Effect of aging agricultural labor force on banana production efficiency in Hainan province

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Abstract. This paper utilizes the Data Envelopment Analysis (DEA) model to calculate the banana production efficiency of sample farmers in Hainan's major banana-producing counties and cities, analyzing the distribution and variation patterns of banana production technical efficiency in conjunction with the characteristics of banana farmers' families and production processes. Through regression analysis, it further explores the relationship between agricultural labor force aging and banana production technology scale efficiency, deriving deeper insights into the factors influencing banana farmers' production technical efficiency. The study reveals that the sample area faces severe population aging, with a 45.3% decline in banana planting area and a 34.5% reduction in output between 2010 and 2020. The average age of banana production decision-makers is 53.43 years, with 74.14% being over 45 years old. Notably, the banana production efficiency of sample farmers was relatively low in 2021, averaging at 0.24. Moreover, the age of decision-makers and the degree of family aging have a significantly negative impact on banana production technical efficiency. In response to these findings, the paper proposes policy recommendations, including improving the rural old-age security system, enhancing banana production mechanization, allocating production factors reasonably, and intensifying the promotion of banana production technologies, to address the impact of agricultural labor force aging on banana production efficiency in Hainan.

Keywords: Aging of Labor Force; Production Efficiency; DEA-Tobit; Bananas.

1 Introduction

1.1 Background of the Study

In the early 20th century, the Frenchman Landry proposed that with the development of the economy and society, population aging seemed to be an inevitable process for a society or region, and scholars from various countries have reached a consensus on this. Since 1978, China has achieved remarkable economic success and rapid social development. From this perspective, the advent of aging is a normal phenomenon. However, the intensification of aging in rural areas is bound to reduce the supply of agricultural labor, thereby affecting agricultural production efficiency, subsequently

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lowering agricultural output value and influencing economic development[1]. As a major agricultural province, Hainan has bananas as one of its main tropical fruits, and the banana industry is a pillar agricultural industry of its economy. According to the "Hainan Statistical Yearbook 2021", the banana output of Hainan Province in 2020 was 1.129 million tons, and the planting area was 31,916 hectares. As a high value-added cash crop, it has led thousands of banana farmers to prosperity. In 2020, the average age of banana production decision-makers in the main banana-producing areas of Hainan was 53.47 years old, with up to 74.17% of the population being over 45 years old and 32.53% being over 60 years old. In the next 15 years, the population over 45 years old will enter the aging ranks intensively, and 78.09% of banana farmers' families have laborers over 60 years old (National Banana Industry Technology System, 2021), and the aging problem is relatively prominent. The banana industry, as a labor-intensive industry, requires more labor input compared to field-intensive industries such as wheat and corn. With the intensification of population aging in the main banana-producing areas of Hainan, it is inevitable that the supply of agricultural labor will decrease [2], which will have an impact on the sustainable development of Hainan's banana industry. Therefore, in the current context of agricultural aging, it is of significant practical importance to study the impact of the aging of agricultural labor on the production efficiency of bananas in Hainan and put forward targeted countermeasures and suggestions.

1.2 Research Purposes and Implications

Research Objectives.

Hainan is one of the five major banana-producing provinces in China and also a superior production region for bananas in the country. According to the data from "Statistics of Tropical Crop Production in Hainan Province 2020", the banana planting area in the entire province in 2020 was 478,700 mu (approximately 31,913.33 hectares), with a production value of 2.653 billion yuan, ranking fourth among the planting industries in the province and serving as a pillar industry of tropical agriculture in Hainan. In 2021, the labor cost in Hainan's banana production accounted for approximately 31.96% of the total cost (National Banana Industry Technology System, 2021). In the banana industry where labor costs hold a relatively high proportion, the aging of the agricultural labor force may exert certain influences on the banana industry and thereby impact the development of agriculture in Hainan. This article endeavors to quantitatively delineate the impact of the aging of the agricultural labor force on the production efficiency of bananas in Hainan. Taking banana growers in the main banana-producing areas of Hainan as the research subjects, it constructs relevant econometric models to measure and study the production efficiency of sample households in the main banana-producing areas of Hainan. Moreover, it employs the Tobit regression model to clarify the influence of the aging of the agricultural labor force on the technical efficiency of banana production in Hainan. On this basis, it proposes optimization plans for banana production inputs. Finally, it offers proactive policy recommendations to address the impact of aging on banana production.

