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Farmers' perceptions of developing forest based bioenergy in China

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ABSTRACT

Farmers′ awareness of forest-based bioenergy developments will greatly determine the direction and succession of forestry projects. To obtain a better understanding of this awareness, a logistic regression model was applied to analyze the factors influencing farmers′ willingness to participate in the construction of bioenergy bases. The model was developed based on a survey of 573 household farmers in eight Chinese provinces. This study found that a majority of households have increased their daily use of commercial fuel. Moreover, a significant number of farmers are either uncertain about or unfamiliar with the concept of forest-based bioenergy. The model found that households with young and educated individuals, a higher forestland endowment, and a higher cognition and understanding of fossil fuels, have a higher willingness to learn about and participate in forest based bioenergy issues. The findings of this study will be useful for bioenergy forest cultivators, extension foresters, forest landowners, and policy makers.

Contents

1. Introduction

The function of forests as carbon sinks makes them essential to terrestrial ecosystems and the biosphere as a whole. The economic and social values of this and other ecosystem services provided by forests are immeasurable. Furthermore, forests provide low-cost and effective climate change mitigation mechanisms by offsetting carbon

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emissions from industries. Therefore, it is imperative for countries to promote, implement, and support forestry programs at the national level when considering issues related to climate change. By prioritizing ecologically sound forestry establishments, countries can benefit from sustainable economic and social developments, as well as combat climate change through providing potential for key developments in forest based bioenergy. Currently, bioenergy use serves a significant role in mitigating climate change through reducing poverty, enhancing rural development, and relieving negative environmental impacts. FAO estimates that wood currently provides over 9% of the global primary energy supply; the potential for bioenergy use is expected to increase in the near future [1]. However, forest based bioenergy will only account for 0.45% of the total energy supply in China by 2020 [2].

Low productivity forests have the potential to provide biomass for energy generation that does not compete with timber forestry or with food production activities [3]. Wood energy is marketed as an environmentally friendly alternative to fossil fuel energy. Due to the many advantages of bioenergy sources, energy policies have been modified in several parts of the world to promote wood-energy based systems for combating the impending energy crisis and for mitigating climate change. Besides changing energy policies, wood-energy generating technologies have also been improved in Europe, the U.S., and other developed countries. Although there are debates regarding the methods used to extract biomass, the evidence strongly suggests that the development of forest based bioenergy[1] promotes new businesses and employment, strengthens rural economies, and encourages partnerships between urban and rural populations at the local and regional scales [4,5].

Bioenergy production has received significant attention in the media, research, politics, and decision-making platforms in China due to national energy security issues and responsibilities to mitigate climate change. There exists a significant amount of woody biomass that could potentially be used for sustainably generating energy in the future. Although the Chinese government employs incentives and supporting policies to promote the production and use of bioenergy, the share and distribution of bioenergy products is still very low. Currently, China has a total forestland area of about 300 million ha (3×10 exp.8 m^2), with about 200 million ha (2×10 exp.8 m^2) of which are forest areas with a growing stock of 13.7 billion m^3. There are also about 60 million ha (6×10 exp.7 m^2) of planted forest with a growing stock of 2 billion m^3. The total forest biomass is predicted to be about 18 billion tons [6]. According to the National Forestry Bioenergy Development Plan, by 2020, China should have grown 16.78 million ha of oil forest, wood energy forest and starch energy forest; the forestry biomass volume intended for utilization should be more than 20 million tons of the standard coal equivalents (tce). According to the report, by 2035, China′ energy consumption will increase by 60% and dependency on foreign imports will rise from 15% to 23%. By 2035, coal use will have decreased from the current 68% to 51%, natural gas use will increase to 12%, and the average proportion of oil consumed will not have changed. Moreover, the overall consumption of renewable energy (including biofuels) will rise from the current 3% to 8%, with most of the biofuels being extracted from forest biomass [7]. Thus, it appears that in the near future, forest biomass will likely play a prominent role in rural energy allocation and will also form a significant share of the national energy supply for transportation and power generation in China [2].

According to the National Statistics of China, the current rural population is 674 million and accounts for 50.32% of the total population [8]. It is predicted that in 2020 the energy demand of China's rural residents will be about 295–375 billion tce [9]. Moreover, bioenergy consumption in rural areas has decreased from 1997 to 2007 due to increases in air pollution, public health concerns, and low energy conversion efficiencies for firewood and straw combustions [10]. Total CO_2 emissions from rural residential energy consumption have increased significantly from 152.2 million tons in 2001 to 283.6 million tons in 2008 [11]. Moreover, rural residential commercial energy consumption grew at a yearly rate of 2.15% during the 1991–2010 time period due developments in the rural economy [12,13]. With increases in the incomes of rural farmers and a growing desire for a less burdensome life, it can be expected that the use of traditional biomass energy will continue to decrease [11].

