SANDEE

Working Paper, No 82–14

To Cultivate or Not? Examining Factors that Influence *Jatropha* Agriculture in North East India

Kishor Goswami
Hari Kanta Choudhury

ECONOMICS & THE ENVIRONMENT

Published by the South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056, Kathmandu, Nepal.
Tel: 977-1-5003222 Fax: 977-1-5003299

SANDEE research reports are the output of research projects supported by the South Asian Network for Development and Environmental Economics. The reports have been peer reviewed and edited. A summary of the findings of SANDEE reports are also available as SANDEE Policy Briefs.

National Library of Nepal Catalogue Service:

Kishor Goswami and Hari Kanta Choudhury
To Cultivate or Not? Examining Factors that Influence *Jatropha* Agriculture in North East India

(SANDEE Working Paper, ISSN 1893-1891; WP 82–14)

ISBN: 978-9937-596-11-4

Key words:
Jatropha
Adoption and Continuation Behavior
Current-farmers
Previous-farmers, and Non-Growers
Biodiesel Industry
North East India

To Cultivate or Not? Examining Factors that Influence *Jatropha* Agriculture in North East India

Kishor Goswami
Indian Institute of Technology Kharagpur
West Bengal 721302
India

and

Hari Kanta Choudhury
National Institute of Technology Sikkim
Ravangla Campus
South Sikkim - 737 139
India

January 2014

South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056, Kathmandu, Nepal

SANDEE Working Paper No. 82–14

The South Asian Network for Development and Environmental Economics

The South Asian Network for Development and Environmental Economics (SANDEE) is a regional network that brings together analysts from different countries in South Asia to address environment-development problems. SANDEE's activities include research support, training, and information dissemination. Please see www.sandeeonline.org for further information about SANDEE.

SANDEE is financially supported by the International Development Research Center (IDRC), The Swedish International Development Cooperation Agency (SIDA), the World Bank and the Norwegian Agency for Development Cooperation (NORAD). The opinions expressed in this paper are the author's and do not necessarily represent those of SANDEE's donors.

The Working Paper series is based on research funded by SANDEE and supported with technical assistance from network members, SANDEE staff and advisors.

Advisor
Subhrendu K. Pattanayak

Technical Editor
Mani Nepal

English Editor
Carmen Wickramagamage

Comments should be sent to
Kishor Goswami
Associate Professor of Economics, Department of Humanities & Social Sciences
Indian Institute of Technology Kharagpur
West Bengal 721 302; India

Email: kishor_00@yahoo.com

Contents

Tables

Figures

Annexes

Abstract

This study examines factors that determine the adoption and continued production of *Jatropha* in plantations in North East India. The study is based on a sample of 144 current-farmers, 137 previous-farmers, and 145 non-growers of *Jatropha* in the states of Assam and Arunachal Pradesh. The findings suggest that farmer characteristics such as their willingness to take risks, whether they have land that is not in use in agriculture, and knowledge of the product play an important role. Institutional factors such as availability of credit, and structural issues related to product and labor markets and travel time and distance are important considerations in whether *Jatropha* is adopted and plantations are continued. The study shows that, although there are serious bottlenecks to increasing *Jatropha* production, these problems can be remedied with some important institutional interventions. The study recommends extension of government credit facilities to farmers since the opportunity costs of labor and land, the initial low return, and the approximately 7-year payback period from *Jatropha* cultivation reduce farmer interest in continuing with *Jatropha* cultivation.

Key Words: *Jatropha; Adoption and Continuation Behavior; Current-farmers, Previous-farmers, and Non-Growers; Biodiesel Industry; North East India.*

To Cultivate or Not? Examining Factors that Influence *Jatropha* Agriculture in North East India

1. Introduction

Biofuel has been gaining in popularity in recent years because of its potential as a clean energy source and a means to stimulate rural development (Kumar and Mohan, 2005; Hazell and Pachauri, 2006; Jongschaap et al., 2007; Kumar and Sarma, 2008; Rajagopal and Zilberman, 2007). Many countries are prioritizing renewable energy generation both because of commitments made to the Kyoto Protocol and because they want to improve domestic energy security (Chandak and Somani, 2011). Several goverments are encouraging biofuels such as ethanol and biodiesel through measures such as mandatory blending of biofuel with gasoline or diesel, tax exemptions, subsidies, supply and demand stimulation and formal targets for biofuel usage (Walburger et al., 2006; Kojima et al., 2007; Rajagopal and Zilberman, 2007).

India ranks sixth in the world in terms of total energy demand (TERI, 2005), with energy demand growing at a rate of 4.8% per annum (Agoramoorthy et al., 2009). However, domestic production seriously lags behind consumption.[1] Thus, oil import expenditure has grown nearly three folds since 2004-05 (Singh, 2009) and India is expected to become the fourth largest net importer of oil in the world by 2025 (EIA, 2010). This implies a large out flow of foreign currency reserves. Additionally, any instability in the price and supply of crude oil can adversely affect the domestic economy as experienced in the 1970s and in the 2007-08 (Hamilton, 2009). Thus, energy security is a vital issue for India, making the use of domestically produced biodiesel quite attractive.

India's biofuel policy seeks to increase demand for biodiesel to 16.72 million tons by 2017 and encourages 20% blending of biodiesel with other fuels (Planning Commission, 2003). The main source for biodiesel is the plant *Jatropha*, which is a relatively new crop in Indian agriculture (Raja et al., 2011; Aradhey, 2013). There are, however, several supply side problems associated with *Jatropha* cultivation that are hampering biodiesel production. In order to meet the 20% blending of biodiesel with petro diesel by 2030, about 38 million hectares of wastelands have to be brought under *Jatropha* plantation with a potential yield of 5 tons per hectare (TERI, 2005). This is a major challenge as *Jatropha* is a new perennial crop for the farmers, who see considerable risk and uncertainty in its production, profitability and employment generation. There are reports that farmers who had taken up *Jatropha* in certain regions are abandoning their plantations for alternate uses, while others are not taking care of their plantation (Montobbio and Lele, 2010). Further, there are questions related to whether *Jatropha* should be encouraged since it may replace staple crops (McMichael, 2010; Wilkinson and Herrera, 2010). Given, the explicit government policy to encourage *Jatropha* production and emerging information on the lagging farm supply response, our study seeks to identify and analyze the factors that influence *Jatropha* plantations by farmers.

Our study relies on micro-economic theory to examine farmers' behavior and adoption of a new crop such as *Jatropha*. It also builds on a large emprical literature on why farmers adopt new technologies to identify (Welch, 1978; Feder et al., 1985; Adesina and Forson, 1995; Rogers, 2003). Our empirical analyses is based on data from a survey of 426 farmers, categorized into current-farmers, previous-farmers and non-growers of *Jatropha*, undertaken in North East India during November 2011 to March 2012.

In the following section, we first briefly review the literature on farmers' adoption behavior. Section 3 presents the theoretical background and empirical methods. Section 4 discusses the study areas and sampling strategy. Section 5 presents the results and discusses their implications while Section 6 concludes and provides future research directions.