Research Significance.

Theoretical Significance.

By perusing relevant literature, it is observed that studies on the influence of aging on agricultural production efficiency are abundant. However, most of these studies focus on grain crops such as wheat and corn. Research on economic and labor-intensive crops is relatively scarce. In the case of bananas in Hainan, although there have been some investigations into production efficiency, as of now, there is no study on the effect of the aging of the agricultural labor force on the production efficiency of bananas in Hainan. This research can offer certain theoretical supplementation for the development of labor-intensive agricultural industries.

Practical Significance.

Hainan, as a major banana-producing region, features extensive planting areas and a long cultivation history. Studying the production efficiency of bananas in Hainan might uncover an effective approach to further enhance banana production efficiency within the existing constraints of resources and the environment for banana production in Hainan, and provide references and models for other similar industries.

1.3 Literature Review and Evaluation

The academic circle has always placed great emphasis on the research of agricultural production efficiency. The academic field has also touched upon the research of banana production efficiency, but the research on the impact of aging on the production efficiency of bananas in Hainan remains blank to date.

After perusing the relevant literature, current scholars have three conclusions regarding the influence of agricultural aging on agricultural production efficiency. The first viewpoint holds that there is a negative impact. In light of the escalating situation of agricultural aging in China, Xu Na and Zhang Liqin conducted a study using the data from the fixed observation points in rural China in 2009 and discovered a negative impact[3]. Liu Jian et al. (2019), when studying the tea production situation in southwestern China, also found a negative impact[4]. “Ngadi N et al. (2023), Wang Wei and Wang Jiamei (2019)” respectively carried out research based on rural survey data in Gansu Province and Heilongjiang Province and arrived at the same conclusion[5-6]. The second viewpoint argues for a facilitating role. China is a major grain-consuming country. Given the reality of the continuous increase in the aging trend in China, there is an urgent need to clarify the impact of aging on wheat production. Gao Sheng and Deng Feng (2019) evaluated the production efficiency of wheat in the major wheat-producing provinces of China and found a positive impact[7]. Han Lingmei et al. (2021) also discovered the same conclusion when studying the production of flue-cured tobacco[8]. Zou Yonglin et al. (2022) even perceived that aging has certain positive advantages[9]. The third viewpoint holds that there is an adverse impact. “Brauw et al. (2012), Wen Saisai et al. (2024), Peng Weizhuojia (2021)” and others opine that aging has no adverse impact on production efficiency[10-12].

The influence of agricultural aging on the input of production factors presents three scenarios: positive, negative, and irregular. The impact on agricultural output mainly consists of negative and no negative impact situations. Regarding the influence on agricultural production efficiency, there are positive, negative, and no negative impact situations. Reviewing the above literature, scholars have conducted numerous studies on aging. However, no unified understanding has been reached on the influence of aging on agricultural production efficiency. Therefore, this paper conducts research based on the above scholars as a supplement to the above research conclusions.

2 The Measurement and Comparative Analysis of the Production Technical Efficiency of Banana Growers in Hainan Province

2.1 Questionnaire Design

The main purpose of this questionnaire survey is to investigate the characteristics of banana production, family characteristics, and input-output situation in the main banana-producing areas of Hainan Province.

