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Does Cognition of Resources and the Environment Affect Farmers' Production Efficiency? Study of Oasis Agriculture in China

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Abstract: Improving production efficiency can help overcome the constraints of resource scarcity and fragile environments in oasis agriculture. However, there are few studies about the effect of farmers' cognition of resources and the environment on their production efficiency. Taking farmers in the Ganzhou District of Zhangye—a typical representative of oasis agriculture in an inland river basin in Northwest China—this study empirically analyzed the effect of farmers' cognition of resources and the environment on agricultural production efficiency. The average agricultural productivity of the surveyed farmers is 0.64, which is much lower than the average level in China. Farmers' cognition of resources and the environment is related to green production willingness and behavior. Green production willingness, green production behavior between cognition of resources and the environment, and agricultural production efficiency play a chain mediating role, showing that farmers' cognition of resources and the environment indirectly affects production efficiency. Green planting willingness is formed based on cognition of resources and the environment; when farmers translate willingness into behavior, it will further improve agricultural production efficiency. Recommendations are made based on the findings, such as strengthening the cognition of resources and the environment, mobilizing enthusiasm for green production, and promoting the practice of green planting.

Keywords: agricultural production efficiency; cognition of resources and the environment; green production; planned behavior theory; structural equation model

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1. Introduction

Oasis agriculture is distributed in arid and semiarid areas with water source irrigation. It can be considered a basis for ensuring the food supply and maintaining social and economic stability in arid areas. However, it continues to face issues related to scale, socioeconomic development, and resource and environmental problems. How to improve agricultural production efficiency and ensure food security under the premise of environmental sustainability has thus become an urgent problem to be solved. According to several studies, objective factors such as planting scale [1–3], agricultural technology [4–7], and human resources [8,9] all have an impact on agricultural output efficiency. However, we must recognize that the majority of China's agricultural production is produced by small-scale farmers who intend to maximize their yield from agricultural production activities. The subjective cognition of these economic subjects, especially the cognition of resources and the environment, will also have an impact on production efficiency.

Farmers are the basic unit of agricultural production and important actors in rural environmental protection. Therefore, farmers' knowledge and understanding of resource issues affect their environmental attitudes and behavior and thereby affect their production efficiency. Investigating the effect of farmers' resource cognition and green production willingness on pro-environmental behavior and improving agricultural production efficiency is thus of great significance for agricultural modernization. It can also provide a relevant sociological and psychological basis for formulating environmental policies and achieving sustainable rural development.

As the main factor affecting farmers' psychological evaluation, the influence of cognition on agricultural production has been investigated by many studies, in areas such as farming decision-making [10], organic agricultural production [11,12], and crop marketing decision-making [13]. Farmers' evaluations of resources and the environment refer to their subjective perceptions of the agricultural production environment, which affect their attention to environmental protection and resource conservation and utilization. Each sense of environment can be said to be constituted by a set of resources organisms can make use of [14]. According to Corris [15], farmers' ecological cognition mostly relies on their understanding, perception, and plan of action, which is mostly altered by several externalities. Such cognition, which derives from their own experience, is highly related to farmers' green practices [16]. The existing studies on farmers' cognition of resources and the environment towards willingness and behavior decisions have been relatively wealthy. Taking water scarcity perception as the basis to evaluate residents' social vulnerability perceptions, Singh et al. [17] investigated the effect of farmers' perception of water scarcity on different adaptive behaviors. Welsch et al. [18] took environmental satisfaction as an important perceptual evaluation and analyzed the relationship between satisfaction and green production behavior. Investigating farmers in different regions of the US, Linda et al. [19] found that positive environmental attitudes can improve farmers' agricultural management practices. Wehmeyer et al. [20] examined agricultural sustainability by assessing changes in farmers' perceptions of the agricultural environment since the adoption of "three controls technology".

It is generally believed that the attitude and intention of economic subjects are based on cognition and further affect their decisions and behaviors [21,22]. From the perspective of resources, Kasargodu [23] and Floress et al. [24] evaluated the effect of farmers' behavioral intentions on actual behavior in agricultural practice; they found that there is a positive relationship between intention and behavior. Yang et al. [25] found that farmers' willingness to adopt green planting affects carbon sink management and the implementation of land protection plans. Chouinard et al. [26] found consistency between US farmers' environmental awareness and their pro-environmental behavior. In that study, most farmers are willing to sell part of their straw for energy utilization, but economic factors are not the only factor; many farmers are willing to give up profits to protect the environment. Fu et al. [27] analyze the consistency between farmers' purchase intention and behavior with regard to bio-pesticides, and find that farmers with an industrial organization are more inclined to convert their willingness into behavior. Other studies, meanwhile, find that individual will and behavior are not always consistent, and sometimes there is a situation of "high willingness but low behavior" [28,29].

Based on previous studies, this study conducted a questionnaire survey of 140 farmer households in the Ganzhou District of Zhangye, China. Based on the theory of planned behavior, irrigation water abundance perception and water environment satisfaction were used to measure farmers' cognition of resources and the environment, and green production willingness and behavior were also put into the analysis framework. Through the structural equation model, this article started from the perspective of farmers, and examined the internal mechanism of the effect of farmers' cognition of resources and the environment on production efficiency. Corresponding policy measures are suggested.

When compared with previous studies, the marginal contribution of this article lies in the following: first, we focused on micro-farmers, concentrated on evaluating production efficiency, and analyzing its influencing factors from the perspective of cognition will undoubtedly have strong pertinence and practical significance; second, we added farmers' productivity into the structural equation model to analyze the effects of cognition on efficiency, consequently filling a gap in existing relevant research; third, within a comprehensive analytical framework, we critically investigated the inner relationships between cognition, willingness, behavior, and agricultural productivity.