---

[1] India's domestic production of crude oil satisfying only 29% of its consumption in 2007.

2. Assessing Adoption Behavior and Methodologies

The theory of diffusion of innovations suggests that innovation can lead to either adoption, which signifies a decision to make full use of an innovation as the best course of action available, or rejection, even though such a decision can be reversed at a later point in time (Rogers, 2003). Agricultural innovation adoption generally involves a dynamic process in which information gathering, learning, and experience play pivotal roles, particularly in the early stages of adoption. The decision to adopt, reject or defer the decision at a particular point in time is influenced by the knowledge of farmer at that point in time and his or her perception regarding the issue at hand with the decision open to reconsideration after the acquisition of more knowledge and/or opinions from those who had already adopted. Thus, the characteristics of both the user and the technology play an important role in explaining the adoption behavior (Jabbar et al., 1998).

While it may be expected that profitability is key to adoption decisions (Hipple and Duffy 2002), in reality numerous factors influence adoption of new crops and technologies, particularly perennial crops. Clancy et al. (2008), for instance, in their work on biomass crops in Ireland, found that the returns from the current perennial enterprise was not a significant factor when making an adoption decision – the reluctance of Irish farmers to switch to a higher-return enterprise revealed that there was more than financial considerations involved. Similarly, in the case of *Jatropha* plantations in India, Rajagopal (2011) has argued that the long maturation phase and lack of experience of farmers with *Jatropha*, as compared to annual crops like Sweet Sorghum and Castor, are important barriers to adoption. The long term commitment required and the cost of reversing land-use decisons may make farmers reluctant to adopt perenniel energy crops (Schatzki, 2003; Song et al., 2009).

Analyzing adoption behavior in non-divisible innovations, Feder et al. (1985) argues that factors such as off-farm income might affect adoption by providing a source of cash flow to buffer the risk associated with the introduction of new crop management practices. Moreover, structural issues such as the existence of effective extension services, adequate access to inputs, timely credit availability, transportation, and functional marketing channels are of paramount importance. These arguments are reinforced by Pattanayak et al. (2003), who identify five categories of factors – preference, resource endowment, market incentives, biophysical factors, and risk and uncertainty – to explain technology adoption within an economic framework.

Farmers' characteristics such as ownership of land and age and subjective preferences and economic motivation with regard to new agricultural technologies have a significant bearing on adoption behavior (Adesina and Forson, 1995; Suhendar, 1997). Similarly, education and other attributes related to human capital such as attendance of extension programs, and membership in farm-related organizations play a positive role in adoption, particularly for the more sophisticated technologies (Welch, 1978; Ellis, 2006; Breen et al., 2009). Farm-related characteristics such as the total number of acres farmed, erosion, and no-till production methods also matter in adoption decision (Ellis, 2006; Breen et al., 2009). We draw from these studies in the identifying factors that are likely to affect farmers' *Jatropha* adoption decisions.

Intangible factors, not easily quantified or explained by economic theory, are also important determinants of adoption behavior. Farmers, who perceive themselves to be “late adopters” or who take a wait-and-watch attitude, are less likely to be interested in growing a new crop (Qualls et al., 2011). Older producers are also less likely to be interested because of the limited timeframe available for them to benefit from the crop. At the other end, farmers willing to take risks and are experienced would be more likely to express interest in adoption. Higher income farmers too may take the risk of growing a new crop because of the availability of resources to tide them over while they await benefits from the new crop or in the case of failure.

Mercer (2004) argues that in agroforestry, in particular, the role of risk and uncertainty with regard to adoption behavior is largely under-studied. Only in a few instances has risk been directly evaluated with researchers typically emphasizing a few risk proxies such as tenure, experience and extension. Mercer therefore suggests that studies should try to measure risk preferences and perceptions directly. In the same vein, Just and Zilberman (1983) identify risk associated with yield, price, and government policy as important factors affecting adoption of agricultural technologies. In the next section, we discuss our data collection strategy to ensure that risk is accounted for in the analyses of adoption decisions.

Numerous studies in recent years have used different econometric models to analyze the influence of different factors on decision variables, with a few such studies conducted on adoption-related decisions (Neupane et al., 2002; Pattanayak et al., 2003; Johnson, 2005; Macandog et al., 2006; Pundo and Fraser, 2006; Jensen et al., 2007; Adeogun et al., 2008; Uzmay et al., 2009; Goswami and Choudhury, 2012; Choudhury and Goswami, 2013). Annex I and Annex II show that Logit and Probit models are most frequently used in analyzing the farmers' adoption behavior. The available literature makes it evident that farmers' adoption behavior is influenced by many factors and that researchers have resorted to proxies to measure the impact of these factors. We use this literature to build our methods for analysing factors that are most likely to affect farmers's decisions to adopt and continue with *Jatropha* plantations.

3. Adoption Behavior: Theory and Empirical Methods

We base our theoretical model for the purpose of testing farmers' adoption behavior with regard to *Jatropha* mostly on the household production theory of Singh et al. (1986) and Strauss (1986). We also closely follow the agroforestry adoption model developed by Mercer and Pattanayak (2003).

Similar to agroforestry adoption (Mercer and Pattanayak, 2003), adoption of *Jatropha* plantations requires joint investments of money, labor, and land to acquire *Jatropha* based capital i.e., labor and money are collectively embodied in the amount of land dedicated to the *Jatropha* plantation. This joint investment is conditioned by the resource endowment and bio-physical conditions faced by the household. We may therefore conceive of the *Jatropha* plantation (J_A) as one among many sets of coordinated investments that produce an annual rate of return to enhance the overall well-being of the farmer concerned. Since the returns to *Jatropha* plantation occur in the future, households consider the expected stream of income net of consumption or the market-based incentives in choosing between alternate investments. These expectations are based on the household's assessment of the relative importance of *Jatropha* plantations' income to total farm income, which depends on the farmer's calculation of risks and uncertainty both in the short and long terms.

We now consider the choice facing household i when deciding whether to adopt *Jatropha*. The utility maximizing household compares its expected net utility (EU^*_i) with and without adoption. A reduced form of the net utility can be expressed as:

$$EU^*_i = Xi\,\beta + \varepsilon i \tag{1}$$

Where, X_i is the vector of explanatory variables and β is the vector of coefficients to be estimated. Since we do not know the true net utility function, the estimated function is considered as random by including the error term εi. A farmer adopts *Jatropha*, if he/she finds that expected utility (EU^*_i) of adoption of *Jatropha* is greater than non-adoption.

We can represent the adoption of a technology or a new crop or a management practice by a number of different indicators. These include a discrete decision to use or not to use (a variable defined as either one or zero), a proportional indicator (such as a share of the land or share of plants), an index of scale or extent of use (such as the number of hectares or the number of plants), the level of choices or intensity of use (per hectare or per plant), or frequency of use (such as the number of seasons or the number of applications per season).