This questionnaire is altogether divided into three parts. The first part pertains to the basic information of the farmers, mainly encompassing the basic characteristics of the banana growers and their families, such as the age of the banana cultivation decision-makers, gender, total number of family members, number of family laborers, number of family members over 60 years old, total number of agricultural laborers, and the number of those over 60 years old. The second part relates to the basic situation of banana cultivation, mainly including the cultivated varieties, banana cultivation area, number of banana cultivation plots, planting density, main land type, degree of mechanization, etc. The third part concerns the cost and revenue of banana cultivation, mainly including costs such as seedlings, pre-planting preparations, land, labor, chemical fertilizers, organic fertilizers, pesticides, irrigation, etc., as well as yield, selling price, etc. Among them, the labor cost is the sum of self-employed labor and hired labor. If the farmer has hired labor, the price of self-employed labor is calculated based on the average price of hired labor. If there is no hired labor in the family, then the self-employed labor is calculated based on the average price of hired labor in the local area. The total land area is the sum of owned land and rented land. If the family has rented land, the owned land is calculated based on the rental price. If there is no rented land in the family, then it is calculated based on the average rental price of the local area. The yield is calculated by multiplying the number of bananas per plant (in pounds/plant) by the planting density (in plants/acre), and the selling price is based on the actual average selling price of the farmers.

To ensure the reliability of the questionnaire, a pre-research was conducted in Chengmai County in advance. By consulting relevant literature and combining the results of the pre-research, the questionnaire was repeatedly revised. Daily summaries were made during the research period. If any issues with the questionnaire were identified, immediate revisions were carried out. To ensure the accuracy of the data, one-on-one interviews were conducted with each banana producer and the questionnaire was filled out. Visits and interviews were conducted in banana cultivation bases and fields. Inquiries were made to large-scale growers, skilled growers, and small-scale farmers regarding the entire process of banana production, input-output, precautions, and cultivation experience, to gain an in-depth understanding of the banana cultivation and production situation in Hainan.

2.2 Data Sources

The data in this paper were obtained by the economic post members of the National Banana Industrial Technology System during two surveys conducted in June and September 2021 in the main banana-producing cities and counties of Hainan Province, namely Chengmai, Changjiang, Ledong, Haikou, Lingao, Dongfang, and Danzhou. The survey locations were selected randomly within the main banana-producing villages at the county and city levels. The survey method adopted was one-on-one household interviews, and the survey subjects were all family banana production decision-makers. A total of 490 questionnaires were collected in the two surveys, among which 461 were valid and 29 were invalid, with a validity rate of 94%.

2.3 Model and Index Selection

Model Selection.

Regarding the measurement of agricultural production efficiency, the main methods utilized in the academic circle include stochastic frontier analysis, grey relational analysis, analytic hierarchy process, total factor productivity analysis, and data envelopment analysis[13], etc.

Through comparison, data envelopment analysis possesses the following characteristics: The DEA method is highly suitable for handling the data in this paper. It is simple and effective, and this method rarely incorporates the subjective will of the researcher. It employs linear programming to determine the relative magnitude of the efficiency value; there is no need to construct a production function; nor is there a need to handle the dimension. It can not only compare the production efficiency of all decision-making units and determine whether a decision-making unit is efficient, inefficient, or weakly efficient but also obtain the improvement direction and the magnitude of improvement required for DEA effectiveness [14].

Model Introduction.

Data Envelopment Analysis (DEA) is a common mathematical analysis method for relative efficiency evaluation. It was first proposed by Charnes, Cooper, and Rhodes in 1978. The first model was named the CCR model. This model is highly suitable for "systems" with multiple inputs and outputs and is extremely effective in the evaluation of "scale and technical efficiency" [15]. Since the introduction of the first DEA model, with the continuous efforts of scholars from various countries, the DEA method has flourished. New models have been continuously proposed, and its application scope spreads across multiple fields such as economics and management, with fruitful application achievements [15]. Among them, the most commonly applied models are the CCR and BCC models. The CCR and BCC models were proposed based on the assumptions of constant and variable returns to scale, respectively. Based on the data and actual situation of this paper, this paper decides to employ the BCC model with variable returns to scale.