2. Theoretical Framework

This study took Ajzen's [30] theory of planned behavior (TPB) as the theoretical basis. According to TPB, human behavior is the result of deliberate planning, and all factors that may affect decision-making are the indirect performance of behavior via behavioral intention [31]. In the TPB framework, behavioral intention is affected by three factors: attitude, subjective norm, and perceived behavioral control. Attitude refers to an individual's psychological evaluation of a particular behavior. Subjective norm refers to the guiding effects of the social environment on individual behavioral intention. Perceived behavioral control refers to an individual's perception of control when performing a particular behavior. TPB has been widely used to study farmers' intentions and behaviors, mainly focusing on pesticide and fertilizer use [32–34], water conservation [35,36], and mixed cropping [37]. Such studies have laid a theoretical foundation for the present study. This study attempted to apply and expand TPB, add agricultural output to the theoretical framework, and analyze how farmers' subjective attitudes and behavioral intentions affect output results through behavior.

Based on TPB, this study proposes a research framework that simplifies the intermediate links (the purple part of the dotted box in Figure 1), analyzes the influence of farmers' cognition of resources and the environment and green production willingness on decision-making, and integrates agricultural output results into the analysis. Specifically, this study took farmers' green production willingness and behavior as an intermediary variable and attributes specific indicators to these variables to investigate the effect of farmers' cognition of resources and the environment on their willingness and behavior. Finally, these subjective factors will have an impact on production efficiency through actual behavior.

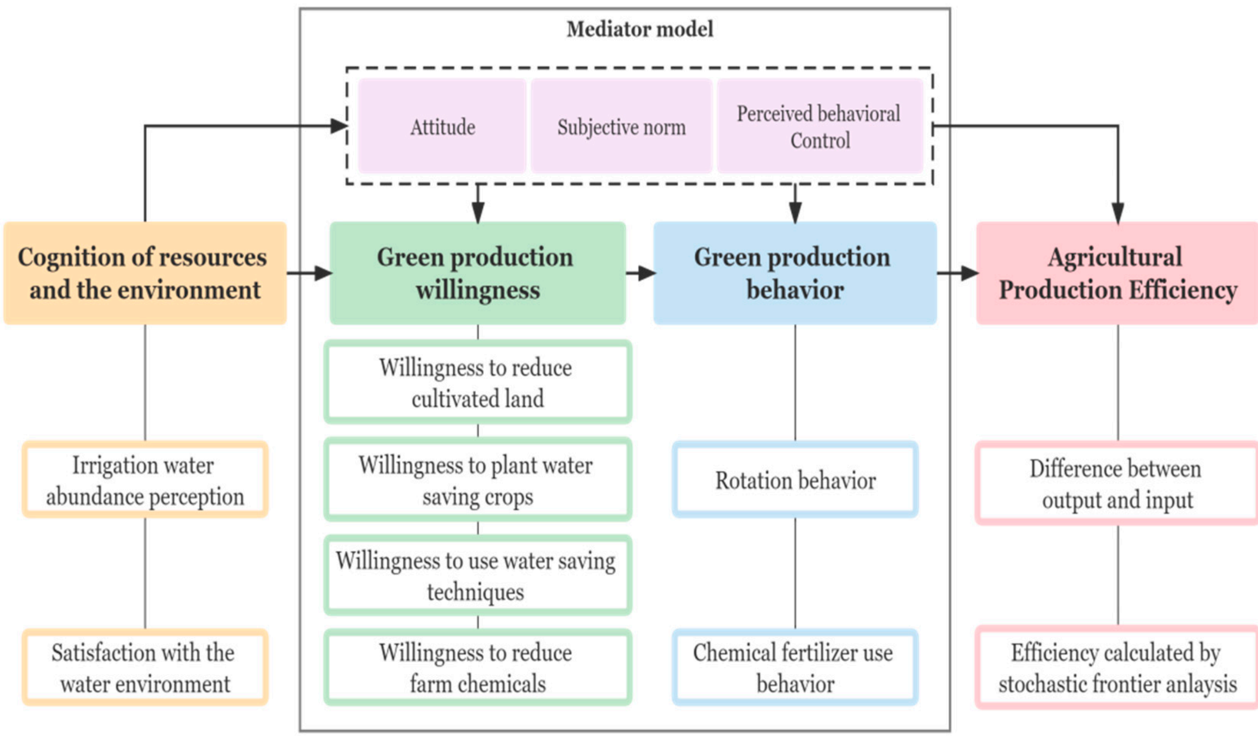

Figure 1. Research framework based on the theory of planned behavior.

Farmers' cognition of resources and the environment with regard to water—which is divided into irrigation water abundance perception and satisfaction with the water environment—can be understood as farmers' subjective evaluations of irrigation water quantity and quality [38]. Generally, when farmers think water is abundant and of high quality, it is more likely to lead to a waste of water resources, which is not conducive to green production [39]. Thus, the following is proposed:

Hypothesis 1. *Cognition of resources and the environment negatively affects green production behavior.*

The emotions or attitudes formed by individuals based on external stimuli can determine specific behaviors [40]. Specifically, the stronger the sense of responsibility, the more positive the attitude toward the environment, and the more likely people are to adopt pro-environmental behaviors. In this study, willingness to reduce cultivated land, willingness to use water-saving crops, willingness to use water-saving techniques, and willingness to reduce farm chemicals were selected as factors to measure farmers' green production willingness. Improving such willingness will enable farmers to choose production modes more in line with social interests [41]. The following is therefore proposed:

Hypothesis 2. *Green production willingness has a positive effect on green production behavior.*

Against the background of agricultural modernization, green production has become the fundamental, long-term way to solve the problem of ecological imbalance in agriculture and improve production efficiency. As for the effect of green production behavior on agricultural output, some studies find that reducing traditional fertilizer application, large-scale production, appropriate rotation, and fallow can improve soil fertility, crop productivity, and agricultural production efficiency [42–44]. Therefore, the following is proposed:

Hypothesis 3. *Green production behavior positively affects agricultural production efficiency.*