Non-commercial energy sources such as biomass account for a substantial portion of the rural residential energy consumption in China; however, the statistics on non-commercial energy are rather incomplete [14]. According to recent estimates, bioenergy utilization accounts for less than 0.5% of the total energy consumption in China, and the proportion of forestry biomass energy (mainly firewood) accounts for the least type of bioenergy consumed [15]. Commercial forces dominate the rural energy consumption structure. Although progress has been made in rural energy policies supporting the development of renewable energy and the growth of rural incomes, increases in the efficiency of forest biomass utilization in rural areas has not made considerable progress. Kahrl et al [3] claimed that in order to make forest based bioenergy for rural use more environmentally and socially sustainable, innovations in silviculture and biotransformation technology are needed, as well as effective policies and social acceptability.

An understanding of farmers′ perception of forest based bioenergy projects has been a topic of recent discussion, especially in the U.K. Europe. Various researchers have argued that it is necessary to have a detailed understanding of farmers′ perceptions in order to enhance their enthusiasm for managing forests and implementing relevant policies [16–19]. In the U.K., Upreti and van der Horst [20] observed that interactive communication, public participation, and collective learning among multiple stakeholders could gain the public's support in promoting biomass energy. Buchholz et al [21] and McCormick and Kaberger [22] stated that participation and communication between stakeholders is vital to the adaptation and implementation of bioenergy projects in Europe. Halder et al. [23] revealed that proper dissemination of bioenergy related knowledge and proper understanding of relevant issues by nonindustrial private forest owners could promote the development of energy wood market.

Although there have been increases in the land area of energy forests, the forest biomass energy industry in China has not yet reached a mature industrialization stage. The high costs of raw materials brings the greatest uncertainties in the forest bio-diesel industry in China [24], and this situation has also been observed in other countries [25–27]. Therefore, the most relevant and interesting topics regarding this field include exploring the factors hindering the development of forest based bioenergy and the reasons leading to the high cost of raw materials and their unsustainable supply. Some researchers have conducted empirical studies based on surveys of these topics in different provinces in China at the micro-level, and the results revealed that the main factors involved in hindering the development of forest based bioenergy were lack of awareness, insufficient investments in science and technology, and an immature follow-up industry chain [15,28]. However, the development and utilization of forest-based bioenergy is a complex process. It is a link of multiple industry chains and includes seedling breeding, forest cultivation, management, and the collection of oil tree fruits. This is followed by purchase, transportation, store, pretreatment of the raw material, product processing, and final sales to the end market. The process includes the participation of the government, enterprises, and

[1] Forest-based bioenergy refers to energy from woody biomass, fuel-wood forest (in Chinese is Xin Tanlin), shrub forest, woody oil plants, SRF (Short Rotation Forest), energy crops, forest residues, and waste wood from forest industries.

farmers. It is an organic system that needs to be managed through an integrated approach in order to meet sustainable development goals [29]. Conflicts related to tenure, forest management, and utilization of natural resources rise in the development of bioenergy. In order to mediate and solve conflicts, there is a need to improve transparency, coordination, impact assessment, and investment security among stakeholders [30]. Reducing the high cost of raw materials and increasing their supply requires coordination between the government's macroeconomic control and farmers′ roles in the micro-economy [29,30]. As exemplified by the implementation of the Green for Grain Program (GGP)[2] in China, farmers serve as the main body in the development of forest-based bioenergy. One of the insufficiencies of the GGP is that public perceptions and land management practices are somewhat in disaccord [31]. However, few studies on understanding farmers′ attitudes towards and perceptions of developing forest based bioenergy in China have been conducted. For instance, why have so few farmers actively participated in biomass energy forest construction, and why have some farmers turned against it? Wu and Huang [32] conducted household surveys to analyze the key drivers of farmers′ negative attitudes towards planting *Jatropha* in Yunnan Province, and the results revealed that government subsidies are needed to encourage farmers′ enthusiasm. Considering the aforementioned study, many researchers have emphasized the role of the government in the establishment of bioenergy forests. However, the researchers fail to account for the role of the farmers as the main functioning body of the establishments.

As stated above, the purpose of this study is to obtain a better understanding of farmers′ awareness and knowledge of forest based bioenergy developments in China. The main research objectives of this study are to: (I) evaluate the current use of energy in rural China; (II) evaluate farmers′ willingness to participate in the construction of forest based bioenergy bases[3]; (III) determine which factors influence farmers′ willingness to participate in the development of forest bioenergy in China; and (IV) discuss methods to promote farmers′ capacities to participate in bioenergy development.

