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Driving and Influencing Factors of Biomass Energy Utilization from the Perspective of Farmers

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ABSTRACT

Biomass energy is one of the most important renewable energy sources. Full utilization of this energy helps to optimize agricultural development, improve our living environment, and replace some non-renewable energy sources, thereby promoting the eco-environment across the country. However, biomass energy has not been extensively utilized in rural areas of China. Many farmers are not very enthusiastic about the use of biomass energy. Many scholars have tried to boost the willingness of farmers to utilize biomass energy. Therefore, this paper collects the relevant data from six aspects, namely, environmental factor, cost factor, income factor, behavior factor, policy factor, and personal factor, and constructs a binary logistic regression model. On this basis, the driving and influencing factors of biomass energy utilization were empirically analyzed from the perspective of farmers. The results show that the development of biomass energy is mainly affected by the farmers' awareness of national energy strategy, the relevant costs of biomass utilization, and the attitude of family members and village committee. The research provides an important reference for further promotion of biomass energy, elevation of its utilization efficiency, and optimization of energy structure in rural China.

1. INTRODUCTION

Global warming is one of the biggest threats facing humans. Scientists estimate that every 2°C increase of global mean temperature will bring death to nearly 100 million people and millions of species [1]. In 2019, the Intergovernmental Panel on Climate Change (IPCC) released a report on greenhouse gases (GHGs), pointing out that the massive emissions of GHGs, including carbon dioxide, methane, and nitrous oxide, significantly increase the possibility of global warming. Due to the wide utilization of fossil fuels, carbon dioxide accounts for about 80% of GHGs. It is an inevitable choice for all countries to reduce GHGs emissions and realize sustainable development, while meeting energy demand [2-4].

Biomass energy is a renewable energy provided by plants in nature. The medium for plants to store solar energy is called biomass, which could be every living organic matter. Biomass refers to any organism produced by photosynthesis of air, water, and soil, including all plants, microorganisms, as well as animals that consume plants and microorganisms, and their wastes. Typical biomasses are crops, crop waste, wood, wood waste, and animal feces [5-9].

Currently, the most effective way to use biomass energy is to make biogas and alcohol [10]. Compared with fossil fuels, biomass energy generates a very small amount of GHGs in production, transport, and utilization. Around the world, researchers are trying to improve the utilization rate of biomass energy [11], with the aim to i) reduce GHG emissions and curb global warming; ii) minimize excessive development; iii) alleviate the dependence on imported energy through continuous production of renewable energy.

So far, a variety of techniques have been developed to convert biomass into energy. The most important techniques are about gasification, biological ethanol production, biogas production, biodiesel production, and combustion [12]. In biogas production, agriculture waste, animal waste, domestic waste, and industrial waste are converted to energy, fresh fertilizers, and irrigation water, through anaerobic digestive system [13]. Filtration, drying, and oil pressing [14] are three key operations that convert raw materials like microalgae [15], forests, and agricultural products into biodiesel. As for gasification, hydrocarbons are turned into carbon monoxide, carbon dioxide, and hydrogen [16] by controlling air volume and partial combustion [16]. Biological ethanol is produced by grinding, heating, water addition, and fermentation of raw materials, such as paper slurry, log, agricultural products, and waste [17, 18].

China has an abundance of straw resources [19-23]. About 90% of the total amount of straws come from food crops like corn, rice, and wheat. In theory, 820 million tons of straws are produced each year, among which 690 million tons are collectable. At present, a total of 350 million of straws can be processed into fertilizers, feeds, edible mushroom matrix, and paper each year, and 340 million can be utilized as energy. In addition, the residual materials of agricultural products, namely, rice shells and bagasse, amounts to 120 million tons per year, among which 60 million can be utilized as energy. If all straws are combusted for heating, the heat released by every 400 million tons of straw is equivalent to that by 200 million standard coal. However, the annual amount of straws that are reasonably utilized for heating is only 10 million tons. A huge amount of straws is yet to be utilized.

Each year, 173 billion tons of materials are produced by photosynthesis around the world, which contain 10-20 times the total energy consumed globally. Nevertheless, only less than 3% of these materials are being utilized. As a result, China and other countries all face the urgent task to increase the utilization rate of biomass energy. However, the existing literature mostly discusses how to technically convert biomass into energy, and rarely talks about how to subjectively improve the biomass utilization rate.

From the perspective of farmers, this paper intends to explore the factors affecting the utilization rate of biomass energy in China, aiming to increase the utilization of biomass energy in rural areas of the country. The remainder of this paper is organized as follows: Section 2 briefly introduces the questionnaire design and data collection; Section 3 provides the descriptive statistics of the data and constructs a binary logistic regression model; Section 4 presents the analysis results on the model; Section 5 discusses how Chinese government and enterprises should do to further improve the utilization rate of biomass energy, and gives some suggestions to policymakers.