An important issue pertaining to all of these indicators is that practice at any one point in time is not a robust indicator of adoption (Smale et al., 2007). Thus, in order to study the farmers' adoption behavior, we need to define the term "adoption" in the context of time. In our study, we consider only those farmers who are continuing with a *Jatropha* plantation as an adopter of *Jatropha*. Following Jabbar et al. (1998), and Wendland and Sills (2008), we divide the farmers' adoption of *Jatropha* into two stages. In the first stage, we analyze whether a farmer adopts *Jatropha* or not. If a farmer adopts *Jatropha*, we analyze whether he will continue or abandon it in the second stage. In both the cases, the dependent variable is binary in nature. Those farmers who discontinue their plantations are considered as previous-farmers for the purposes of the study. On the other hand, those farmers who are yet to adopt *Jatropha* are defined as non-growers.

As the different studies on adoption behavior discussed in Section 2 suggest, the decision of farmers to adopt *Jatropha* is influenced by a host of factors. Farmers in the first instance will decide whether to continue with *Jatropha* or abandon it on the basis of their experience after their initial adoption experience. This decision will be influenced again by a combination of economic, personal, institutional, and physical factors. Figure 1 gives the conceptual framework of farmers' adoption of *Jatropha* in the form of a flow chart.

The literature shows that risk and uncertainty remain among the most under-studied aspects of adoption behavior. Following Mercer's suggestion (Mercer, 2004), our study identifies farmers' risk preferences through an experiment and integrates it to the adoption decision analyses. Our understanding of risk is based on the Neumann-Morgenstern expected utility concept (Sen, 2007). In the experiment, we give the farmer the option to choose from two alternatives: (A) either the farmer could have INR 10 now for sure or (B) a coin would be flipped and, if the outcome is a head, he would receive INR 30 now and if it is a tail, he would receive no money. We kept the incentive payoffs at a lower level as the literature shows that nearly all individuals, regardless of personal characteristics, are moderately risk averse at higher payoff levels (Binswanger, 1980). A farmer was categorized as a risk averter if he chooses option A and a risk taker if he chooses option B. Though we made available a third option (C) for those who are indifferent, in the present study, no respondent was found to choose this option. Accordingly, we do not consider this option in the study.

We based the farmers' adoption of *Jatropha* on the theoretical model developed by Mercer and Pattanayak (2003), where the i^{th} farmer adopts *Jatropha* if the expected utility/ net benefit of adoption (J^*_A) is positive. Thus the model is specified as:

$$\begin{aligned}J_A^* = {} & \Phi_0 + \Phi_1\,\textit{Age} + \Phi_2\,\textit{Age square} + \Phi_3\,\textit{Education} + \Phi_4\,\textit{Primary occupation} + \Phi_5\,\textit{Farming experience} + \\ & \Phi_6\,\textit{Cultivable land} + \Phi_7\,\textit{Distance to nearest market} + \Phi_8\,\textit{Availability of unemployed family member} + \\ & \Phi_9\,\textit{Labor shortage} + \Phi_{10}\,\textit{Location} + \Phi_{11}\,\textit{Rainfall} + \Phi_{12}\,\textit{Non-farm employment opportunity} + \Phi_{13}\,\textit{Credit} \\ & \textit{availability} + \Phi_{14}\,\textit{Extension service} + \Phi_{15}\,\textit{Risk behavior} + e_i \qquad (2)\end{aligned}$$

Where,

J^*_A is not directly observable. The researcher can observe a farmer's adoption decision of *Jatropha* such that J_A is equal to *1* if the farmer adopts *Jatropha*, and *0* if he does not, which is observable, i.e.,

$$J_A = \begin{cases} 1 \text{ if } J^*_A > 0 \\ 0 \text{ if } J^*_A \geq 0 \end{cases}$$

Whether a farmer continues with *Jatropha* or abandons it is also specified similarly to the model of the farmers who adopt *Jatropha*. The i^{th} farmer continues with *Jatropha* if the expected utility/net benefit of continuation (J^*_c) is positive. Thus, we specify the model as:

$$\begin{aligned}J^*_c = {} & \mu_0 + \mu_1\,\textit{Age} + \mu_2\,\textit{Age square} + \mu_3\,\textit{Education} + \mu_4\,\textit{Knowledge about Jatropha} + \mu_5\,\textit{Availability of unemployed} \\ & \textit{family member} + \mu_6\,\textit{Labor shortage} + \mu_7\,\textit{Distance to nearest market} + \mu_8\,\textit{Slope of land under Jatropha} + \\ & \mu_9\,\textit{Average time to reach plantation site} + \mu_{10}\,\textit{Location} + \mu_{11}\,\textit{Rainfall} + \mu_{12}\,\textit{Non-farm employment opportunity} + \\ & \mu_{13}\,\textit{Alternative use of the land} + \mu_{14}\,\textit{Minimum expected income to continue with Jatropha} + \mu_{15}\,\textit{Expected market} \\ & \textit{price} + \mu_{16}\,\textit{Expected payback period} + \mu_{17}\,\textit{Access to credit} + \mu_{18}\,\textit{Technical help in planting and pruning} + \mu_{19} \\ & \textit{Extension services} + \mu_{20}\,\textit{Risk behavior} + \mu_{21}\,\textit{Ant and pests attack} + \upsilon I \qquad (3)\end{aligned}$$

Where,

J^*_c is not directly observable. The researcher can observe a farmer's adoption decision of *Jatropha* such that J_C is equal to 1 if the farmer continues with *Jatropha*, and 0 if he does not, which is observable, i.e.,

$$J_C = \begin{cases} 1 \text{ if } J^*_A > 0 \\ 0 \text{ if } J^*_A \geq 0 \end{cases}$$

4. Study Area and Sampling Strategy

4.1 Study Area

One of the major concerns of the biofuel policy in India is how to make suitable land available for *Jatropha* plantation without exerting a negative impact on food production. However, this problem is not acute in North East India as the total wasteland in North East India is 44,315.06 km^2 in 2008-09, which is about 9.5% of the total wasteland of India (Wastelands Atlas of India, 2011). Out of this wasteland, about 46% is land with scrub or without scrub. Shifting cultivation, a form of cultivation resulting in soil erosion and degradation of forest, constitutes 17%, and underutilized/degraded forest area (scrub dominated) constitutes 8.2% the total wasteland of the region (Wastelands Atlas of India, 2011). These three categories of land can easily be used for *Jatropha* plantation and may work as a green cover to reduce soil erosion and landslides in the region.

The initiative with regard to *Jatropha* plantation in NE India mostly remains in the hands of private companies such as D1 Williamson Magor Bio Fuels Limited (D1WMBF Ltd), Sun Plant Agro Limited, etc. These private companies encouraged *Jatropha* plantation activities in the region for making profit through production and sale of biodiesel. D1WMBF Ltd, for instance, started a major initiative by encouraging farmers to undertake *Jatropha* plantations in 2007-08. They brought under *Jatropha* a total area of 39,400 hectares and 46,020 hectares in 2007 and 2008 respectively (D1WMBF Ltd, n.d.) in seven north eastern states. Of the various north eastern states, Assam has the largest amount of area under *Jatropha* plantation (33,900 hectares) followed by Tripura (26,000 hectares). However, since 2010-11, farmers have started switching from *Jatropha* plantation to other activities in many places.