If there are n decision-making units (DMUs), each having m input indicators and s outputs. Among them, for any DMUj, the i-th input and the r-th output can be expressed as: x_{ij} and y_{rj} , $i = 1,2,\ldots,m.$, $r = 1,2,\ldots S.$, $j = 1,2,\ldots,n.$, then the efficiency value of the evaluated unit DMUd can be derived by the following DEA model [16]:

$$
\begin{aligned}
&\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&s.t \quad \sum_{j=1}^{n} \lambda_j x_{ij} = \theta_0 x_{i0} - s_i^-, i = 1,\ldots,m, \\
&\qquad \sum_{j=1}^{n} \lambda_j y_{rj} = y_{r0} + s_r^+, r = 1,\ldots s, \\
&\qquad \sum_{j=1}^{n} \lambda_j = 1, \\
&\qquad \lambda_j \geq 0, j = 1,\ldots,n, \\
&\qquad \theta_0, s_i^-, s_r^+ \geq 0,
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
&\max \delta_0 - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&s.t. \sum_{j=1}^{n} \lambda_j x_{ij} = x_{i0} - s_r^+, i = 1,\ldots,m, \\
&\qquad \sum_{j=1}^{n} \lambda_j y_{rj} = \delta_0 y_{r0} + s_r^+, r = 1,\ldots,s, \\
&\qquad \sum_{j=1}^{n} \lambda_j = 1, \\
&\qquad \lambda_j \geq 0, j = 1,\ldots,n, \\
&\qquad \delta_0, s_i^-, s_r^+ \geq 1.
\end{aligned} \tag{2}
$$

Model (1) is an input-oriented DEA model, and Model (2) is an output-oriented DEA model. θ_d and φ_d represent the efficiency values of the dth decision unit (DMU), S_i^- and s_r^+ represent the slack variables of inputs and outputs, ε is a non-Archimedean infinitesimal, λ_i is the weight of the i th decision unit, and if $(\theta_d^*, \lambda_j^*, s_i^{-*}, s_r^{+*})((\varphi_d^*, \lambda_j^*, s_i^{-*}, s_r^{+*}))$ are the optimal solutions of (1) and (2), if $\theta_d^* = 1\ (\phi_d^* > 1)$, then the decision unit DMU is inefficient; if $\theta_d^* = 1\ (\varphi_d^* = 1)$ and $s_i^{-*} = 0$ and $s_r^{+*} = 0$, then the decision unit DMU is strongly efficient; if $\theta_d^* = 1\ (\varphi_d^* = 1)$, and $s_i^{-*} \neq 0$ or $s_r^{+*} \neq 0$, then the decision unit DMU is weakly efficient[16] .

Because farmers can only make changes to production inputs, the output value has random errors that cannot be controlled artificially, so this paper proposes to use Model (1), an input-oriented DEA model, where the production input index for banana farming is set to x , Then $x = (x_1, x_2, x_3)$, and the output value is set to y . The t banana farming household's average input-output function per mu is $y = f(x_1, x_2, x_3)$, x_1 , x_2 , x_3 are material costs, land costs, labor costs, and y is the banana output value[17] .

Model Indicator Selection.

Output Indicators.

By perusing relevant literature, agricultural production efficiency is typically measured by its output value. Given the scarcity of by-products throughout the banana production process, the output is based on the value of the main product, bananas. Incorporating the data from the two field investigations, the total output value per mu for each banana farmer household is calculated, with the price calculated based on the average actual selling price of bananas by the farmers in the corresponding year. The units are yuan/mu and yuan/jin.

Input Indicators.

In combination with relevant literature and the data obtained in this paper, the input factors for banana production in this paper encompass labor input, material input, and land input.

Labor Input

In agricultural production, particularly in labor-intensive agriculture, agricultural labor input is indispensable, and alterations in its input value can have a significant impact on agricultural output. Agricultural input encompasses both quality and quantity aspects. Due to the high difficulty in the survey and the potential unavailability of data, labor cost is calculated in this paper based on the number of input days. According to the survey data, 250 sample households have the phenomenon of hired labor, accounting for 54.2% of the total sample, and 211 households have no hired labor, accounting for 45.8% of the total sample. More than half of the banana-growing households have hired labor, highlighting the significance of agricultural labor. Therefore, all labor input in this paper includes (self-employed labor + hired labor), and is based on the average labor input per mu for each banana farmer household, with the unit being yuan/mu.