2. QUESTIONNAIRE DESIGN AND DATA COLLECTION

Our questionnaire survey covered 291 households. Excluding the missing and suspended ones, a total of 246 valid questionnaires were returned, putting the effective rate at 84.5%. Drawing on the relevant literature, the questionnaire covers six aspects: environmental factor, cost factor, income factor, behavior factor, policy factor, and personal factor. Table 1 lists the variables and their meanings and values.

Table 1. Variables and their meanings

Variable	Name	Code	Meaning and value
Dependent variable	Biomass energy utilization Y/N?	B	Yes=1, Not=0
Environmental factor	Abundance of land	X_1	Strongly abundant=3, slightly abundant=2, relatively poor=1
	Resource abundance	X_2	Strongly abundant=3, slightly abundant=2, relatively poor=1
	Land-food crop compatibility	X_3	Very high=3, general=2, relatively low=1
	Energy crop yield per unit land	X_4	Very high=3, general=2, relatively low=1
Cost factor	Total initial investment cost	X_5	Very high=1, general=2, relatively low =3
	Raw material purchase cost	X_6	Very high=1, general=2, relatively low =3
	Raw material transport cost	X_7	Very high=1, general=2, relatively low =3
	Management cost	X_8	Very high=1, general=2, relatively low =3
	Labor cost	X_9	Very high=1, general=2, relatively low =3
	Operating cost	X_{10}	Very high=1, general=2, relatively low =3
Income factor	Annual family income	X_{11}	Rated based on survey data
	Biomass planting and selling subsidy	X_{12}	Strongly necessary=3, slightly necessary=2, strongly unnecessary=1
	Biogas subsidy	X_{13}	Strongly necessary=3, slightly necessary=2, strongly unnecessary=1
	Biogas transport subsidy	X_{14}	Strongly necessary=3, slightly necessary=2, strongly unnecessary=1
Behavior factor	Awareness of national energy strategy	X_{15}	Strongly clear=3, slightly clear=2, unclear=1
	Awareness of biomass energy	X_{16}	Strongly clear=3, slightly clear=2, unclear=1
	Awareness of environmental regulations	X_{17}	Strongly clear=3, slightly clear=2, unclear=1
	Attitude of family members and village committee	X_{18}	Strict prohibition=2, relaxed management=1, no management=0
Policy factor	Agricultural training experience	X_{19}	The sum of the types of environmental training, waste recycling training, agricultural technology training, and other trainings
	Professional training policy	X_{20}	Strongly clear=3, slightly clear=2, unclear=1
	Publicity and education policy	X_{21}	Strongly clear=3, slightly clear=2, unclear=1
	Forest conservation policy	X_{22}	Strongly clear=3, slightly clear=2, unclear=1
Personal factor	Gender	X_{23}	Rated based on survey data
	Age	X_{24}	Rated based on survey data
	Education	X_{25}	Rated based on survey data
	Family population	X_{26}	Rated based on survey data

3. DESCRIPTIVE STATISTICS AND MODEL CONSTRUCTION

Figures 1 and 2 show the personal factor of the respondents. Table 2 provides the preliminary statistics on the survey data.

The factors affecting biomass were studied according to the definition of the binary logistic model. Taking "Biomass energy utilization Y/N?" as dependent variable and X_{1-26} as 26 independent variables, the following logistics regression model can be established as:

$$p = F(y = 1|X_i) = \frac{1}{1 + e^{-y}} \quad (1)$$

where, y is biomass energy utilization Y/N (if $y = 1$, the farmer household utilizes biomass energy; if y=0, the farmer household does not utilize biomass energy); p is the probability for the farmer household to utilize biomass energy; X_i(i=1, 2, …, n) is the factors that may affect biomass energy utilization among farmer households.

$$Ln\left(\frac{p}{1-p}\right) = b_0 + b_1x_1 + b_2x_2 + \cdots + b_nx_n + \varepsilon \quad (2)$$

where, y is the linear combination of variables x_i(i=1, 2, …, n); b_0 is the constant term; ε is a random error; b_i(i=1, 2, …, n) is the regression coefficient of the i-th independent coefficient. Transforming formulas (1) and (2):