Our study is confined to the Indian states of Assam and Arunachal Pradesh. We selected Assam because it is different from the other North Eastern states in terms of altitude and topography. In contrast, Arunachal Pradesh is meant to represent the other North Eastern states as it is similar in topography to these states.

4.2 Sampling Strategy

Our study is based on both primary and secondary data. We collected primary data from 22 villages in five districts in Assam[2] and 6 villages in the Papumpare district of Arunachal Pradesh (see Map 1). We first identified the districts, then blocks, and finally villages based on the intensity of current-farmers and previous-farmers of *Jatropha*. Information on intensity of *Jatropha* production was based on personal visits, discussions with block development officers (BDOs), and agricultural extension officials.

We collected primary data from 426 farmers using multistage random sampling. In the first stage, we used purposive sampling based on the fair availability of current-farmers, previous-farmers, and non-growers of *Jatropha* in the villages. Within each category in the selected villages, we randomly selected on average 5 respondants in Assam and 4 respondents in Arunachal Pradesh. We sampled current-farmers, previous-farmers, and non-growers of *Jatropha* from the same villages to ensure that the respondents faced a similar environment. We interviewed 144 current-farmers, 137 previous-farmers, and 145 non-growers of *Jatropha* from different villages in the districts through a pre-tested questionnaire during November 2011 to March 2012 (see Annex III).

We also organized a total of 11 focus group discussions (FGDs), one in each block[3] where the primary survey was conducted, to collect and cross-verify information related to *Jatropha*. We collected secondary data from the North Eastern Council, Ministry of Environment and Forest, Ministry of Development of North Eastern Region, Department of Economics and Statistics of Assam and Arunachal Pradesh, libraries, Internet, etc. We were also able to collect secondary data from companies/organizations directly involved in the industry such as D1 Williamson Magor Bio Fuels Ltd and the North Eastern Development Finance Corporation Ltd.

---

[2] Cachar, Karimganj, Karbi Anglong, North Lakhimpur, and Dhemaji.

[3] Blocks are the local revenue sub-divisions in a district of an Indian state.

4.3 *Jatropha* Plantations in North East India

Our field survey shows that the average *Jatropha* farmer is 41 years old, has a household of 6 members and has 7 years of education (Tables 1a and 1b). With regard to the current-farmers and non-growers, t-tests and McNemar's Chi2 tests suggest significant differences in socio-economic variables such as age, primary occupation, cultivable land, availability of unemployed family member, availability of credit, and extension services (see Table 2 and Figure 2). In general, *Jatropha* farmers were older (41 years vs. 37 years), were more likely to be farmers (61% vs. 55% of primary occupation) and had more land (3 ha vs. 2 ha) relative to non-growers.

In the case of current-farmers and previous-farmers, we also observed significant differences in the availability of unemployed family members, labor shortage, average time to reach the plantation site, non-farm employment opportunities, alternative use of the land, minimum expected income to continue with *Jatropha*, expected market price, expected payback period, access to credit, technical help in planting and pruning, extension service, and risk behavior (Table 2 and Figure 2). Of these, the largest difference was related to expected payback period. Current-farmers expected payback period is 16 years, while for previous-farmers it is 24 years. Similarly, average time to reach *Jatropha* plantation site is higher (27 minutes) for previous-farmers than the current-farmers (14 minutes). Figure 2 also shows that the current-farmers are more knowledgable, seem to have less labor shortages and are willing to take higher risks relative to previous farmers.

The majority of the farmers cultivated *Jatropha* in less than one hectare of the area. Statistical testing suggests that there is a small but significant difference (at the 10% level) in the average area brought under *Jatropha* plantation between current-farmers and previous-farmers, with current-farmers having slightly more land in *Jatropha*. Most farmers (50%) allocated less than 20% of their land, i.e., a small portion, as would be expected, to *Jatropha*.

A *Jatropha* plant provides yields only after the sixth year (NABARD Consultancy Service, 2007; Punia, 2010). As the oldest plantations in our sample were around 4 to 5 years old at the time of the survey, only a few farmers reported economic yields in terms of *Jatropha* seed. We found during focus group discussions that *Jatropha* seedling distribution in our study area started 4 to 5 years ago. Almost all the respondents reported that the seedling provided by D1WMBF Ltd was used for *Jatropha* plantation.

It is also interesting to note that on average the previous-farmers had abandoned their *Jatropha* plantation after 2.5 years. This suggests that farmers were un-willing to wait for yields and profits before abandoning their plantations. Figure 3 shows the reasons identified by the previous-farmers for abandoning their planations. A majority of the growers (both previous and current farmers) cited additional sources of income generation as the primary reason for opting for *Jatropha* cultivation, followed by financial support from government in terms of loan (Figure 4). The main reason cited for abandoning *Jatropha* was lack of profits. It may be noted that into their third years, farmers perceived the lack of returns from the plantation crop more strongly and abandoned it.

5. Results and Discussion

5.1 Farmers' Adoption of *Jatropha*

We estimate a Probit model, with and without village fixed effects, to analyze the influence of personal, physical, economic, institutional, and risk and uncertainty factors on farmers' adoption as well as continuation decisions. Table 1a and 1b portray the summary statistics of the factors used.

Table 3a and 3b presents the regression results of the Probit model and specification test of adoption of *Jatropha* with and without village fixed effects. The results indicate that cultivable land, availability of credit, extension service, and risk behavior have a statistically significant and positive influence on adoption in both models (see Table 3a and 3b). Non-farm employment opportunity and rainfall have a negative influence on the adoption of *Jatropha* plantations.[4]

---

[4] In order to avoid the problem of heteroscedasticity, we use robust standard error to test the significance of the coefficients. The study however fails to reject the null hypothesis of a few factors, namely, age, education, primary occupation, farming experience, distance to the nearest market, availability of unemployed family member and labor shortage. Thus, the study finds the influence of these factors on the adoption decision to be statistically not significant.

The estimates of the marginal effects calculated at sample mean indicate that holding other factors constant, a) an increase in the amount of cultivable land by one hectare increases the probability of adoption by about 4% (in both models); b) an increase in rainfall by 1,000 milimeter reduces the probability of adoption of *Jatropha* by 33 to 228%; c) availability of non-farm employment opportunity reduces the probability of adoption by 24 to 32%; d) credit availability for *Jatropha* increases the likelihood of adoption by 49 to 72%; e) the availability of extension services increases the probability of adoption by 15 to 46%; and f) being a risk lover or risk taker increases the probability of adoption of *Jatropha* by around 15% (see Table 3a).

Scarcity of suitable land is one of the major constraints facing biofuel development in developing countries (Peters and Thielmann, 2008; TERI, 2005). Our study confirms that availability of cultivable land has a positive impact on the adoption of *Jatropha*, the reason being that farmers with a sizeable amount of cultivable land adopt *Jatropha* as a means of diversifying their cropping pattern. Among the respondents in our study, the average available cultivable land suitable for *Jatropha* with adopting farmers was about 50% more than that among the non-adopting farmers, the variation ranging from 2-3 ha.