Behavioral intention refers to individuals' motivation to adopt a specific behavior. Theoretically, the stronger the willingness of farmers to participate, the more likely they are to take practical actions [23,40]. Behavioral intention in this study is specifically manifested as the pro-environmental will of farmers in production. Therefore, the stronger the pro-environmental will, the more likely it is to be adopted in production to improve land productivity and increase food output through green production behavior. This leads to the following:

Hypothesis 4. *Green production behavior plays an intermediary role between green production willingness and agricultural production efficiency.*

Individuals' perceptions of internal and external factors will affect their choice preferences [45]. Farmers' willingness to protect resources and the environment in production is influenced by external factors such as economics, culture, and policy. Internal factors such as perceptions, motivation, and cognition will transform into concrete participation behaviors, thus influencing output results [46]. It is proposed, therefore, that farmers' cognition of resources and the environment will have direct and indirect effects on production behavior through green production willingness, which will then affect agricultural production efficiency. Hypothesis 5 is thus proposed:

Hypothesis 5. *Green production willingness and behavior play a sequential intermediary role between cognition of resources and the environment and agricultural production efficiency.*

3. Materials and Data

3.1. Study Area and Data Sources

Located in the middle of the Hexi Corridor, the southern edge of the Badain Jaran Desert, and the northern Qilian Mountain, the Ganzhou District of Zhangye is a transition zone between the Qinghai–Tibet Plateau and the Mongolian Plateau. The terrain consists of the Qilian Mountains in the south, the Heli and Longshou Mountains in the north, and the corridor plain in the middle. Between 1400 and 2000 m above sea level, the terrain is high in the north and south and low in the middle, tilting from the southeast to the northwest of the basin, with a unique corridor terrain and desert oasis scene. The corridor oasis basin is the main farming area in the region, with a flat terrain, fertile land, and the Heihe River running through the whole area; irrigation conditions are therefore convenient [47]. It has a typical temperate continental climate. The whole area is 65 km long from east to west and 98 km wide from north to south, with a total area of 3,661 square kilometers, of which 925.2 square kilometers are cultivated.

The Zhangye oasis is the largest in the Hexi Corridor. Ganzhou District, as an example of an oasis agricultural representative, is the agriculture production area in northwest China, with a significant strategic position. For the field investigation, in November 2020, the researchers visited 38 villages in 11 townships to survey local farmers engaged in agriculture. These towns in the irrigation district type and major crops are not the same, with a particular feature. One-on-one interviews were conducted to understand the family's basic situation, crop conditions, cognition of resources and the environment, and green production willingness and behavior. Figure 2 shows the specific survey sites. A total of 174 questionnaires were collected, of which 140 were valid. Table 1 shows the indicators of cognition of resources and the environment, green production willingness, and green production behavior. For the observed variable of fertilizer application behavior, 759.89 kg/ha is the ratio of fertilizer application amount to cultivated land area in China in 2020. This represents the overall situation of fertilizer application in China. Therefore, we took this value as the standard to measure whether farmers carry out green production. The data come from China Statistical Yearbook.

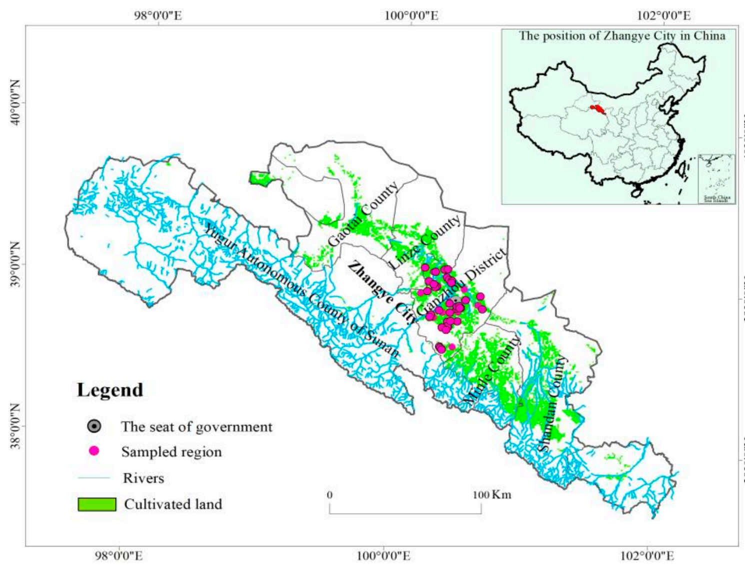

Figure 2. Distribution of study area.

Table 1. Settings and variables of the questionnaire.

Indicator	Observed Variable	Problem Setting	Description	Mean	Standard Deviation
Cognition of resources and the environment	Irrigation water abundance perception	Do you think irrigation water is sufficient in your locality?	Very sufficient = 5, relatively sufficient = 4, moderate = 3, less sufficient = 2, insufficient = 1	3.921	1.190
	Satisfaction with the water environment	Are you satisfied with the surrounding water environment?	Very satisfied = 5, satisfied = 4, moderate = 3, not very satisfied = 2, dissatisfied = 1	4.021	0.841
Green production willingness	Willingness to reduce cultivated land	Are you willing to change livelihoods to reduce cultivated land?	Yes = 1, no = 0	0.479	0.500
	Willingness to plant water-saving crops	Are you willing to plant water-saving crops?	Yes = 1, no = 0	0.800	0.400
	Willingness to use water-saving techniques	Are you willing to use water-saving technology?	Yes = 1, no = 0	0.886	0.318
	Willingness to reduce farm chemicals	Are you willing to reduce farm chemicals?	Yes = 1, no = 0	0.764	0.424
Green production behavior	Rotation behavior	Have you been rotating crops?	Yes = 1, no = 0	0.293	0.455
	Chemical fertilizer use behavior	How many kilograms of fertilizer do you use per hectare in your production?	Less than 759.89 kg/ha = 1, more than 759.89 kg/ha = 0	0.257	0.437

3.2. Statistical Description

According to Table 2, the average age of the sampled farmers is 51.94 years old, with those aged 50–59 accounting for the largest proportion. They are mainly male, accounting for 79.29%. Their education level is mainly junior high school, accounting for 42.86%. In terms of agricultural production, the average input of the agricultural labor force is two people, and 48.57% of the families have someone who has participated in agriculture-related training. Overall, the farmers' characteristics are consistent with the current situation in China's rural areas. The left-behind farmers are older and generally not highly educated.