$$y = b_0 + b_1x_1 + b_2x_2 + \cdots + b_nx_n + \varepsilon \quad (3)$$

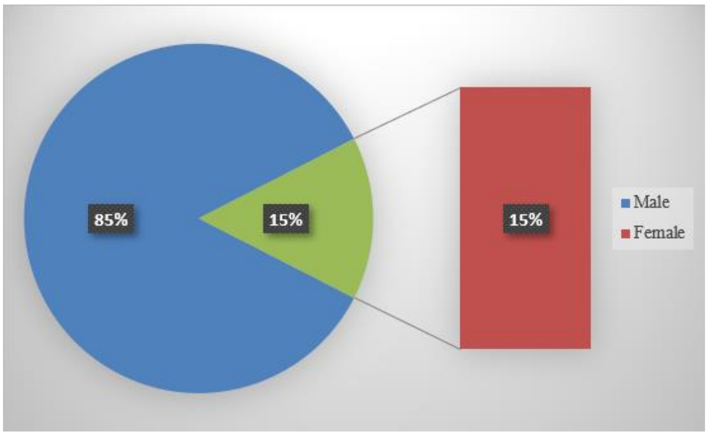

Figure 1. Gender distribution of respondents

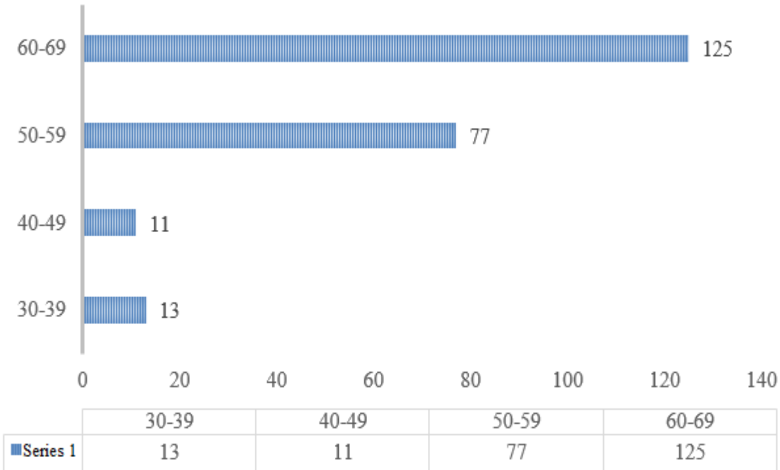

Figure 2. Age distribution of respondents

Table 2. Descriptive statistics on the variables

	Variable name	Minimum	Maximum	Mean	Std. Deviation
X_1	Biomass energy utilization Y/N?	2	22	2.93	1.780
X_2	Abundance of land	1	3	1.75	.451
X_3	Resource abundance	3	3	3.00	.000
X_4	Land-food crop compatibility	1	2	1.66	.475
X_5	Energy crop yield per unit land	1	2	1.52	.501
X_6	Total initial investment cost	2	3	2.53	.500
X_7	Raw material purchase cost	1	2	1.73	.444
X_8	Raw material transport cost	1	3	1.66	.569
X_9	Management cost	1	2	1.46	.500
X_{10}	Labor cost	2	3	2.47	.500
X_{11}	Operating cost	4	7	5.46	.665
X_{12}	Annual family income	2	3	2.52	.501
X_{13}	Biomass planting and selling subsidy	2	3	2.75	.433
X_{14}	Biogas subsidy	3	3	3.00	.000
X_{15}	Biogas transport subsidy	1	2	1.54	.499
X_{16}	Awareness of national energy strategy	1	3	1.99	.731
X_{17}	Awareness of biomass energy	1	2	1.64	.481
X_{18}	Awareness of environmental regulations	1	3	1.66	.523
X_{19}	Attitude of family members and village committee	1	3	1.94	.806
X_{20}	Agricultural training experience	2	2	2.00	.000
X_{21}	Professional training policy	2	3	2.17	.373
X_{22}	Publicity and education policy	1	3	1.91	.643
X_{23}	Forest conservation policy	0	1	.70	.458
X_{24}	Gender	37	65	54.12	6.772
X_{25}	Age	3	4	3.39	.489
X_{26}	Education	3	5	3.86	.754
Valid N (listwise)	246				

4. ANALYSIS ON MODEL RESULTS

The influencing factors of biomass energy utilization among farmer households were investigated through binary logistics regression on SPSS24.0. The results are presented in Table 3.

Judging by the regression results, several significantly uncorrelated factors were removed, including X_3: resource abundance, X_{14}: biogas subsidy, and X_{20}: agricultural training experience. The factors that significantly affect the utilization of biomass energy are (significant at the 5% level): X_7: raw material purchase cost (Sig.=0.043), X_8: raw material transport cost (Sig.=0.076), X_9: management cost (Sig.= 0.070), X_{16}: awareness of national energy strategy (Sig.= 0.11), and X_{19}: attitude of family members and village committee (Sig.= 0.001).