Rainfall has a negative influence on the adoption of *Jatropha*, which may be due to the fact that higher rainfall causes severe damage at 'flowering' time to *Jatropha* and may, in turn, lead to low production. The negative influence of non-farm employment opportunity on the adoption of *Jatropha* is attributable to the fact that *Jatropha* is a new crop with a 5 to 6 year gestation period. Coupled with the element of uncertainty emanating from the adoption of a new crop, it is therefore natural for farmers to consider *Jatropha* plantation as a secondary option with regard to income generation. This leads in turn to a trade-off in the allocation of labor between *Jatropha* plantation and other primary crops or activities.

The availability of institutional help also plays a key role in farmers' decisions on adoption. The study shows that the availability of credit for *Jatropha* plantation and extension services increases the likelihood of adoption of *Jatropha*. Since *Jatropha* is a new perennial crop for the farmers, awareness about the different uses of *Jatropha* is very low among the farmers. Therefore, the impact of extension services is positive as predicted.

The literature on farmers' adoption behavior shows that risk is an important factor in explaining the adoption of any new crop or technology, with the likelihood of adoption being higher for persons who are risk takers. Those who adopt a wait-and-see attitude are less likely to be interested in growing a new crop, as Qualls et al. (2011) show for switchgrass in the South Eastern United States. The present study confirms this finding in that the likelihood of adoption of *Jatropha* plantation is higher among risk takers.

5.2 Farmers' Continued production of *Jatropha*

We analyzed the factors influencing continuation with *Jatropha* plantation by farmers in order to throw some light on the post-adoption scenario. We considered continuation as an activity where farmers continued with same *Jatropha* plantation for at least 3 years.

Knowledge about *Jatropha*, distance to nearest market, access to credit and risk behavior have a positive and significant influence on continuation, whereas labor shortage, average time to reach the plantation site, rainfall, non-farm employment opportunity, alternative uses of the land, and expected payback period have a negative influence (see Table 4a and 4b). Other factors remaining constant, the estimates of signicant marginal effects calculated at sample mean show that, in the two models (see Table 4a and 4b):

a. Some knowledge about *Jatropha* increases the probability of continuation by 30 and 36%;
b. Labor shortage reduces the likelihood of continuation by 28% and 21%;
c. A one kilometer increase in the distance to nearest market increases the probability of continuation by 36% in the second model;
d. Every 1,000 milimeters increase in the average rainfall reduces the probability of continuation by 148% in the second model;
e. A one minute increase in the average time to reach the plantation site reduces the probability of continuation by about 2% in both the models;

f. The availability of non-farm employment opportunities reduces the probability of continuation by 38% in both the models;
g. The availability of alternative uses for the land under *Jatropha* reduces the probability of continuation by 36% and 40%;
h. The probability of continuation decreases by 3% and 4% with every one year increase in the expected payback period. Since the usual payback period for *Jatropha* is about 7 years (Goswami et al., 2011), initial financial support for low income growers becomes vital for continuation.
i. Access to credit increases the probability of continuation by 29% and 44%.
j. Being a risk taker increases the probability of continuation with *Jatropha* by 45% in the first model and 50% in the second model (see Table 4a).

The positive influence of knowledge about *Jatropha* on continuation with *Jatropha* plantation indicates that lack of knowledge leads to inadequate plantation practices on the part of the growers, which results in inadequate maintenance, poor growth, and higher mortality of plants, with farmers consequently losing interest and abandoning their plantations. Moreover, knowledge enables farmers to anticipate correctly the prospects of and benefits from *Jatropha*, thus motivating them to adopt *Jatropha* plantation.

The negative impact of the labor shortage problem on continuation with *Jatropha* arises from the fact that, when faced with labor shortages, farmers prioritize agricultural activities to ensure food security. Further, *Jatropha* plantations suffer when farmers face labor shortage as this reduces the time spent on proper maintenance of plantation sites. In contrast, increases in the distance to nearest market increases the probability of continuation with *Jatropha*. This is because access for selling of non-plantation crops on a regular basis is limited. Since *Jatropha* is not harvested frequently, growers may prefer to continue with this crop instead of shifting to other activities.

The time required to reach the plantation site is related to an increase in the transportation cost. At a constant price of *Jatropha* seed, the increase in transportation cost reduces profits, thus adversely affecting the interest of farmers in *Jatropha* plantations, which would lead eventually to the abandonment of the plantation.

Similarly, non-farm employment opportunities and alternative uses for the land under *Jatropha* represent an opportunity cost for farmers of *Jatropha* plantations. Since the plantation of *Jatropha* involves a long-term commitment from farmers along with the opportunity cost of land and labor, the higher opportunity cost induces the farmers to switch land or labor from *Jatropha* plantation to some other use, particularly in the absence of a reasonable return from the plantation.

The negative effects of the expected payback period from the *Jatropha* plantation on the decision to continue with *Jatropha* are explicable on the grounds that *Jatropha* plantations entail a certain amount of up-front investment. An increase in the expected payback period would discourage investors from continuing with that project.

Utilizing credit facilties for activities connected with *Jatropha* plantation increases the probability of continuation with *Jatropha* since access to credit enables the farmers to meet the expenses of the establishment, and the operation and maintenance costs of the *Jatropha* plantation. Moreover, farmers would want to delay the burden of loan repayment by showing that they are still continuing with *Jatropha* plantation.

The positive relation between continuation with *Jatropha* and farmers' risk-taking behavior implies that the risk-loving farmers are more likely to take the risk of plantation and wait longer than risk-averse farmers in anticipation of positive results. Therefore, the probability of continuation with *Jatropha* increases with risk-taking behavior.

5.3 Discussion

The econometric analyses suggests that several factors (both economic and non-economic) play an important role in the process of adoption and continuation of *Jatropha* plantation in North East India.

Availability of land and labor for *Jatropha* plantation are significant constraints. Although, at governmental level, policies are designed to stop conversion of normal cultivable land for *Jatropha*, our study suggests that these policies are not fully implemented at the ground level. About 19% of *Jatropha* growers used their regular agricultural land for *Jatropha* plantations. Land conversion from agriculture to *Jatropha*, interestingly was higher for previous-farmers (26%) relative to current-farmers (13%). Moreover, about 73% of the amount of land brought under *Jatropha* plantation can be used for other agricultural activities, but limited markets make this difficult. In general, however, since there are alternative uses of land, this makes the adoption and continuation decisions tenuous. Similarly, availability of non-farm employment opportunity works against the continued production of *Jatropha*. Thus, *Jatropha* production, like many other agricultural decisions, are driven by the local demand and supply of labor and land.

Several institutional factors need further discussion. To the extent, that farmers are able to grow *Jatropha* in land that is not economically viable for alternate uses, the more likely that they will continue with these plantions. Extension services can play an important role in educating farmers in making these land use decisions. As our econometric analyses suggest, farmers with better knowledge are more likely to continue with *Jatropha* plantations. Similarly, availability of credit is an important variable. This is more so during the gestation period as financial support in the intial stage is crucial to continue with the crop. However, proper use of credit is also equally important. Our background research suggests that credit is available only in Cachar, Lakhimpur, and Papumpare districts. Of the total sampled *Jatropha* growers (both current and previous farmers), about 40% received loans for *Jatropha* plantation. Out of those who received loans, only 42% used their loan for the given purpose with misuse of loans being signficantly higher for the previous-farmers (93%) than the current-farmers (28%).