Table 2. Basic characteristics of the sample.

Variable	Description	Min	Max	Mean	Standard Deviation
Age	In years	19	78	51.936	12.983
Gender	Male = 1, female = 0	0	1	0.793	0.407
Education	Illiterate or barely literate = 1, elementary = 2, junior high = 3, high school or technical secondary school = 4, university or above = 5	1	5	2.557	0.969
Trained	Yes = 1, no = 0	0	1	0.486	0.502
Labor	Number of laborers in the household	1	6	2.014	0.739

4. Methods

4.1. Structural Equation Modeling

In this study, structural equation modeling (SEM) was used for analysis; it is a statistical method integrating factor analysis and path analysis. When compared with traditional econometric methods, SEM can simultaneously analyze the relationships among observed, potential, interference, and error variables [48]. Variables that cannot be directly measured are called potential variables; the indicators used to reflect these potential variables are called observed variables. SEM in this study included (1) a structural model, which reflects the linear relationship between potential variables, and (2) a measurement model, which reflects the linear relationships between potential and observed variables. The regression equation of the model is as follows:

$$x = \lambda_x \xi + \delta \tag{1}$$

$$y = \lambda_y \eta + \varepsilon \tag{2}$$

$$\eta = \beta\eta + \gamma\xi + \zeta \tag{3}$$

Equations (1) and (2) are measurement models, reflecting the relationship between potential variables and observed variables. Equation (3) is a structural model, reflecting the linear relationship between potential variables. Here, x is an exogenous observed variable, ξ is an exogenous potential variable, λ_x is the correlation coefficient matrix of ξ, and δ is the measurement error of x. y is the endogenous observed variable, η is the endogenous potential variable, λ_y is the correlation coefficient matrix of η, and ε is the measurement error of y. Both β and γ are path coefficients, and ζ is the error term of the structural equation.

4.2. Stochastic Frontier Analysis

Agricultural production efficiency is measured using stochastic frontier analysis (SFA) [49]. SFA divides the output into production function, random factor, and technical inefficiency. Its advantages are that it can overcome the influence of some random factors on efficiency loss, it has better stability, and it is more suitable for the calculation of micro-data. SFA can be expressed as:

$$Y_i = f(X_i\,,\ \beta)\ \exp\ (v_i - u_i) \tag{4}$$

Y_i is the output of the ith decision-making unit (DMU), X_i is the input of ith DMU, $f\ (\cdot)$ is the production function, β is the parameter to be estimated, and v_i is the random disturbance term. It is generally assumed to be $v_i \sim N\ (0,\ \sigma_v^2)$; μ_i represents the error caused by technical inefficiency, and v_i and u_i are independent of each other. In this study, SFA based on the Cobb–Douglas production function was used to measure farmers' agricultural production efficiency. The general form of the production function is:

$$\ln Y_i = \ln f(X_i\,,\ \beta) + v_i - u_i \tag{5}$$

Maximum likelihood estimation was used to estimate the parameter β and the error term $v_i - u_i$. Efficiency can then be obtained:

$$TE_i = \frac{Y_i}{\exp(X_i, \beta)} = \exp(-u_i) \tag{6}$$

When u_i = 0, there is no efficiency loss, and TE = 1. When u_i > 0, the production unit is in a state of technical inefficiency, and 0 < TE < l. Battese and Coelli [50] proposed the technical inefficiency model as an extension model for inefficiency effects in stochastic frontiers. The inefficiency term u_i is defined as:

$$u_i = M_i\delta + \omega_i \tag{7}$$

where M_i is an exogenous variable affecting technical inefficiency, δ is the parameter to be estimated, and ω_i is the random disturbance term. It is generally assumed to be $\omega_i \sim N\ (0, \sigma^2)$.

5. Empirical Analysis and Results

5.1. Analysis of Agricultural Production Efficiency

Before studying the direct and indirect effects of farmers' cognition of resources and the environment, green production willingness, and green production behavior on production efficiency, agricultural production efficiency was first calculated according to the input–output situation. Output is represented by farmers' gross agricultural income, only planting income is included in this statistic, and it has subtracted the cost of pesticides, fertilizers, machinery and so on. The inputs include land, capital investment, and labor. Land is the amount of cultivated land; capital investment includes seed purchases, fertilizer purchases, pesticide purchases, plastic sheeting purchases, irrigation water fees, mechanical and hired workers costs; labor input is the family farming population. Table 3 describes these variables.

Table 3. Descriptive statistics of input–output variables.

Input-Output Variable		Unit	Mean	Standard Deviation	Max	Min
Output	Gross agricultural income	10,000 yuan	1.944	2.156	18	0.04
Input	Land	Ha	0.850	1.308	10	0.067
	Capital investment	10,000 yuan	1.245	1.401	8.085	0.072
	Labor	Number of people	2.014	0.737	6	1

First, in the likelihood method, the variance parameter $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ was used as the judgment function for whether to apply the SFA model. γ shows the percentage of inefficient items in the random perturbation. When γ approaches zero, it implies that the discrepancy between the actual and ideal outputs is mostly due to uncontrollable random perturbation factors and that the model setup is incorrect. On the contrary, the SFA model produced the best estimation results. As shown in the top half of Table 4, the estimated value is 0.886, which passes the significance test at the 1% level, so it was possible to implement this function. Second, the estimation results show that the log likelihood function is very large, much higher than the critical value of the 1% level, indicating that the model is stable overall. Third, excluding labor, each coefficient has passed the significance test, so it can be seen that the SFA model setting is reasonable. The land has a negative effect on agricultural income, indicating that small-scale land is easier to manage in household production, they take greater care of crops. This is consistent with the study of Smith et al. [51]. Higher capital investment can result in more productivity, and lead to more agricultural income.