2. Materials and methods

2.1. Questionnaire design

The data was collected using a structured questionnaire, which was developed based on previous studies [31,33–35]. Before the formal survey was conducted, a pilot survey was delivered to ten farmers in Wuqi County in March 2012. The pilot survey was also sent to three experts in China. The questionnaire was revised and modified based on the responses to the pilot survey. The aims of the survey and a definition of forest based bioenergy were introduced to the participants at the beginning of the questionnaire. The questionnaire contains questions that fall into four categories: information regarding farmers′ social demographics, farmers′ land characteristics, family's energy-use structure, and farmers′ awareness of bioenergy and its issues.

2.2. Data collection

This survey was conducted in summer 2012. The study areas were selected according to regional distribution, socio-economic development level, the distribution of forest resources, and the progress of the collective forest tenure reform. The study area included the following eight

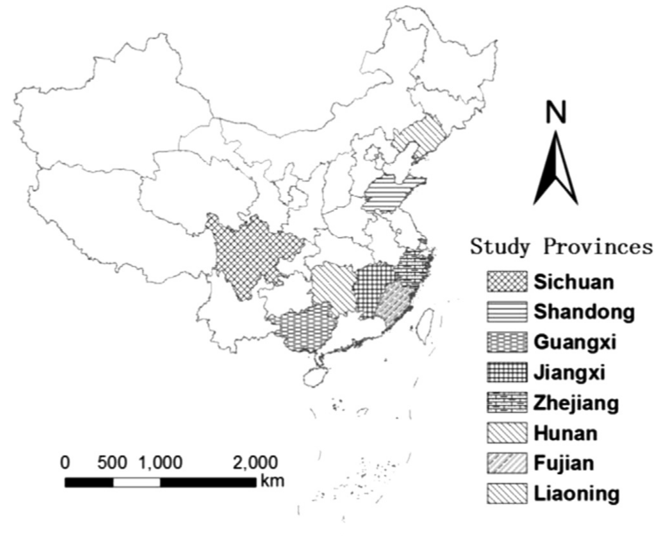

Fig. 1. Map of the People's Republic of China. The map highlights the eight provinces surveyed in this study.

provinces[4]: Shandong, Liaoning, Sichuan, Zhejiang, Fujian, Hunan, Jiangxi, and Guangxi. Shandong is part of the plains region while Hunan, Jiangxi, Guangxi, Zhejiang and Fujian are in the southern collective forest zone. Liaoning and Sichuan are in the northwest and southeast of China, respectively (Fig. 1). Stratified sampling was applied when conducting the individual household survey. Face-to-face interviews were conducted on a total of 573 household farmers who were chosen at random in the 45 villages.

2.3. Statistical analysis

In the survey, we investigate farmers′ willingness to participate in the construction of the energy forests bases. We define participation in general terms, which includes planting biomass species on private-owned forestland, contracting with the government, and/or labor participation in construction on state-owned or collective forestlands. Participation is a binary variable taking the value of 1 if the respondent states that he/she is willing to participate in the construction of the energy forests bases, and 0 otherwise. Therefore, we used the logistic model presented in Eq. (1) to identify and assess the factors influencing the probability of farmers′ willingness to participate in energy forest base construction [36].

$$\Pr[Y_i = 1X_i] = \frac{1}{1+\exp(-\alpha-\beta X_i)} \quad (1)$$

with the inverse of the logistic function, $g(X_i)$, the logit:

$$g(X_i) = \alpha + \beta X_i$$

In Eq. (1), $Y_i = 1$ if the respondent of household i is willing to participate. α is constant. The regression coefficient vector β indicates the relative effect of a particular explanatory variable on the logit, which is estimated using Stata 13.0. The vector of explanatory variables, X_i, used in the literature often includes

(a) demographic characteristics: household size, age of household head, education level of household head, annual total income, off-farm employment, and living consumption [33,37]; (b) land ownership: area of forestland and number of tracks of forestland [38]; (c) energy consumption: total energy consumption, the ratio

[2] In 1999, the Chinese government introduced the Grain for Green Programme (GGP), also known as the Slope Land Conversion Programme or the Conversion of Cropland to Forest and Grassland Programme aiming to control erosion and increase vegetation cover.

[3] The base refers to a place with large scale of bioenergy plantations and can provide raw materials for bioenergy production.

[4] The 8 provinces (15 counties, 45 villages surveyed) are Shandong (Laizhou, Mengyin), Liaoning (Benxi, Qingyuan), Sichuan (Weiyuan, Danling), Zhejiang (Deqing, Suichang), Fujian (Shunchang), Hunan (Pingjiang, Hongjiang), Jiangxi (Suichuan, Tonggu), Guangxi (Huanjiang, Pingguo).

Table 1
Defination of variables in logistic model.