We undertook a simple cost-benefit analysis to better understand the net returns to a hectare of *Jatropha* plantation. This simple analysis shows that labor and seedling costs are the major establishment cost component of a plantation. Costs incurred on cleaning and weeding are the primary operational and maintenance cost components (Goswami et al., 2011). We note, however, that in North East India, seedlings have been distributed for free so it is only the labor costs that matter. Our econometric analyses reinforces this understanding, as it is found in the Table 4a that labor shortage problem reduces the likelihood of continuation by 21 to 28%.

Different studies indicate that *Jatropha* plantations are economically viable, although not highly profitable (Goswami et al., 2011; Shinoj et al., 2010). Our preliminary analysis shows that plantations are not viable at the current market price of *Jatropha* seeds of INR 5 and a low harvest of 1.5 tons of seeds per hectare. However, the expected harvest from plantations in NE India is 2.5 tons (Goswami et al., 2011). Thus, price of seeds and production level play crucial role. However, the profitability of *Jatropha* cannot be compared with other perennial crops (like rubber and tea[5]) as *Jatropha* are grown in areas where the opportunities of growing other crops are limited. Moreover, the harvests of these plantation crops require nearby processing units, which is not the case with *Jatropha* seeds.

6. Conclusion and Recommendations

India's biofuel policy seeks to increase demand for biodiesel and encourages blending of 20% biodiesel with other fuels. This is a major challenge as *Jatropha* is a new perennial crop for the farmers, who see considerable risk and uncertainty in its production, profitability and employment generation. Thus, our study seeks to identify and analyze the factors that influence the adoption of and continuation with *Jatropha* plantations by farmers.

The study shows that three sets of factors, i.e., farmers' characteristics, institutional factors and structural issues are very important for the decision to adopt and continue with *Jatropha* planations. Farmer characteristic such as their willingness to take risks and whether they have land that is not in use in agriculture play an important role. Two institutional factors are critical – availability of credit and extension services. The first of these helps reduce the short term pinch imposed by growing a perennial crop, while the second leads to better knowlege and land use decisions. If farmers are able to grow *Jatropha* in land that is really not suitable for agriculture, they are more likely to stick with the plantation. Structural factors such as non-farm labor availability and travel and time related to transportation of labor, seedlings, etc., also matter. Thus, to the extent that markets and transport infrastructure improves, this will aid *Jatropha* production.

---

[5] Initial investments in rubber and tea are INR 38,070 (http://planning.up.nic.in/innovations/inno3/ph/rubber.htm) and INR 136,900 (http://planning.up.nic.in/innovations/inno3/ph/tea.htm) respectively against *Jatropha* where it is about INR 13,945 (Goswami et al., 2011).

The findings of the study have important implications for policy measures to expand the biodiesel industry in the region. Since institutional factors, such as the access to credit, help in the adoption and continuation of *Jatropha* plantations, government institutions ought to extend such facilities to farmers where they are currently not available. Moreover, credit provision needs to be coupled with proper utilization of approved credit and here the role of extension services comes in. Apparently, there have already been improvements in the use of credit, possibly because of improved monitoring, but this aspect needs to be further strengthened.

As the opportunity cost of labor and land have a negative and significant influence on continuation with *Jatropha* plantations, the government could think about increasing the market price for *Jatropha*. The biodiesel price in India is artificially low and is less than half of that of subsidized fossil diesel (INR 26.5 per liter[6,7] of biodiesel against INR 53.1 of fossil diesel in Delhi[8]). Low biodiesel price make *Jatropha* less attractive and can demotivate farmers. Therefore, for achieving sustainability in production of *Jatropha* seeds, it is necessary to increase the market price of biodiesel which will ultimately minimize the gap between the expected and actual income from *Jatropha*.

Jatropha production is a small but essential part of India's strategy for increasing reneweable energy sources in the country. Our study shows that there are serious bottlenecks to increasing *Jatropha* production but these problems can be remedied with some important institutional interventions.

Acknowledgements

This paper is the outcome of a project entitled *Sustainability of Biodiesel Industry in North East India*, which is financially supported by SANDEE. We gratefully acknowledge this support. We wish to thank our SANDEE advisor Subhrendu K. Pattanayak for helpful suggestions and comments. We also thank Priya Shyamsundar, Mani Nepal and the SANDEE Secretariat for all the support they have provided towards the execution of the project. We found the comments and suggestions from J.M. Baland, M.N. Murty, E. Somanathan, and an anonymous reviewer helpful. We also acknowledge the assistance from Bhabesh Hazarika, Atanu Hazarika, and from organizations like D1 Williamson Magor Bio Fuels Limited, and North Eastern Development Finance Corporation Ltd in carring out this study.

---

[6] http://www.biodieselmagazine.com/articles/7508/study-recommends-raising-biodiesel-price-in-india

[7] http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0CEgQFjAD&url=http%3A%2F%2Farticles.timesofindia.indiatimes.com%2F2011-01-02%2Findia-business%2F28351977_1_*Jatropha*-bio-diesel-record-fluctuation-average-procurement-price&ei=6oGVUp6PO4iRrQeMjoGADw&usg=AFQjCNGOWEj1fSK-b46vPHNLrBBcuwkwgQ&bvm=bv.57155469,d.bmk&cad=rja

[8] http://www.mypetrolprice.com/2/Diesel-price-in-Delhi?FuelType=1&LocationId=2

References

Adeogun, OA; Ajana, AM; Ayinla, OA; Yarhere, MT; Adeogun, MO (2008) 'Application of Logit model in adoption decision: a study of Hybrid Clarias in Lagos State, Nigeria', *American-Eurasian Journal of Agricultural & Environmental Science* 4(4): 468-472

Adesina, AA; Forson, JB (1995) 'Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa', *Agricultural Economics* 13: 1-9

Adesina, AA; Mbila, D; Nkamleu, GB; Endamana, D (2000) 'Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon', *Agriculture, Ecosystems and Environment* 80: 255–265

Agoramoorthy, G; Hsu, MJ; Chaudhary, S; Shieh, P (2009) 'Can biofuel crops alleviate tribal poverty in Inida's drylands?', *Applied Energy* 86: S118-S124

Aradhey, A (2013) India: Biofuels Annual, GAIN Report No. IN3073, USDA Foreign Agricultural Service. Available at http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CC8QFjAB&url=http%3A%2F%2Fgain.fas.usda.gov%2FRecent%2520GAIN%2520Publications%2FBiofuels%2520Annual_New%2520Delhi_India_8-13-2013.pdf&ei=JvB9UvL0J4GRrQek0oDQAw&usg=AFQjCNH1dqH-2EPe1sa4Re9J-XrJe9SqAg&bvm=bv.56146854,d.bmk&cad=rja [Accessed on 4th November 2013]

Binswanger, HP (1980) 'Attitudes toward risk: Experimental measurement in rural India', *American Journal of Agricultural Economics* 62: 395–407