According to Equation (7), we considered cognition of resources and the environment, which was measured by irrigation water abundance perception and satisfaction with the water environment. The estimated results are shown in the bottom half of Table 4. It is worthy to note that the direction of the regression coefficient in the technical inefficiency is different from the general case. The positive sign implies that increasing the value of this variable will lower technical efficiency, whereas the negative sign suggests that increasing the value of this variable will increase technical efficiency. Both water abundance perception and satisfaction with the water environment have a negative impact on technical inefficiency, as can be shown in Table 4. In other words, farmers' cognition of resources and the environment has a positive impact on agricultural production efficiency. The affected path will be further analyzed in the following study.

When measuring agricultural production efficiency, this study first calculated the difference between farmers' gross agricultural income and capital investment, which is considered the absolute index for measuring agricultural production efficiency. The value is concentrated between 0 and 5, with an average of 2.31. Efficiency was calculated using SFA. The results show that the average agricultural production efficiency of the farmers is 0.64; this is lower than the average level in China (0.791) [52]. It can be seen from the division of agricultural production efficiency, with 0.1 as the interval, that the efficiency distribution of the surveyed households is relatively concentrated, mainly between 0.6 and 0.8; 4.28% of households have a production efficiency lower than 0.3, and no households have an efficiency value above 0.9. Figure 3 shows the results for agricultural production efficiency.

Table 4. Estimation of stochastic frontier model and technical inefficiency model.

	Estimate	Standard Deviation	T Statistic
Constant	1.006	0.130	7.76 ***
Land	−0.025	0.101	−2.46 **
Capital investment	0.927	0.106	8.77 ***
Labor	−0.208	0.162	−1.28
σ^2	0.244	0.143	1.71 *
γ	0.886	0.085	10.43 ***
Log likelihood function		−151.768	
Technical inefficiency model			
Constant	0.443	0.060	7.40 ***
Irrigation water abundance perception	−0.022	0.013	−1.76 *
Satisfaction with the water environment	−0.035	0.018	−1.95 *

Note: *, **, and *** indicate significance levels of 10, 5, and 1%, respectively.

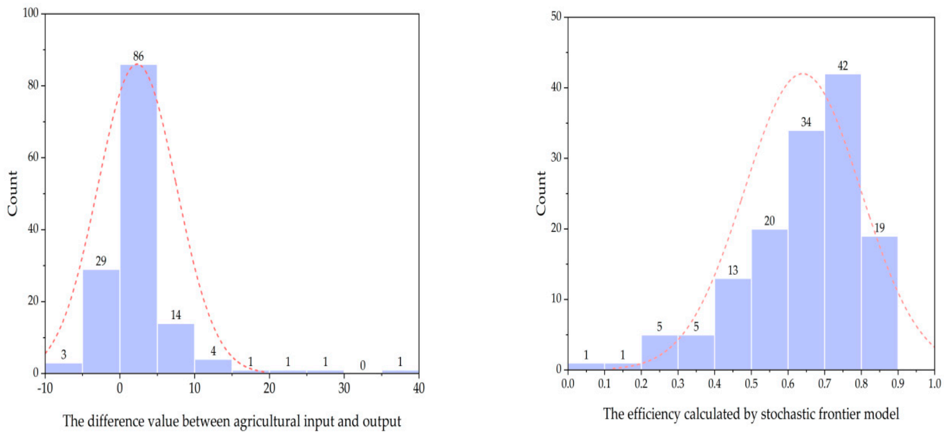

Figure 3. Distribution of agricultural production efficiency.

5.2. Validity and Reliability Tests

This study used SEM to analyze the variables. To ensure reliability, SPSS 25.0 was used to conduct reliability analysis on the four main dimensions (i.e., cognition of resources and the environment, green production willingness, green production behavior, agricultural production efficiency), 10 observed variables, and the overall scale of the questionnaire; Table 5 shows the results. The Cronbach's α of the standardized questionnaire items is 0.737 and that of each dimension is above 0.5. Thus, based on the standard Cronbach's α criteria ($\geq$0.8: excellent reliability; $\geq$0.7: good reliability; >0.5: acceptable reliability) [53], the reliability of the questionnaire and variables is good.

To measure whether the overall internal structure of the questionnaire is reasonable, Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests were further applied to cognition of resources and the environment, green production willingness, green production behavior, and agricultural production efficiency. The results show that the overall KMO of the questionnaire is 0.722, and χ^2 in Bartlett's sphericity test is 302.518. The KMO of the four dimensions ranges from 0.5 to 0.739, all being greater than or equal to 0.5. Bartlett's sphericity test is significant (*Sig.* < 0.001), indicating that the questionnaire has good structural validity and is suitable for factor analysis.

Table 5. Questionnaire reliability analysis results.

Dimension	Observed Variables	Abbreviaton	KMO	Bartlett's Test	Cronbach's α of Standardized Items
Cognition of resources and the environment (CRE)	Irrigation water abundance perception	CRE1	0.500	59.960 (*Sig.* = 0.000)	0.746
	Satisfaction with the water environment	CRE2			
Green production willingness (GPW)	Willingness to reduce cultivated land	GPW1	0.739	89.833 (*Sig.* = 0.000)	0.700
	Willingness to plant water-saving crops	GPW2			
	Willingness to use water-saving techniques	GPW3			
	Willingness to reduce chemical use	GPW4			
Green production behavior (GPB)	Rotation behavior	GPB1	0.500	43.191 (*Sig.* = 0.000)	0.684
	Chemical fertilizer use behavior	GPB2			
Agricultural production efficiency (APE)	Difference between output and input	APE1	0.500	27.006 (*Sig.* = 0.000)	0.594
	Efficiency calculated by SFA	APE2			

5.3. Test of Overall Degree of Fitness

AMOS 24.0 was used to fit the SEM; Table 6 shows the results. The absolute fitting index includes the Chi-squared value of the model (χ^2), Chi-squared degree of freedom ratio (χ^2/DF), goodness-of-fit index (GFI), and adjusted goodness-of-fit index (AGFI). The relative goodness-of-fit index includes the normative fit index (NFI), incremental fit index (IFI), Tucker Lewis index (TLI), and comparative fit index (CFI).

