However, in the process of the utilization of conservation tillage, with a deepening understanding of conservation tillage technology, farmers were more reluctant to maintain conservation tillage practices. Nevertheless, the high adoption rate of 89% observed in the survey is likely to be temporary, because most farmers indicated that they would not continue the practice after the government incentive program was completed (Table 7). More importantly, the empirical evidence we present here indicated that ACT was based on complex decision-making; adoption itself was a complex process, and it was influenced by many factors [42]. Thus, the high adoption rate is the result of only a temporal utilization of conservation tillage driven strongly by the implementation of the government extension system.

In this context, it appears impossible to establish conservation tillage as an ongoing management practice for this group of farmers. Farming systems are multifunctional, so socio-economic and environmental factors need to be considered. It has previously been demonstrated that resource-poor and vulnerable smallholder farming systems will have the greatest challenges adopting conservation tillage [2].

4.2. Farmers’ Livelihood Assets

ACT was negatively and significantly related to NFL. Households with a large amount of family labor were able to generate more income through non-farm work because of the surplus labor force. Contrary to our expectation, DIS had a positive relationship with ACT. Despite being further from the market, these farmers seemed more curious about conservation tillage and willing to try new technology. These farmers are more concerned about agricultural production because alternative employment prospects are limited compared with those closer to the markets. On the other hand, these farmers are usually poorer than those closer to the markets, and therefore need to consider issues such as transportation costs and time. Farmers whose houses are closer to markets can reduce costs, as well as buy and sell production materials and products in the market resulting in more resources, including money, to facilitate ACT.

FARM had a negative effect on ACT, as per some other studies [43,44]. In this study, the higher FARM reflected a larger household and labor force. Such households could engage in other activities
to earn more money, and not depend only on the farm land for income. In cases with more farmland, it was usually allocated to cash crops (maize) to increase the economic benefit.

The variable \textit{WWA} contributed to the model as expected. Due to the widespread use of machinery, ACT saves labor so farmers can do other work to increase their income. Meanwhile, households with more land holdings would be more likely to allocate part of their farms to try new agricultural technologies such as conservation tillage [31]. This is because farmers with a larger winter wheat cultivation area would have more flexibility in how they used the land. They do not worry about food and income shortages. For example, they would have a greater capacity to apply new technologies in comparison to those whose winter wheat cultivation area is smaller. Thus, farmers with relatively larger winter wheat cultivation areas have the capability to overcome the bottleneck of income under conservation tillage. Thus, the foregoing reasons promote ACT.

The result for \textit{NUM} in the model was unexpected but explainable. Many practicing farmers in the study area are elderly and/or women, and it is difficult for them to manage more plots of farmland. ACT could easily solve this problem. At the same time, more plots mean less area per piece of farmland. Maize yields more than does winter wheat, so farmers use their larger plots for maize. Thus, the results for \textit{NUM} in the model were convincing.

4.3. External Driving Forces

Both \textit{TRAI} and \textit{DEM} are important positive factors influencing ACT. ACT was positively related to \textit{TRAI} and significantly positively related to \textit{DEM}. The finding for \textit{TRAI} is similar to previous adoption decision findings [45]. In our research, training on conservation tillage technology was mainly related to technical personnel or experts hired by the government and carried out in classrooms. In the process of the extension of conservation tillage, the local government provided full technical guidance and training, as well as demonstration in key aspects of winter wheat cultivation. The farmer group leaders also had the responsibility to extend the task to the lowest socio-economic areas and household numbers. The local farmers have to follow the group leaders in order for the task to be extended. Currently, in the study area, the promotion of ACT is the result of government top–down forces, with almost no participatory management by farmers. However, actually, when the farmers adopted the conservation tillage, they found that the technical effect was lower than they expected. When they obtain more understanding of conservation tillage, they are not willing to adopt conservation tillage.

4.4. Continued Field Management Practices Innovation

The two counties we surveyed are national-level demonstration sites for conservation tillage technology. The implementation area for conservation tillage is a priority at all levels of government. Thus far, farmers’ opinions have been ignored. Our interviews with local farmers established that until 10 years ago, the area planted to winter wheat was larger than that of spring maize, but now, much of the farmland is sown to spring maize. Spring maize is becoming an important cash crop in this region, bringing economic benefit to farmers.

Recently, film fully-mulched ridge–furrow cropping has been used widely in this region, particularly for cultivating spring maize [46–48]. However, the sustainability of rainfed agroecosystems may be impaired by the use of non-degradable plastic film and failing to return crop residues to farmland [49].

Field management needs to be optimized to suit individual farmers’ needs in different agro-ecological environments. The combination of film fully-mulched ridge–furrow cropping with residue-covered furrows may be a better field-management choice for spring-sown maize, but until now, this has not been considered a form of conservation tillage. According to the definition of conservation tillage [4], such improvements differ markedly from the existing patterns of conservation tillage on the Loess Plateau. Meanwhile, the principles of conservation tillage have been widely implemented across many agro-ecological and physiographical environments. In order to make these principles valid and applicable, they need to be adjusted to a farmer’s particular conditions [50].
According to Llewellyn et al. [51], intensive knowledge and sustained innovation processes used in connection with no-tillage systems have resulted in remarkable changes in agricultural landscapes. This is a continuous process that proceeds in later-adopting regions, as well as in sustaining extensive implementation. Consequently, use of film fully-mulched ridge–furrows combined with crop residues in furrows may be an efficient measure to increase crop yield and maintain or improve soil fertility in regions of the world with a similar climate to the semi-arid Loess Plateau in northwestern China.

5. Conclusions

In 2013, we conducted a survey questionnaire in two counties in the Loess Plateau that were selected 11 and seven years previously as national-level conservation tillage demonstration counties. Farm household, biophysical variables, and exogenous variables significantly affected the ACT. Farmers with more farmland used for winter wheat cultivation and those with more plots were more willing to adopt this technology. Farmers who lived further from the nearest agricultural market preferred to practice conservation tillage. Government training and demonstrations can strongly promote ACT. However, farmers’ perceptions about the technology had a strong negative impact on ACT. Farmers with more farmland and households with a more active labor force were less willing to adopt this technology compared with those who had smaller farms. Although some measures and policies have been implemented to promote conservation tillage technology, farmers are generally not willing to permanently accept and adopt this technology. It was only a once-off adoption, rather than a sustained adoption. These results have limited the area that improves the sustainability of farming systems.

The concept of conservation tillage has not taken root in the decision-making processes of these farmers. According to our survey, farmers who had a better understanding of conservation tillage were less willing to adopt this technology than those who understood it less. In essence, farmers on the semi-arid Loess Plateau seemed reluctant to adopt conservation tillage. The farmers think that the technology of conservation tillage is too complex and knowledge-intensive to learn and implement, and any increases in winter wheat yields were not stable. Winter wheat is not a cash crop in this region, so little economic benefits will be gained from conservation tillage compared with maize production. Indeed, maize is the main economic crop in this area, and the plastic film fully mulched ridge–furrow system for maize production can obtain very high grain yields and economic benefits for the local people. Thus, it is difficult for the local farmers to accept the wheat-based conservation tillage technology. However, the plastic film fully mulched ridge–furrow system for maize production is not considered conservation tillage. The planting pattern of maize for conservation tillage is still in the experimental stage.

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