Breen, J; Clancy, D; Moran, B; Thorne, F (2009) 'Modeling the potential supply of energy crops in Ireland: results from a Probit Model examining the factors affecting willingness to adopt', RERC Working Paper Series 09-WP-RE-05, Rural Economy Research Centre, Teagasc, Athenry, Ireland. Available at ww.agresearch.teagasc.ie/rerc/downloads/workingpapers/09wpre05.pdf [Accessed on 20th March 2011]

Chandak, A; Somani, S (2011) 'Renewable fuel saving obligation: Innovative mechanism for emission reduction', *Journal of Petroleum Technology and Alternative Fuels* 2(1): 21-24

Choudhury, HK; Goswami, K (2013) 'Determinants of expansion of area under Jatropha plantation in North East India: A Tobit analysis', Forest Policy and Economics 13: 46-52. Available at http://www.sciencedirect.com/science/article/pii/S1389934113000336/pdfft?md5=bfba3ef05325c6b30a1e62487d50e4b5&pid=1-s2.0-S1389934113000336-main.pdf [Accessed on 20th March 2013]

Clancy, D; Breen, J; Butler, AM; Thorne, F (2008) 'The economic viability of biomass crops versus conventional agricultural systems and its potential impact on farm incomes in Ireland', Paper presented at the 107th EAAE Seminar, Sevilla, Spain, January 29 - February 1, 2008

D1 Williamson Magor Biofuel Limited (n.d.) Available at http://d1wm.co.in/ [Accessed on 5th July 2009]

Ellis, PC (2006) *Evaluation of socioeconomic characteristics of farmers who choose to adopt a new type of crop and factors that influence the decision to adopt switchgrass for energy production*, Unpublished MA Thesis, University of Tennessee, Knoxville

Energy Information Administration (2010) *Country Analysis Briefs: India*. Available at http://www.eia.doe.gov/cabs/India/pdf.pdf. [Accessed on 19th September 2010]

Feder, G; Just, RE; Zilberman, D (1985) 'Adoption of agricultural innovations in developing countries: a survey', *Economic Development and Cultural Change* 33(2): 255-298

Finco, MVA; Doppler, D (2011) 'Biodiesel and social inclusion: a fuzzy set and regression analysis in the north of Brazil', *Revista de Economia* 37(1): 7-32

Fujisaka, A; Jayson, E; Dapusala, A (1994) 'Trees, grasses, and weeds: species choices in farmed-developed contour hedgerows', *Agroforestry System* 25: 13-22

Goswami, K; Choudhury, HK (2012) 'Factors influencing farmers' adoption of slash and burn agriculture in North East India', *Forest Policy and Economics* 15: 146-151

Goswami, K; Saikia, J; Choudhury, HK (2011) 'Economic benefits and costs of Jatropha plantation in North-East India', *Agricultural Economics Research Review* 24: 99-108

Gregg, D (2009) 'Non adoption of improved maize varieties in East Timor', Paper presented at the 53rd Annual Conference of the Australian Agricultural and Resource Economics Society, Cairns, 10-13 February, 2009. Available at http://ageconsearch.umn.edu/bitstream/48159/2/Gregg.pdf [Accessed on 20th November, 2010]

Hamilton, JD (2009) 'Causes and consequences of the Oil Shock of 2007–08', Brookings Papers on Economic Activity

40(1): pp. 215-261, The Brookings Institution, Washington DC. Available at http://www.brookings.edu/~/media/Files/Programs/ES/BPEA/2009_spring_bpea_papers/2009a_bpea_hamilton.pdf [Accessed on 13th of April, 2013]

Hazell, P; Pachauri, RK (2006) 'Overview: bioenergy and agriculture, promises and challenges', International Food Policy Research Institute, Washington, DC. Available at http://www.ifpri.org/sites/default/files/pubs/2020/focus/focus14/focus14.pdf [Accessed on 12th February, 2011]

Hipple, PC; Duffy, MD (2002) 'Farmers' motivations for adoption of switchgrass', in Janick, J; Whipkey, A (eds) *Trends in New Crops and New Uses*, Alexandria, VA: ASHS Press, pp. 252–266

Iqbal, M; Bashir, A; Farooq, U (1999) 'Factors affecting the adoption of hybrid maize varieties in the irrigated Punjab', *International Journal of Agriculture & Biology*. Available at http://www.fspublishers.org/ijab/past-issues/IJABVOL_1_NO_3/26.pdf [Accessed on 27th December 2010]

Iqbal, SMM; Ireland, CR; Rodrigo, VHL (2006) 'A logistic analysis of the factors determining the decision of smallholder farmers to intercrop: A case study involving rubber–tea intercropping in Sri Lanka', *Agricultural Systems* 87(3): 296-312

Jabbar, MA; Beyene, H; Saleem, MA; Gebreselassie, S (1998) 'Adoption pathways for new agricultural technologies: an approach and an application to vertisol management technology in Ethiopia', Socioeconomic and Policy Research Working Paper No. 23, International Livestock Research Institute, Ethiopia

Jensen, K; Clark, CD; Ellis, P; English, B; Menard, J; Walsh, M; Ugarte, D. de la T (2007) 'Farmer willingness to grow switchgrass for energy production', *Biomass and Bioenergy* 37: 773-781

Johnson, JE (2005), 'Agroforestry adoption potential in Cape Verde', Small-Scall Forest Economics, *Management and Policy* 4(2):205-214

Jongschaap, REE; Corre, WJ; Brindaban, PS; Brandenburg, WA (2007), Claims and Facts on Jatropha curcas L., Report No. 158, Plant Research International, Wageningen University. Available at http://library.wur.nl/way/bestanden/clc/1858843.pdf [Accessed on 18th February 2011]

Just, RE; Zilberman, D (1983) 'Stochastic structure, farm size, and technology adoption in developing agriculture', *Oxford Economic Papers*, 35: 307–328

Kojima, M; Mitchell, D; Ward, W (2007) *Considering Trade Policies for Liquid Biofuels*, Energy Sector Management Assistance Program (ESPM), World Bank, Washington, D.C. Available at http://www.fao.org/uploads/media/0705_ESMAP_World_Bank-_Considering_Trade_Policies_for_Liquid_Biofuels_02.pdf [Accessed on 15th January 2011]

Kumar, A; Sharma, S (2008) 'An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas L.*): a review', *Industrial Crops and Products* 28(1): 1-10

Kumar, L; Mohan, MPR (2005) 'Biofuels: the key to India's sustainable energy needs', Riso-R-1517 (EN), pp. 423-438. Available at http://www.risoe.dk/rispubl/SYS/syspdf/energconf05/Session17_kumar.pdf [Accessed on 5th July 2009]

Macandog, DBM; Visco, RG; Delgado, MEM (2006) 'Agroforestry adoption, innovations and smallholder farmers' motivations in tropical uplands of Southern Philippines', *Journal of Sustainable Agriculture* 28(1): 133-143

Manivong, V; Cramb, RA (2008) 'The adoption of smallholder rubber production by shifting cultivators in Northern Laos: a village case study', in Snelder, DJ; Lasco, RD (eds), *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia*, Springer Science + Business Media B.V., The Netherlands, pp. 117-137