Material Input

Banana planting and production are inseparable from a series of material inputs, mainly including pre-planting preparation costs, seedling costs, fertilizer costs, organic fertilizer costs, pesticide costs, harvesting costs, irrigation costs, and other costs (such as staking, bagging, etc.), with the unit being yuan/mu.

Land Input

To date, land is a necessity for agricultural production. Based on the survey data, 50.76% of the sample households have rented land for banana cultivation. Hence, land includes (owned land + rented land), with the unit being yuan/mu.

2.4 Measurement and Analysis of Production Efficiency

Measurement Results.

The obtained data was arranged in the form of input-output and measured using the DEAP2.1 software. The arrangement is as follows:

Table 1. Crste, Vrste, Scale frequency

Technical efficiency value	Percentage(%)	Pure technical efficiency value	Percentage(%)	Scale efficiency value	Percentage(%)
[0,0.1)	2.8%	[0,0.1)	0%	[0,0.1)	0.7%
[0.1,0.2)	8.2%	[0.1,0.2)	0%	[0.1,0.2)	18.7%
[0.2,0.3)	9.3%	[0.2,0.3)	0%	[0.2,0.3)	25.4%
[0.3,0.4)	34%	[0.3,0.4)	0.6%	[0.3,0.4)	24.1%
[0.4,0.5)	28.2%	[0.4,0.5)	10.8%	[0.4,0.5)	17.1%
[0.5,0.6)	4.6%	[0.5,0.6)	23.4%	[0.5,0.6)	8.5%
[0.6,0.7)	3.5%	[0.6,0.7)	27.3%	[0.6,0.7)	2.2%
[0.7,0.8)	3%	[0.7,0.8)	21%	[0.7,0.8)	1.1%
[0.8,0.9)	2.8%	[0.8,0.9)	9.5%	[0.8,0.9)	0.9%
[0.9,1]	3.5%	[0.9,1]	7.2%	[0.9,1]	1.5%

Table 2. Descriptive analysis of production efficiency

	average value	maximum values	minimum value	standard deviation
Technical efficiency values	0.24	1	0.028	0.15
Pure technical efficiency values	0.67	1	0.376	0.14
Scale efficiency value	0.34	1	0.051	0.16

Result Analysis.

As presented in Table 1, on the whole, the technical efficiency values of 381 peasant households are lower than 0.5, accounting for 82.6% of the total sample. The overall technical efficiency is relatively low, and merely 10 peasant households have reached the valid technical efficiency, accounting for only 2.2% of the total sample.

As indicated in Table 2, the standard deviations of all three are relatively small, suggesting a relatively concentrated distribution and a scarcity of banana farmers with high production efficiency values. The technical efficiency value is relatively low, with an average of merely 0.24, and the average scale efficiency is only 0.34, imposing significant restrictions on the technical efficiency value. If the technical efficiency value equals 1, it implies that the DEA is effective, further suggesting that the input-output of banana production for this farmer has achieved the optimal efficiency. The maximum, minimum, and average values of technical efficiency are 1, 0.028, and 0.24, respectively. This indicates that if the sample households reduce their input by 76%, the output value obtained by the banana farmers will remain unchanged.

3 An Empirical Research on the Impact of Aging Agricultural Labor Force on the Productivity of Banana Production in Hainan Province

3.1 Model Specification

In 1958, for the purpose of investigating the demand for durable consumer goods, J. Tobin (James, Tobin) put forward the Tobit econometric model. In 1971, in order to clarify the specific influencing factors of the efficiency values measured through the Data Envelopment (DEA) model, Timmer proposed the DEA-Tobit two-stage analysis method. Through the improvements made by numerous scholars, it has become highly mature and has led to a significant amount of academic outputs. With the efficiency values measured by the Data Envelopment (DEA) serving as the explained variable and the observable characteristics of banana production as the explanatory variables, the Tobit model is utilized to estimate the direction and extent of the influence of each characteristic of banana production on banana production efficiency. Since the efficiency values measured by the Data Envelopment (DEA) are within the range of (0, 1], and there is a truncation phenomenon in the data, if the least squares regression method is employed, the results would be biased and inconsistent. Therefore, the Tobit model is typically adopted to handle such issues. The model (3) is as follows:

$$y_i^* = \beta^t x_i + \varepsilon_i \;\; i = 1,2,\cdots,n, \text{ as } y_i^* > 0, y_i = y_i^*; \text{ as } y_i^* \le 0, y_i = 0 \tag{3}$$