Table 6. Test results for the degree of model fitness.

Evaluation Index		Estimate	Evaluation Standard	Result
Absolute fit index	χ^2	87.870	As small as possible	Accept
	X^2/DF	1.331	<5	Accept
	GFI	0.927	>0.90	Accept
	AGFI	0.867	>0.90	Generally acceptable
Relative fit index	*NFI*	0.819	>0.90	Generally acceptable
	IFI	0.948	>0.90	Accept
	TLI	0.908	>0.90	Accept
	CFI	0.942	>0.90	Accept

5.4. Inter-Correlations among Variables

Figure 4 shows a heat map of the correlations among variables measuring cognition, willingness, behavior, and efficiency. The darker the color, the higher the absolute value of the correlation coefficient between variables. Based on the theoretical model, the relationship between the observed variables was analyzed based on the correlation heat map. First, regarding the effect of farmers' cognition of resources and the environment on green production willingness and behavior, the correlation coefficients of all variables are basically positive. This is consistent with the assumed estimate. In other words, the more abundant the water resources in the locality, the more satisfied farmers are with the water environment, which is conducive to local green production in terms of both willingness and practical behavior. The reason for this result could be that the abundance of irrigation water shapes farmers' perceptions of the amount of irrigation water. The larger the value, the greater the amount of irrigation water, and the worse the water resource waste behavior.

Therefore, farmers' desire to save water is stronger. In addition, abundant irrigation water is conducive to food production. With good output results, farmers are more likely to reduce agricultural non-point source pollution and implement green production in actual production processes. Similarly, from the psychological perspective, the better the surrounding water environment, the more motivated farmers are to protect their environment, improve resource utilization, and improve agricultural production efficiency.

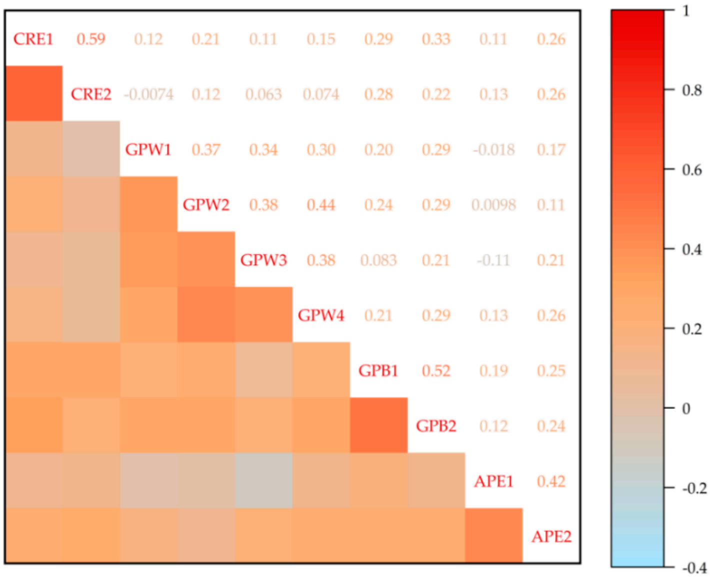

Figure 4. Heat map of the correlation coefficient matrix.

In influencing green production willingness in the four observed variables, farmers reduce cultivated land willingness, which reflects their tendency toward scale planting. When compared to small-scale productions organized by families, cooperatives can pool resources effectively. The technical level of large-scale mechanized cultivation will be improved [54], which supports conservation practices such as rotation, green planting, and pesticide fertilizer reduction [55]. The crops planted in the Zhangye region are mainly corn [56]. Thus, the promotion of water-saving crops and technologies in the region can not only adapt to water shortages in arid areas but also diversify crops. The improvement of this willingness is consistent with the implementation results of green production behavior. Farmers' willingness to reduce pesticide and chemical fertilizer also has a significant effect on their crop rotation behavior and pesticide and chemical fertilizer application behavior. For farmers, the increase of this willingness will accelerate green production.

It can also be seen in Figure 4 that two measurement variables of farmers' green production behavior—rotation behavior and chemical fertilizer use behavior—have a positive effect on production efficiency. Rotation is a kind of conservation tillage that can reduce soil erosion, balance the use of soil nutrients, improve soil fertility, and improve crop productivity [57]. Similarly, reducing the use of fertilizers and pesticides in the production process can improve long-term soil fertility and land production efficiency.

5.5. SEM Parameter Estimation

Based on the survey data, SEM was estimated, and the standardized path coefficients of the hypotheses and the estimation results of each parameter were obtained, as shown in Table 7. Figure 5 presents the specific standardized path coefficients.

Table 7. Estimation results for the standardized path coefficients.

Variable Relationship	Estimate	SE	CR
GPW ← CRE	0.250 **	0.059	2.281
GPB ← GPW	0.449 ***	0.169	3.367
GPB ← CRE	0.295 ***	0.072	2.819
APE ← GPB	0.354 ***	1.374	2.690
APE ← Age	0.081	0.033	0.678
APE ← Gender	−0.328 ***	1.017	−2.861
APE ← Education	0.027	0.480	0.206
APE ← Trained	0.225 **	0.771	2.097
APE ← Labor	−0.200 *	0.520	−1.875

Note: *, **, and *** indicate significance levels of 10, 5, and 1%, respectively.