Table 3. Results of binary logistics regression

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	X_1	-.024	.092	.069	1	.792	.976
	X_2	-.109	.363	.091	1	.763	.897
	X_4	-.203	.339	.358	1	.550	.816
	X_5	-.758	1.228	.381	1	.537	.469
	X_6	.255	.323	.625	1	.429	1.290
	X_7	-.774	.382	4.114	1	.043	.461
	X_8	-.518	.292	3.138	1	.076	.596
	X_9	-.584	.323	3.273	1	.070	.557
	X_{10}	-.229	.325	.497	1	.481	.795
	X_{11}	-.142	.236	.362	1	.548	.868
	X_{12}	.133	1.194	.012	1	.912	1.142
	X_{13}	.119	.453	.069	1	.793	1.126
	X_{15}	-.469	.354	1.755	1	.185	.625
	X_{16}	.541	.213	6.471	1	.011	1.718
	X_{17}	.035	.322	.012	1	.912	1.036
	X_{18}	.133	.308	.187	1	.665	1.143
	X_{19}	.646	.199	10.533	1	.001	1.907
	X_{21}	-.384	.720	.285	1	.594	.681
	X_{22}	.126	.409	.095	1	.758	1.134
	X_{23}	.311	.348	.800	1	.371	1.365
	X_{24}	.026	.024	1.132	1	.287	1.026
	X_{25}	.481	.322	2.225	1	.136	1.617
	X_{26}	-.165	.198	.694	1	.405	.848
	Constant	1.444	3.798	.145	1	.704	4.236

a. Variable(s) entered on step 1: X1, X2, X4, X5, X6, X7, X8, X9, X10, X11, X12, X13, X15, X16, X17, X18, X19, X21, X22, X23, X24, X25, and X26.

5. CONCLUSIONS

After collecting data on environmental factor, cost factor, income factor, behavior factor, policy factor, and personal factor, this paper sets up a binary logistic regression model, and empirically analyzes the driving and influencing factors of biomass energy development, from the perspectives of farmers. The results show that the development of biomass energy is mainly affected by the farmers' awareness of national energy strategy, the relevant costs of biomass utilization, and the attitude of family members and village committee. To further improve the utilization rate of biomass energy, the authors recommended the following measures:

(1) Enhance farmers' awareness of biomass energy through multiple means, such as training and publicity.

Our survey results show that farmers' awareness of biomass energy greatly affects the development of biomass energy. Hence, the government should make farmers better understand the economic and social advantages of biomass energy through various channels, such as training and publicity, reshaping their conventional notion that biomass energy is dirty, as it is converted from wastes. The government could step up promotion by holding lectures or largescale activities to publicize the knowledge about biomass energy, such that the farmers quickly understand biomass energy, and actively participate and interact in biomass energy utilization. After the activities, the government should revisit the farmers to check their degree of participation and cognition level, and evaluate if they are willing to continue utilize biomass energy and promote the energy to friends and relatives. The improvement of cognition level cannot be completed in one action. Thus, the government must continuously interact with farmers and get timely feedbacks. In addition, the government could organize one-one-one assistance to help farmers improve their understanding of biomass energy.

(2) Reduce the cost of biomass energy utilization through multiple channels.

Currently, it is relatively expensive to utilize biomass energy, mainly due to the high labor cost and transport cost. The high cost will suppress the enthusiasm of farmers to use biomass energy. Take straw recycling as an example. Despite the strong advocation by the government, not many farmers accept straw recycling, owing to the high economic and labor costs. The government and enterprises must strive to lower the recycling cost of straws, find a feasible way to process straws, and enable farmers to handle straws in a scientific manner. In straw recycling, the raw materials are rather cheap, and most of the cost incurs in terms of transport and labor. Therefore, the government could subsidize the farmers that recycle straws, so as to solve their worries. Through continued subsidy, the government can encourage farmers to give full play to subjective initiative, and properly handle straws in an environmentally friendly way, rather than direct incineration. Relevant research units should also actively develop technologies to rot the straws, turning them into useful organic fertilizers for the farmland.

(3) Step up agricultural training and supervision.

The farmers should be provided with agricultural trainings or related lectures. The contents must be in line with the local situation, and give farmers pertinent skills and suggestions. The village committee needs to popularize relevant laws and regulations, limiting the biomass energy utilization within the reasonable range specified in related standards. Meanwhile, the subsidies should be increased and maintained to provide a guarantee to farmers and enterprises, making them more active in realizing the sustainable development of biomass energy industry. For the quality and safety of biomass products, the government should vigorously strengthen the supervision of biomass energy projects, and step up the management and certification of products. For example, the government could establish a monitoring and service platform for the biomass industry, and forge a complete policy support system. In addition, it is also very important to provide biomass energy information consulting and technical services, which can technically promote the stable development of the biomass industry.

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