Dependent variable	
Willingness to participate	Willingness to participate in the construction of the energy forests bases (Yes=1; No=0)
Independent variables	
Demographic characteristics (DC)	
Household size	Size of household
Age	Age of household head
Education	Education of household head (number of years)
ln (Income)	ln (annual total income ($))
Off-farm employment	Level of off-farm empolyment of household head (not a labor=0; agricultural labor=1; animal husbandry labor=2; migrant worker or self-employment labor=3)
ln (living consumption)	ln (annual cash consumption on living ($))
Land ownership (LO)	
ln (forestland area)	ln (area of forestland (Hectare))
ln (Num. of tracks)	ln (Number of tracks of forestland)
Energy structure (SE)	
ln (energy consumption)	ln (annual cash consumption on household energy use ($))
Firewood ratio	Ratio of firewood to total energy use
Power ratio	Ratio of power to total energy use
Bioenergy awareness (BA)	
Sensitivity to fuel price	Level of sensitivity to the price of fuel (do not care about it=1; care a little bit=2; generally indifferent=3; care=4; care very much=5)
Exhaustion of fossil fuels	Awareness of the exhaustion of fossil fuels (do not care about it=1; do not know about it=2; having awareness about the exhaustion=3
Importance of substitution	Awareness of the importance of substitution between fossile fuels and bioenergy (not important at all=1; not important=2; generally indifferent=3; important=4; very important=5)

Note: The symbol ln before the variables indicates that the variable was transformed by normalizing the data using the natural logarithm.

of firewood to energy consumption, and the ratio of power to energy consumption [39,40]; and (d) awareness: sensitivity to fuel price, awareness on the exhaustion of fossil fuels, and awareness on the importance of substituting fossil fuels for bioenergy [41].

2.4. Model and variable definitions

The willingness of farmers to participate in the construction of energy forests bases are influenced by multiple factors, and potential variables have been defined in previous studies [33,37–38,42]. Therefore, in this article we describe potential influencing variables and factors from four aspects: households′ demographic characteristics, forestland ownership, peasant household energy consumption, and biomass energy cognitive characteristics. The selection of various explanatory variables and technical definitions are presented in Table 1.

Our hypothesis is that the dependent variable is correlated to the four kinds of independent variables mentioned above. We use the binary logistic model, as presented by Eq. (1).

The household members′ ages and years of education are important indicators of the quality of a family's decision making capital, and are expressed as a continuous variable in the model. Younger individuals with higher levels of education indicate a higher cognition and understanding of the importance of participation, as well as greater awareness of the conditions of relevant policies and the importance of future energy development trends. The level of off-farm employment is expressed by the primary occupation of the individual during the research period. If the head of the household has a higher level of off-farm employment, this helps to improve the family income and therefore it is difficult to change their production pattern. Moreover, this group of farmers does not have much time at home and results in having little to no time for establishing biomass energy forest bases.

Households′ land characteristics are expressed by forestland area and number of tracks owned by farmers, which are also factors that determine engagement in forestry production and construction of energy forest bases.

Households′ energy consumption is expressed by energy consumption level, fuel wood usage, and electricity usage.

Farmers′ awareness of bioenergy issues is expressed by their level of sensitivity to the price of fuel, awareness of the issues surrounding the exhaustion of fossil fuels, and awareness of the importance of substituting fossil fuels for bioenergy. Theoretically, farmers who have a higher understanding of bioenergy are expected to have a higher willingness to participate in the construction of energy forests bases [41].

3. Results

3.1. Status of household energy consumption in rural households

Demographic characteristics of the samples are presented in Table 2. In total, 573 households were interviewed. Of the families surveyed, most consisted of three to four people, with an average household size of four individuals. The average size of forestland area owned by a household is 3.82 ha (Max=75.66 ha; Min=0.01 ha). The average number of years of education is seven years (Max=16 years; Min=0 year). 62% of the households are identified as civil servants or party members. 33% of the households surveyed are willing to participate in the construction of energy forests bases, while 67% are not. The average ratio of energy and daily cash consumption, firewood and energy consumption, and electricity or commercial energy consumption is 5%, 47%, and 35%, respectively. However, 72% of the respondents stated that the use of firewood as energy in their household decreased; the reasons for the decrease in use are stated in Table 3. Furthermore, respondents claimed that energy for cooking and heating was mainly derived from firewood and straw, followed by electricity. Forest tenure reform gained wide support from the farmers. Most of the respondents claimed that family income and owned property increased after the reform. 87% of the farmers received a certificate, which guarantees the development of forest management by the farmers. Nevertheless, 13% of the farmers have not received the certificate due to forest rights disputes and other reasons.

3.2. Farmers′ awareness of bioenergy

The farmers′ awareness of bioenergy was investigated through posing three related questions[5] (Table 1). Descriptive statistics of

[5] Cronbach's alpha value for bioenergy awareness is 0.44. The estimated correlation between it and the underlying factor it measures is 0.67.