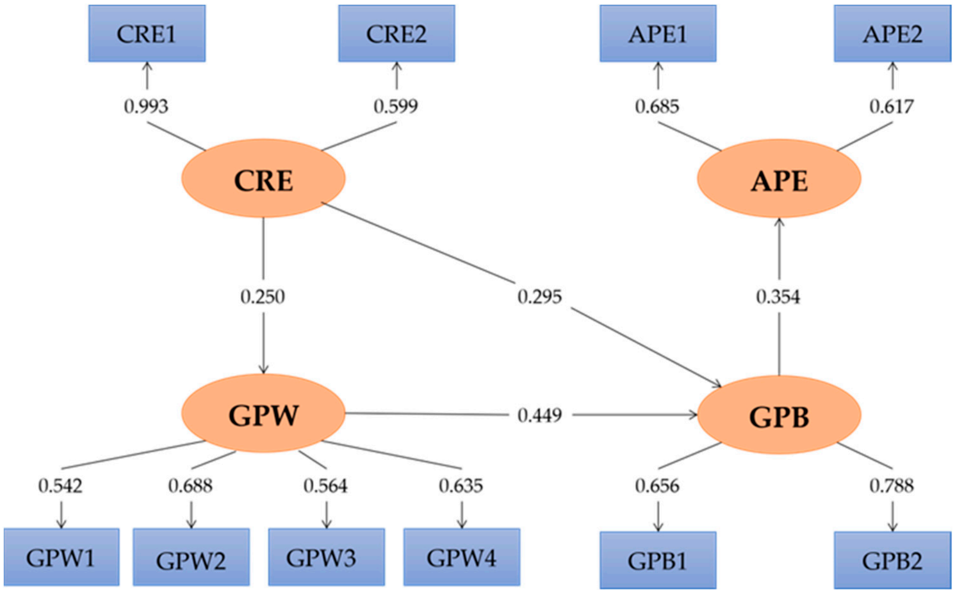

Figure 5. Structural equation model with standardized path coefficients.

According to the standardized parameter estimation results, cognition of resources and the environment positively affects green production willingness and behavior; the standardized path coefficients are 0.25 and 0.295. It can be seen that cognition of resources and the environment has a positive effect on green production behavior. This direction is different from that of Hypothesis 1. This is perhaps because when farmers have higher confidence in local resources and the environment, in order to maintain the environmental conditions, they have stronger psychological motivation to protect the region's resources and environment. Farmers are therefore more inclined to adopt green production behaviors in terms of improving resource utilization and reducing pollution. Green production willingness has a significant effect on green production behavior, and the standardized path coefficient is 0.449, which is consistent with Hypothesis 2. This indicates that farmers will transform their willingness into actual behavior in production processes. The stronger the farmers' green production willingness, the more likely they translate this willingness into behavior. Green production behavior in farming output and efficiency also has a positive effect, and the standardized path coefficient is 0.354, supporting Hypothesis 3. By adopting green production behavior, farmers improve land productivity and agricultural production efficiency.

Regarding other control variables, gender affects agricultural production efficiency. Women are likely to play a larger role in improving agricultural production efficiency. This could be because women typically perform less physical labor on farms than men; thus, they might be more likely to support using technology to improve productivity. Improved agricultural training can also improve productivity. Farmers can learn more planting techniques through technical training, thus avoiding "detours" in production processes and further improving their technical efficiency. There is a negative relationship between the amount of labor input and agricultural production efficiency. This is probably because for smaller farms with more laborers, there is usually a reduced use of machinery and equipment. Thus, human cultivation falls behind existing mechanical means, and production efficiency is not high.

5.6. Mediating Effect Analysis

To further explore the effect of farmers' cognition of resources and the environment and green production willingness on production behavior and output results, this study estimated the direct and indirect effects between cognition of resources and the environment and green production willingness on green production behavior and agricultural production efficiency. Table 8 shows the results.

Table 8. Standardized direct and indirect effects.

	CRE		GPW	
	Direct Effect	**Indirect Effect**	**Direct Effect**	**Indirect Effect**
GPW	0.253	-	-	-
GPW1	-	0.137	0.542	-
GPW2	-	0.174	0.686	-
GPW3	-	0.143	0.565	-
GPW4	-	0.161	0.636	-
GPB	0.299	0.113	0.445	-
GPB1	-	0.269	-	0.291
GPB2	-	0.327	-	0.353
APE	0.053	0.138	0.025	0.142
APE1	-	0.128	-	0.112
APE2	-	0.121	-	0.106

Farmers' cognition of resources and the environment has a direct effect on agricultural production willingness, production behavior, and production efficiency. The improvement of green production willingness directly affects the implementation of farmers' green production behavior and the improvement of agricultural production efficiency. However, the estimated direct effects about cognition of resources and the environment and green production willingness on production efficiency are very small—respectively, 0.053 and 0.025—while the estimated indirect effects are improved. Thus, the influence relationships among cognition of resources and the environment, green production willingness, and production behavior are multiple and complex, and there may be a chain mediating model. The bootstrap method is therefore used to test the mediation effects.

Bootstrapping simulates the process of randomly sampling a large number of samples from the population [58]. This study used the bootstrap method with the deviation correction percentile to analyze chained multiple mediating effects. First, repeated random sampling was used to extract 2000 samples from the original data. The model was fitted from these samples with a 95% confidence level to generate estimates of mediating effects. Based on this model, the mediating effect relationships and estimated values were obtained, as shown in Table 9.

Table 9. Standardized bootstrap mediating effect test.

Path	Estimate	SE	Lower	Upper
R_1: GPW → GPB → APE	0.142 *	0.135	0.000	0.659
R_2: CRE → GPW → GPB	0.113 ***	0.053	0.039	0.282
R_3: CRE → GPB → APE	0.095 **	0.115	0.004	0.483
R_4: CRE → GPW → GPB → APE	0.036 **	0.035	0.005	0.475

Note: *, **, and *** indicate significance levels of 10, 5, and 1%, respectively.