In which y_i^* is a latent variable; y_i is the production efficiency value measured by the data envelopment analysis (DEA) model for each banana producer in the previous chapter; x_i is the observed value of the production characteristic variables; β^t

is the correlation coefficient vector; and ε_i is the random error term, with $\varepsilon_i \sim N(0,\delta^2)$.

3.2 Indicator Selection and Basic Hypotheses

Indicator Selection.
As shown in Table 3, the following were chosen as explanatory variables: the age of the decision-makers, health condition, educational attainment, years of banana cultivation, frequency of training, degree of family aging, the aging rate of the agricultural labor force, the number of migrant workers, the number of banana cultivation plots, leased land, banana cultivation area, difficulty in fundraising, labor cost, land cost, and material cost[8]. The efficiency values of each decision-making unit measured by the Data Envelopment Approach (DEA) were selected as the explained variables [17].

Table 3. Tobit model variable selection and definition

	Variable name	Unit	Definition of variables	forecast
Dependent variable	Productivity of Banana Producers in Hainan Province		Calculated production efficiency	
Explanatory variable				
Core variables	Age of decision-makers	year	According to the person's actual age.	Negative
	The degree of aging in the family	-	The number of people over 60 years old in the family	Negative
	The aging rate of agricultural labor force	-	The proportion of agricultural labor force exceeding the proportion of population over 60 years old.	Negative
Characteristics of Farm Households				
	Level of decision-makers	-	By elementary school, junior high school, high school, and college.	Positive
	Level of Health	-	Excellent=5 Good=4 Average=3 Poor=2 Very Poor=1	Positive
	Is there any Communist Party member or village official in your family?	-	True=1, False=0	Positive
	Difficulty in raising funds	-	1=very difficult; 2=somewhat difficult; 3=average; 4=easier; 5=very easy.	Positive
Plant characteristics				
	planting area	mu	Calculated based on the actual number of banana planted per acre.	Positive
	Number of banana planting plots	block	Calculated based on the actual number of planted fields.	Negative
	More in line with the academic scene	Year	The continuous cultivation years of bananas.	Positive
Investment Characteristics				

	labor cost	yuan per mu	Average human input per acre of farmers	Positive
	Land cost	yuan per mu	Land rent	Positive
	Material cost	yuan per mu	Average capital input per hectare of farmland	Positive
Other features				
	Number of training sessions	time	Calculated based on the actual number of training sessions attended per year.	Positive
	Leased land	mu	The actual amount of land rented by farmers	Positive

Basic Assumptions.

Based on relevant literature and field research findings, the following assumptions are made in this chapter:

Hypothesis: H_{01} Decision-maker age, H_{02} degree of aging in the family, H_{03} aging rate of agricultural labor force, H_{04} number of out-of-town laborers, and H_{05} number of banana planting plots have a negative impact on the efficiency of banana production in Hainan.

Agricultural production demands a considerable amount of labor, especially in banana production. The older the decision-makers are, the higher the degree of family aging, and the higher the aging rate of agricultural laborers (as learned from the research, the decision-makers of banana production are generally agricultural laborers), the more their physical strength deteriorates, and subsequently, the efficiency of banana production drops. The out-migrants for work are mostly young adults, who are the main labor force and technical backbones of an agricultural family. If a large number of them leave for work outside, it may exert a negative influence on the efficiency of banana production in Hainan. The greater the number of banana planting plots, the more exhausted the banana farmers may become, and they may fail to take proper care of the entire banana field, which is unfavorable for large-scale planting.