Table 2
Demographic characteristics of the household samples and summary statistics by different groups of willingness to participate.

	$Y=0$		$Y=1$		Whole sample	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Demographic characteristics						
Household size	3.61	1.56	3.70	1.40	3.64	1.51
Age	55.52	10.55	51.55	8.73	54.21	10.15
Education	6.89	2.79	7.92	2.50	7.23	2.74
ln (Income)	7.96	1.01	8.09	0.99	8.01	1.00
Off-farm employment	1.48	0.84	1.77	0.80	1.58	0.84
ln (living consumption)	7.42	1.01	7.51	0.92	7.45	0.98
Land ownership						
ln (forestland area)	0.32	1.54	0.35	1.51	0.33	1.53
ln (Num. of tracks)	1.35	0.83	1.24	0.76	1.31	0.80
Energy structure						
ln (energy consumption)	4.00	1.42	4.02	1.27	4.01	1.37
Firewood ratio	0.51	0.28	0.40	0.28	0.47	0.29
Power ratio	0.33	0.22	0.40	0.24	0.35	0.23
Awareness						
Sensitivity to fuel price	2.51	1.26	3.35	1.22	2.79	1.30
Exhaustion of fossil fuels	2.22	0.74	2.49	0.74	2.31	0.75
Importance of substitution	2.52	1.32	3.27	1.24	2.77	1.34
Num. of observations	384		189		573	

Table 3
Respondents' reasons for reducing the use of firewood.

Reason for reducing the use of firewood	Percentage	Rank
Harvesting firewood was not allowed for various reasons	1.3%	5
Quantity of demand for firewood has been changed	9.2%	3
Need of commercial energy has increased	**68.6%**	**1**
Heating and cooking systems were changed	16%	2
Use of firewood is inconvenient	4.8%	4

Table 4
Reasons for farmers' lack of participation in the construction of the energy forest bases.

The reasons for not participating	Percentage	Rank
Lack of cultivating experience	11.3%	2
Worry about the sale of products	4.4%	4
Lack of information	**39.3%**	**1**
Lack of labor	10.5%	3
The property of forest land is not clear	1.2%	6
Worry about diseases and pests involved when cultivating bioenergy forests	1.6%	5

farmers' awareness of bioenergy are shown in Table 2. Generally, it appears that farmers perceive little about bioenergy and the energy crisis. Most of the farmers are not aware of the concepts and policies related to bioenergy; only less than 2% have an adequate awareness of the issues. 1.9% of the respondents participated in a local training regarding bioenergy issues (the training took place in the years 2003, 2006, and 2009), with the reason being that the local government required them to attend. Furthermore, few farmers (about 1%) have participated in the establishment of forest based bioenergy bases. The results show that "lack of information" is the primary reason for famers' lack of participation in the establishment of forest based bioenergy bases. Other reasons for lack of participation in the establishments are presented in Table 4.

Table 5
Logistic model estimation results.

Demographic characteristics				
Household size	0.0052	0.0064	0.0064	0.0086
	0.0139	0.0139	0.0139	0.0132
Age	−0.0050**	−0.0048**	−0.0053**	−0.0032
	0.0022	0.0022	0.0021	0.0020
Education	0.0202***	0.0198***	0.0162**	0.0163**
	0.0076	0.0075	0.0074	0.0069
ln (Total Income)	0.0206	0.0220	0.0003	0.0068
	0.0274	0.0272	0.0343	0.0319
Off-farm employment	0.0612**	0.0617***	0.0535**	0.0180
	0.0241	0.0239	0.0237	0.0225
ln (Living consumption)	−0.0253	−0.0267	−0.0122	−0.0312
	0.0273	0.0273	0.0507	0.0479
Land ownership				
ln (forestland area)		0.0154	0.0188	0.0230*
		0.0134	0.0129	0.0125
ln (Num. of tracks)		−0.0364	−0.0367	−0.0332
		0.0251	0.0249	0.0230
Energy structure				
ln (Energy consumption)			−0.0149	−0.0196
			0.0264	0.0254
Firewood ratio			−0.2211**	−0.1212
			0.0951	0.0917
Power ratio			0.0702	0.1196
			0.1102	0.1056
Awareness				
Sensitivity to fuel price				0.0772***
				0.0153
Exhaustion of fossil fuels				0.0589**
				0.0237
Importance of substitution				0.0560***
				0.0148
Num. of observations	573	573	573	573
Wald chi^2	33.62	34.53	49.17	81.18
Pseudo R^2	0.05	0.05	0.07	0.16

Average marginal effects are reported; Delta-method standard errors are in parentheses; $^*P<0.10$; $^{**}P<0.05$; $^{***}P<0.01$.