Green production willingness can have a significant positive effect on production efficiency through the intermediary variable of green production behavior, as shown in path R1. This supports Hypothesis 4. Cognition of resources and the environment has direct and indirect effects on other indices. Path R2 indicates that farmers' cognition of resources and the environment can affect their production behaviors by improving their green production willingness. Path R3 is also significant, indicating that cognition of resources and the environment can also directly affect green production behavior and have an effect on agricultural production efficiency. Based on these results, we can see that farmers' cognition of local resources will enhance their green production willingness. When farmers turn that willingness into behavior, agricultural production efficiency will be further improved. Hypothesis 5 is thus verified. Therefore, green production willingness and behavior play a sequential intermediary role between cognition of resources and the environment and agricultural production efficiency.

6. Discussion

This study crafted its findings based on micro-survey data from 140 farmers in Zhangye City, and used SFA to measure farmers' agricultural production efficiency. According to the calculation results, the average production efficiency of farmers in the survey area is 0.64, which is lower than the average level in China, and there is room to improve efficiency by 36%. This result may be related to the ecological environment in the Northwest of China. Its natural conditions are relatively dry when compared to the rest of the regions of China. It is difficult to improve the agricultural income for small-scale farmers due to the fragmentation of land. Furthermore, with the outflow of populations, the agricultural labor force in the northwest region is continuously decreasing and demonstrating an aging trend. On the other hand, with the growth of nonagricultural employment, the young people left behind in rural areas are not only engaged in agricultural activities, all of which contribute to low agricultural production efficiency.

According to the agricultural production efficiency calculated by SFA, regression analysis was conducted by using structural equation modeling to explore the influence of cognition of resources and the environment on the production efficiency. The study first put agricultural production into the TPB framework, and analyzed the effect of farmers' subjective cognition on efficiency. The finding also highlights the mediating effect of green production willingness and behavior, and it demonstrates that cognition of resources and the environment can affect willingness and behavior. These findings of this study are consistent with Zhang et al. [59], Guo et al. [60], Jiang et al. [61], and Rezaei et al. [62], who also found that farmers' cognition is an essential factor in farmers' willingness and behavior. These findings are also consistent with the theory of planned behavior, which suggests that attitudes and subjective norms influence individuals' perceived behavioral control, which influences cognition and rectifies their decision-making behavior.

We can see from the empirical analysis that cognition of resources and the environment is conducive to the promotion of green production willingness and further encourages the adoption of green production behavior. Taking water resources as an example, the study's cognition of resources and the environment refers to farmers' subjective evaluation of the quantity and quality of water resources. We can see that farmers tend to adopt green production when their evaluation of irrigation water environments improves. This is different from previous studies [63,64]. This situation might be attributed to the nation's concentration on sustainable agriculture, the growing popularization of publicity and education in rural regions, and the increasing popularization of farmers' ecological beliefs. On the premise of maintaining their revenue, farmers are motivated to minimize the use of pesticides and fertilizers to retain their revenue, as well as to prevent environmental destruction. Promoting the green development of agriculture is the realization of agricultural modernization in the future, taking the green production behavior of smallholders, as well as to improve the efficiency of agricultural production [65]. It is an inevitable choice to consolidate the foundation of the modern agricultural management system and promote the modernization of China's agriculture.

Besides these results, this study varies from previous studies in another aspect. Our study showed that females are likely to play a larger role in improving agricultural production efficiency. This is not consistent with the previous investigations [66,67]. The main reason for this difference is that with the increasing labor exodus in rural areas, the labor force has shifted mainly from male to female, thus leading to a gradual unimportance of the gender factor. Furthermore, males applied greater quantities of chemical fertilizer as compared to their female counterparts [68]; less use of pesticides and fertilizers will increase production, which is consistent with the findings.

The limitations of this article are that all the variables were assessed using cross-sectional data; the long-term effects of cognition, willingness and behavior on agricultural productivity can be further tracked. At the same time, the sample size in this study is limited, if national-level data can be obtained, the study will be much richer.

7. Conclusions and Suggestions

Based on survey data from villages in Zhangye, this study used SFA to measure farmers' agricultural production efficiency. SEM was then used to analyze the effect of cognition of resources and the environment and green production willingness on agricultural production efficiency. The main conclusions are as follows. The average agricultural production efficiency of the surveyed farmers is 0.64; this indicates a lot of room for improvement when compared with the average level in China. Farmers' cognition of resources and the environment and green production willingness directly affect green production behavior; the standardized path coefficients are 0.295 and 0.449, respectively. Green production intention has a stronger effect. Green production behavior directly improves farmers' production efficiency; the standardized path coefficient is 0.354. Green production behavior plays an intermediary role between green production intention and agricultural production efficiency. When farmers convert their pro-environmental intentions into behavior in production, they improve planting efficiency by strengthening environmental protection and improving resource utilization. In addition, green production willingness and green production behavior play a chain mediating role between cognition of resources and the environment and agricultural production efficiency. Thus, farmers' cognition of resources and the environment can indirectly affect production efficiency, and green planting willingness is formed based on cognition of resources and the environment. When farmers positively perceive environmental conditions, it will improve their green production willingness. When this willingness is turned into behavior, agricultural production efficiency is further improved. Based on these results, the following suggestions are made to improve agricultural productivity.

1. Highlight the benefit of ecological agriculture, and improve farmers' cognition of resources and the environment. Through publicity and education, farmers can be made to realize the important role of the water environment in production and life. A "community of humans and nature" is established in which villagers take the initiative to participate in the governance and protection of the rural environment.
2. Strengthen the role of green production and mobilize farmers' enthusiasm. Practice green development, strengthen subsidies for green planting, encourage farmers to adopt green planting technologies. According to the characteristics of farmers, provide more flexible classification guidance methods such as "home guidance" and "field teaching" to help farmers understand the importance of green production and increase their willingness to adopt it.
3. Practice green production to improve the yield and quality of agriculture. Under the rigid constraints of grain demand, we should integrate arable land, labor, and other resources; reduce the input of pesticides and fertilizers; develop high-efficiency water-saving agriculture; enable farmers to integrate green production into practical action, thereby achieving modernized production and increasing farmers' incomes.

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