Hypothesis: Hypothesis H_{06} : Area of Banana Plantation, Hypothesis H_{07} : Education Level, Hypothesis H_{08} : Health Status, Hypothesis H_{09} : Whether There is a Party Member or Village Officer in the Family, Hypothesis H_{10} : Difficulty of Fund-raising, Hypothesis H_{11} : Years of Banana Plantation, Hypothesis H_{12} : Labor Cost, Hypothesis H_{13} : Material Cost, Hypothesis H_{14} : Land Cost, Hypothesis H_{15} : Number of Training Sessions, Hypothesis H_{16} : Renting Land Positively Impacts the Efficiency of Banana Production in Hainan.

The larger the area of banana cultivation, the more pronounced the scale effect. The higher the educational attainment of decision-makers, the more likely they are to master and correctly apply banana production techniques. Most banana production involves physical labor, and better health is conducive to banana production. If there are Party members or village officials in the family, they can accurately grasp the national policies in the banana industry and take prompt responses. If financing is readily available, banana farmers typically expand production and increase investment. If banana farmers have been engaged in banana cultivation for consecutive years, they have rich planting experience and proficient production skills. To a certain extent, the higher the input of labor costs, material costs, and land costs, the higher the efficiency of banana production. Beyond a certain critical point, the larger the values, the lower the production efficiency. This chapter assumes that the values of labor costs, material costs, and land costs have not reached the redundancy critical value. The more training sessions there are, the more appropriately and proficiently banana farmers master banana production techniques. The more land is rented, the larger the planting scale and the greater the scale benefits.

3.3 Model Estimation and Result Analysis

Estimation and Result Analysis of the Total Sample Model.

Table 4. Regression results of effects of banana production characteristics on banana production technical efficiency in Hainan

Explanatory Variables	Regression Coefficient	Z-value	*p -value*	*Significantness*
Intercept term	0.406	2.485	0.013	**
Age of decision-makers	-0.169	-7.398	0.000	***
Degree of Health	0.003	0.927	0.354	Insignifcant
Degree of Education Attainment	0.002	0.486	0.627	Insignifcant
The length of time of banana cultivation for farmers	-0.001	-0.346	0.730	Insignifcant
Number of training sessions	0.113	21.659	0.000	***
The extent of family aging	-0.041	-4.197	0.000	***
The rate of aging in the agricultural labor force	-0.003	-0.126	0.900	Insignifcant
The quantity of the labor force working outside their hometowns	-0.008	-3.137	0.002	***
Number of banana planting plots	0.002	1.036	0.300	Insignifcant
Leased land	0.009	2.198	0.028	***
Area of Banana Plantation	0.003	1.108	0.268	Insignifcant
Difficulty in raising funds	0.006	2.615	0.009	***
labor cost	-0.012	-1.075	0.283	Insignifcant
Land cost	-0.012	-1.586	0.113	Insignifcant
Material cost	-0.133	-7.311	0.000	***
Likelihood Ratio testing	χ^2 (34)=919.618,p=0.000			
McFadden's R-squared	-2.089			

Table 5. Likelihood ratio test of Tobit regression model

Model	-2 log-likelihood value	Chi-square value	df	p	AIC value	BIC value
Intercept	-440.287					
Final Model	-1359.905	919.618	34	0.000	-1289.905	-1145.388

As presented in Table 5, the chi-square value is 919.618, with $P < 0.05$, suggesting that this model is valid.

As indicated in Table 4, the number of training sessions, the degree of ease in fundraising, and leased land exert a significantly positive influence on the technical efficiency of banana production. Conversely, the age of decision-makers, the extent of family aging, material costs, and the number of migrant workers have a significantly negative effect on it. However, health condition, educational attainment, years of banana cultivation, the aging rate of the agricultural labor force, the number of banana planting plots, leased land, banana planting area, labor costs, and land costs have no significant influence on the technical efficiency of banana production in Hainan.