3.3. Factors influencing farmers' willingness to participate

Eq. (1) was estimated using Stata 13.0 and average marginal effects are reported in Table 5. Farmers' awareness, age, education, extent of off-farm employment, and the ratio of firewood to total household energy use are important factors influencing farmers' willingness to participate in the construction of energy forests bases. For example, an increase in age by one year decreases the probability of participation by 0.53%. The average marginal effect of education is positive with a much higher magnitude. With greater access to off-farm employment, farmers tend to have a higher probability of willingness to participate. For example, compared to those working on animal husbandry, individuals who participate in migrant labor or self-employment labor have a 5.35% probability of being more willing to participate in the construction of energy forests bases. An interesting finding is that the ratio of firewood use has a negative effect on the probability of willingness to participate; on average, a 1% increase in firewood use decreases the probability of willing to participate by 22.11%. This may be because of farmers' expectations of a higher firewood energy price after the construction of the bases. Households with low income tend to use more firewood as an energy source[6]. Presently, most of the rural households have access to firewood in self-owned forestlands with low opportunity costs.

Awareness may play a mediating role on the effects of demographic characteristics and firewood use on willingness to participate. When we incorporate the control variable of awareness, the average marginal effect of age, off-farm employment and firewood

[6] OLS regression of total income on ratio of firewood use shows a negative effect at the 1% significance level.

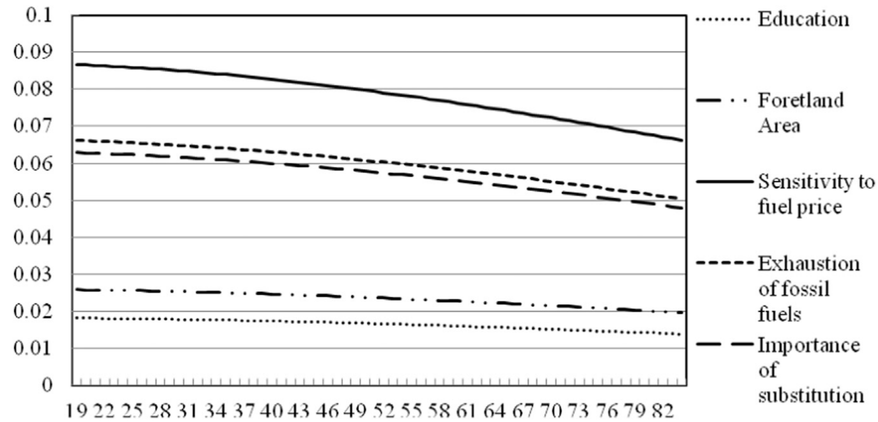

Fig. 2. Trends of marginal effects at different age.

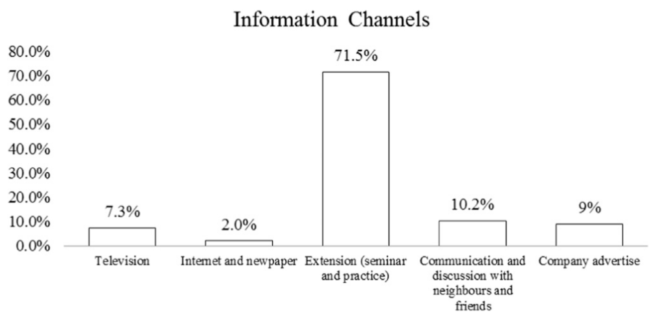

Fig. 3. Farmers' attitudes towards the various information channels. Note: The magnitudes of marginal effects of different variables are not comparable since we use different measurement scales.

ratio become insignificant. The average marginal effect of education remains almost unchanged. Moreover, households with more forestland endowment tend to have a higher probability of participating. On average, a farmer tends to have a higher willingness to participate in the construction of energy forests bases when she/he is more sensitive to the price of fuel, which provides a clearer awareness on the exhaustion of fossil fuels and the importance of substituting fossil fuels for bioenergy.

Fig. 2 shows the trend of marginal effects at different ages. Our respondents ranged between the ages of 19 and 84. With an increase in age, the marginal effects of education, forestland area, and awareness on willingness to participate all decrease at a relatively modest rate. Compared to an 84-year-old farmer, the person with same education level at age 19 has a 0.43% higher probability of being willing to participate. With a same forestland area hold, an 84-year-old has a 0.62% lower probability to participate compared to its 19-year-old counterpart. The marginal effects of sensitivity to fuel price, awareness of the issues surrounding the exhaustion of fossil fuels, and importance of energy source substitution ranges from 8.7 to 6.6, 6.6 to 5.0, and 6.3 to 4.8 percentage points, respectively.

3.4. *Farmers' attitudes towards various information channels*

The farmers were asked from which channels they had received information about forest-based bioenergy. The farmers expressed they hardly receive bioenergy information and knowledge from TV and Internet sources. Moreover, some of them mentioned that the extension officers recommended that they plant energy forests. In addition, the farmers were asked to rank the importance of the possible information sources with respect to their positive influences on the attitudes towards developing forest-based bioenergy. Based on the responses, the most appreciated information channel was forest extension in the forms of seminars and practices (71.5%). The Internet was classified as having the least amount of influence (Fig. 3).

4. Discussion

Rural China has experienced inadequate energy efficiency for a significant amount of time, which has resulted in overconsumption of biomass and an increase in air pollution. However, biomass energy, wind energy, and small hydropower development of other energy sources have been neglected. The actual situation deviates from the rural energy development policy, which aims to "adjust measures to local conditions". Wang and Feng [39] found that rural non-commercial sources of energy such as firewood, straw, and biogas form the main sources of energy in rural areas. According to the China Rural Energy Statistical Yearbook (2009–2013), during the time period 2008–2012, the utilization of fuelwood decreased and the main rural energy form was biogas from agricultural residues. With the improvement of rural household incomes, the energy structure has undergone an important phase of transformation from non-commercial to commercial energy. This has resulted in a gradual decrease in the consumption of firewood, which in turn affects the supply of rural biomass and the transformation of the ecological environment. According to the results of our study, the use of firewood in rural households has decreased, and we attribute this to the increase in the need of commercial energy. This finding is consistent with results from previous studies [10,40]. Chen et al. [43] found that woody bioenergy is not popular in China except when it is traditionally used as firewood by rural people. Moreover, the importance of firewood in traditional rural areas is declining [44]. Han et al. [10] and the National Forestry Biomass Energy Development Plan (2011–2020) claimed that wood energy forests and starch energy forests will become more centralized in the near future and their efficiency will be promoted by technologies and continuous government support [1,10,45]. Demurger and Fournier [44] revealed that increasing educational access to local farmers could modify farmers' energy consumption behavior.

According to our results, age plays a significant and negative role in influencing farmers' willingness to participate in forest bioenergy bases: younger farmers are more willing to participate than older farmers are. This is consistent with the findings of an earlier study on the supply of bioenergy, harvesting, and reforestation behavior of landowners [38]. However, our findings are inconsistent with the findings of Hu et al. [46], where age was an important factor positively correlated with the responses of farmers' attitudes towards GGP in China. Years of education, forestland area, level of sensitivity in the price of fuel, the knowledge and understanding of the exhaustion of fossil fuels, and the importance of substituting fossil fuels for bioenergy all resulted to be both significant and positive factors. These results are consistent with our initial hypothesis as well with results from previous studies [34,47]. This may be explained by the idea that with an increase in the farmers′ level of education, farmers better understand the energy crisis and forest endowment policies, and thus are more willing to participate. Jiang et al. [48] indicated that farmers with higher education were more likely to be willing to pay for participating in fee-based agricultural information services in China. Gruchy et al. [49] found that, in Mississippi, U.S.A., landowners with formal education were more likely to consider global climate change to be an important factor in promoting bioenergy utilization. Similarly, Schirmer and Bull [50] found that, in the case of afforestation, relevant knowledge increases general confidence and experience in tree-growing practices. Households with lower firewood utilization ratios had a higher willingness to participate. This may be because after the construction of the base, farmers have needed to seek and obtain permission to cut firewood forests. Persson et al. [51] discussed that in the Green for Grain Project, there was little potential to grow energy forests (only about 0.6% of the forest had potential to be used as firewood). This, in addition to the positive or negative influence from farmers′ willingness to participate, helps to determine whether farmers reap sufficient benefits from forestlands.