4 Main Research Conclusions and Policy Suggestions

In this paper, by leveraging the micro-survey data of banana production from the main banana-producing areas in Hainan, the data envelopment (DEA) analysis approach is employed to calculate the banana production efficiency of banana growers. On this basis, the regression analysis method is utilized to conduct an empirical analysis of the technical efficiency of banana production. According to the empirical results, research conclusions are drawn, and policy recommendations are proposed thereon.

4.1 Main Research Conclusions

The empirical research on the factors influencing the production efficiency of bananas in Hainan indicates that: Regarding the overall technical efficiency of the sample, the number of training sessions, the ease of fundraising, and material costs have a significant positive influence; the age of decision-makers, the degree of family aging, and the number of migrant workers have a significant negative influence; health status, educational attainment, years of banana cultivation, the aging rate of agricultural labor force, the number of banana planting plots, leased land, banana planting area, labor costs, and land costs have no significant effect. The older the decision-maker is, the more likely they possess outdated banana production techniques and have poor learning ability, resulting in the inability to update new production techniques promptly, thereby leading to lower banana production efficiency among elderly decision-makers. The greater the number of people over 60 years old in the family, the lower the quality of family labor and the older production concepts will influence banana production decision-makers to a certain extent, reducing banana production efficiency. The substantial loss of young and middle-aged laborers has a severe impact on the banana production efficiency in Hainan. Increasing the number of training sessions, optimizing the rural financing environment, and increasing the input of materials for banana production can, to a certain extent, enhance the technical efficiency of banana production in Hainan. Banana cultivation demands continuous updates of planting techniques and continuous learning, and the influence of planting experience is insignificant.

In conclusion, the age of decision-makers and the degree of family aging have a significantly negative impact on the technical efficiency of banana production in Hainan, and the aging rate of agricultural labor force has a significantly negative impact on the technical efficiency of large-scale banana producers. Therefore, this paper concludes that the aging of agricultural labor force has an adverse effect on the technical efficiency of banana production in Hainan.

4.2 Policy Recommendations

Enhance the degree of mechanization in banana production. Based on field research, the degree of mechanization in banana production in Hainan is relatively low. In a strict sense, most banana farmers have only one complete mechanized operation, which is the unified land plowing before planting carried out by professional tractors. Additionally, farmers have very few mechanical devices for banana production. Banana production demands a significant number of laborers. It is essential to intensify the research and development of specialized machinery suitable for banana production in Hainan, in accordance with the characteristics of banana production and the main land types. This would liberate agricultural labor force and address the gradually deepening issue of agricultural aging. Appropriate subsidies should also be provided for banana production machinery to facilitate the wide adoption of mechanized production among numerous banana farmers and enhance the production efficiency of bananas in Hainan.

Allocate production factors rationally. On the whole, continuously increasing the input of material costs, moderately increasing the input of land costs, and moderately reducing the input of labor costs would contribute to improving the production efficiency of bananas in Hainan.

Strengthen the promotion of banana production technologies. Generally speaking, the more technical training sessions there are, the higher the production efficiency of bananas. According to the survey results, the overall banana production technology training in Hainan is relatively scarce. The technical extension activities organized by the authorities and research institutes are relatively few. Many small farmers' participation in technical training was mostly organized by fertilizer or pesticide dealers, etc. Although these had a certain positive impact on the popularization of production technology, because they were promoting products, the banana production technologies they promoted had certain misleading aspects. Moreover, many small banana farmers are reluctant to participate in technical training, considering it useless and a waste of time. This indicates that the existing production technology training is not attractive enough, and farmers have not recognized the benefits of production technology training. The government should first carry out vigorous publicity to make farmers aware of the importance of production technology training, standardize private production technology training, and regularly organize banana production technology training in the main banana-producing areas. Combine this with internet live broadcasts to establish a consultation platform for banana farmers' production technology problems. Hire relevant experts to produce instructional videos on banana production technology, promote them to farmers for free, and conduct regular live interactive explanations of banana production technology and answer questions. Through technical training, fully amplify the "technical effect" to counteract the negative impact of aging and further improve the production efficiency of bananas.

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