Joshi and Mehmood [38] found that landowners′ willingness to harvest woody biomass was influenced by the size of the forest they owned and farmers′ attitudes were largely determined by land ownership. In our study, household's total forest area significantly influences farmers′ willingness to participate. This result is consistent with our hypothesis and the study conducted by Yang and Mi [52], which revealed that households′ forest areas positively influence farmers′ willingness to participate. The new round of forest tenure reform implemented in China in 2003 had devolved forestland user rights from villages to households, individuals or groups. However, the reform also has increased the degree of forestland fragmentation [53], which might have tradeoff effects on stimulating farmers′ willingness to participate in the construction of energy forests bases. Under the collective forest tenure reform, energy forest bases require the integration of scattered forestlands, a role that can be spearheaded by local farmers. In addition, farmers′ roles in the construction of the energy forests bases are highlighted through direct farming of forests and indirect provision of labor for the construction. Relevant policies should allow farmers to initiate active roles in the establishment of energy forests bases and as well as further support their interests. This study revealed that farmers have a low willingness to participate in these activities. Energy forest bases in China are constructed in the provinces where forest tenure reform has been established, allowing farmers to play an important role during the construction period. Farmers participate in the energy forest base construction through transforming the forestland, establishing contracts, and providing labor and other services. In such areas, farmers are more aware of the market economy and also value the economic benefits of energy forests that are derived through participating in the base construction. However, during the actual operations, the forest tenure, forestland contracts, transfer issues, and the purchase of raw materials all directly influence farmers′ attitudes towards participating. Sun and Wang [33] discovered that financial incentive for farmers could promote their interest in participating. Forest extension offices combine practical experiences with scientific knowledge to guide the farmers in sustainable forest management with the aim of maximizing the forest usage, such as for bioenergy purposes [10,54]. Braunholtz [55] found that in rural areas in Scotland, local newspapers and television programs serve a significant role as the main channels of communicating information regarding renewable energy issues. Sources of information such as the aforementioned ones, coupled with education, may account for significant changes in the awareness of bioenergy issues by local people and their participation in relevant programs [55]. Results from previous studies have shown that public knowledge relating to green energy is limited, and this has significantly hindered the development of renewable energy [15,23]. Despite lack of knowledge amongst the public, people have still shown interest in being part of the renewable energy planning process [56]. The results of our study are in accordance to the aforementioned notion. In China, farmers form the main body of bioenergy use and development; thus, their education and awareness should be prioritized. Appropriate policies and easy access to various sources of information, such as open communication with experienced people and extension offices, could increase people's awareness regarding the use of bioenergy.

Energy forest construction is a new concept to farmers and requires a process of learning to understand its process. Farmers′ different understandings of this learning process produces two cognitive responses: to accept the new idea or to refute it. The cognitive response to either accept or refute the idea of constructing energy forests is produced after farmers assess their individual conditions, resource availability, and energy needs. Furthermore, cost-benefit analyses by the farmers may further influence their decision to support the establishment of energy forests. If farmers conclude that planting energy forests is profitable, they will choose to accept the implementation of the idea and confirm their "willingness to act". According to the "willingness to act" mechanism in our model, a farmer′s education is expressed by his or her ability to study as well as total forest resource endowment, which are essential conditions for engaging in the development of forest based bioenergy. Therefore, increasing education is an essential step in achieving the mechanism.

5. Conclusion and policy implications

In the case of the Chinese forest system, farmers form the main body in the construction and development of bioenergy forests. Thus, farmers′ awareness of relevant issues plays an important role in the willingness to participate in the construction of these bases. Farmers′ active participation in the energy forest base construction may guarantee the efficient development of forest-based bioenergy. Our survey regarding farmers′ awareness of bioenergy can help to better understand farmers′ action logic in constructing, managing, and operating energy forests. Furthermore, the results can contribute to the government implementation of target policies, improvement of farmers' behaviors, and enhancement of the efficiency and effectiveness of bioenergy related policies.

The theoretical and empirical analyses in this study show that willingness to participate in the construction of forest bioenergy bases is influenced by various factors. The empirical analysis demonstrates that social demographic aspects such as the household's energy structure and the head of the household's knowledge of fossil fuels influence farmers′ awareness of forest based bioenergy. The households that are comprised of younger members, with more education and a higher cognitive understanding of the fossil fuel issues, have a higher awareness of forest-based bioenergy. Furthermore, the empirical analysis revealed that the factor that drives the mechanisms regarding afforestation with energy plants is "willingness to act" on the part of the farmers. This study shows that the majority of the households have increased their daily use of commercial fuel (oil and coal). Significant numbers of farmers are either uncertain or not familiar with the concept of forest-based bioenergy. Low motivation by farmers towards developing bioenergy sites suggests that they need further education regarding the related policies and techniques surrounding relevant issues.

The government should implement strategies to help farmers in acquiring knowledge in the field of bioenergy, which can further foster farmers′ acceptability of bioenergy and its products. Besides making decisions based on influences by the economy and markets, farmers make decisions on growing bioenergy forests in ways that will maximize their personal interests. Therefore, the government should disseminate knowledge about bioenergy while at the same time helping farmers to reduce reforestation costs and develop markets for bioenergy products. Furthermore, biomass energy promotion policies should focus on emphasizing different strategies according to different income groups. At the same time, we should increase farmers′ incomes through income optimizing strategies, increasing investment in education to improve farmers′ living environments, and optimizing energy consumption to reduce CO_2 emissions.

Certain limitations in our study should be addressed. The survey can improved through incorporating a set of questions regarding household energy consumption. Moreover, the forest areas owed by any individual household should be further defined. Differences in knowledge and practices throughout the provinces may account for differences in farmers′ awareness of certain issues, a factor that we did not take into consideration in our analysis. In addition, farmers′ willingness to participate in the establishment of energy forest bases in reference to existing policies should be further studied, as well as differences in perceptions amongst various stakeholders (non-governmental organizations [NGOs], government, industry, and academia).

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