Mazuze, FM (2004) 'Analysis of adoption and production of orange-fleshed sweet potatoes: the case study of Gaza province in Mozambique', Unpublished M.Sc. Thesis, Department of Agricultural Economics, Michigan State University, Michigan. Available at: http://www.aec.msu.edu/fs2/mozambique/MAZUZE_MS.pdf [Accessed on 5th January 2011]

McMichael, P (2010) 'Agrofuels in the food regime', *The Journal of Peasant Studies* 37: 609-629

Mercer, DE (2004) 'Adoption of agroforestry innovations in the tropics: a review', *Agroforestry Systems* 61-62: 311-328

Mercer, DE; Pattanayak, SK (2003) 'Agroforestry adoption by smallholders', in Sills, E; Abt, K (eds) *Forests in a Market Economy, Forestry Sciences Series*, 72: pp. 283-299

Montobbio, PA; Lele, S (2010) 'Jatropha plantations for biodiesel in Tamil Nadu, India: viability, livelihood trade-offs, and latent conflict', *Ecological Economics* 70(2): 189-195

Mponela, P; Jumbe, CBL; Mwase, WF (2011) 'Determinants and extent of land allocation for Jatropha curcas L. cultivation among smallholder farmers in Malawi', *Biomass and Bioenergy* 35: 2499-2505

Mujeyi, K (2009) ‘Socio-economics of commercial utilization of Jatropha (Jatropha curcas) in Mutoko district, Zimbabwe’, *Journal of Sustainable Development in Africa* 11(2): 36-55

NABARD Consultancy Services (2007) *Jatropha Plantation in Tripura: Techno Feasibility Report*, Tripura Regional Office, Uzirbari Road, Agartala

Ndongo, PAO; Ehabe, EE; Chambon-Poveda, B; Bruneau, JC (2010) ‘Socio-economic determinants of the adoption of budded planting materials in rubber smallholdings of the South West region, Cameroon’, *Scientific Research and Essays* 5(4): 407-411

Neill, SP; Lee, DR (2001), ‘Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in Northern Honduras’, *Economic Development and Cultural Change* 49(4): 793-820

Neupane, RP; Sharma, KR; Thapa, GB (2002) ‘Adoption of agroforestry in the hills of Nepal: a logistic regression analysis’, *Agricultural Systems* 72(3): 177-196

Nkamleu, GB; Manyong, VM (2005) ‘Factors affecting the adoption of agroforestry practices by farmers in Cameroon’, *Small-Scale Forestry* 4(2): 135-148

Pattanayak, S; Mercer, DE; Sills, E; Yang, JC (2003) ‘Taking stock of agroforestry adoption studies’, *Agroforestry Systems* 57(3): 173-186

Paulrud, S; Laitila, T (2010) ‘Farmers’ attitudes about growing energy crops: a choice experiment approach’, *Biomass and Bioenergy* 34: 1770-1779

Planning Commission (2003) *Report of the Committee on Development of Biofuel*, Government of India. Available at http://planningcommission.nic.in/reports/genrep/cmtt_bio.pdf. [Accessed on 5th July 2009]

Peters, J; Thielmann, S (2008), ‘Promoting biofuels: implications for developing countries’, *Energy Policy* 36: 1538-1544

Posthumus, H (2005) *Adoption of terraces in the Peruvian Andes*, Unpublished PhD Thesis, Wageningen University, The Netherlands

Pundo, MO; Fraser, GCG (2006) ‘Multinomial Logit analysis of household cooking fuel choice in rural Kenya: the case of Kisumu District’, *Agrekon* 45(1): 24-37

Punia, MS (2010) *Cultivation and Use of Jatropha for Bio-diesel Production in India*. National Oilseed and Vegetable Oil Development Board, Ministry of Agriculture, Government of India. Available at http://www.cpamn.embrapa.br/agrobioenergia/palestras/CULTIVATION%20AND%20USE%20OF%20Jatropha%20FOR%20BIO-DIESEL%20PRODUCTION%20IN%20INDIA.PDF [Accessed on 26th November, 2010]

Qualls, DJ; Jensen, KL; English, BC; Larson, JA; Clark, CD (2011) ‘Analysis of factors affecting farmers’ willingness to adopt switchgrass production’, Paper Presented at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, Texas, February 5-8, 2011. Available at http://ageconsearch.umn.edu/bitstream/98625/2/SAEA2011Qualls.pdf [Accessed on 20th March, 2011]

Rajagopal, D (2011) *Rethinking Current Strategies for Biofuel Production in India*, Energy and Resources Group, University of California, Berkeley. Available at http://www.Jatropha.pro/PDF%20bestanden/Rethinking%20current%20strategies%20for%20Biofuel%20production%20in%20India.pdf [Accessed on 24th February 2011]

Rajagopal, D; Zilberman, D (2007) ‘Review of environmental, economic and policy aspects of biofuels’, World Bank Policy Research Working Paper 4341, The World Bank, Washington, DC. Available at http://www.wilsoncenter.org/news/docs/worldbankSept.2007.pdf [Accessed on 12th February 2011]

Rogers, EM (2003) *Diffusion of Innovations*, 5th Edition, New York: Free Press

Sadati, SA; Ghobadi, FR; Sadati, SA; Mohamadi, Y; Sharifi, O; Asakereh, A (2010) ‘Survey of effective factors on adoption of crop insurance among farmers: a case study of Behbahan County’, *African Journal of Agricultural Research* 5: 2237-2242

Samiee, A; Rezvanfar, A; Faham, E (2009) ‘Factors influencing the adoption of integrated pest management (IPM) by wheat growers in Varamin County, Iran’, *African Journal of Agricultural Research* 4: 491-497

Schatzki, T (2003) ‘Options, uncertainty and sunk costs: an empirical analysis of land use change’, *Journal of Environmental Economics and Management* 46: 86–105

Sen, A (2007) *Microeconomics: Theory and Applications*, Oxford: Oxford University Press.

Sheikh, AD; Rehman; T; Yates, CM (2003) ‘Logit models for identifying the factors that influence the uptake of new ‘no-tillage’ technologies by farmers in the rice–wheat and the cotton–wheat farming systems of Pakistan’s Punjab’, *Agricultural Systems* 75(1): 79-95

Singh, I; Squire, L; Strauss, J (1986) 'The basic model: theory, empirical results, and policy conclusions', in Singh, I; Squire, L; Strauss, J (eds) *Agricultural Household Models: Extensions, Applications, and Policy*, Baltimore: Johns Hopkins University Press, pp. 39-69

Singh, R (2009) *India: Biofuels Annual*, GAIN Report. Available at http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_New%20Delhi_India_6-12-2009.pdf [Accessed on 19th October 2009]

Shinoj, P; Raju, SS; Kumar, P; Msangi, S; Yadav, P; Thorat, VS; Chaudhary, KR (2010) 'An economic assessment along the Jatropha-based biodiesel value chain in India', *Agricultural Economics Research Review* 23: 393–404

Smale, M; Edmeades, S; Wood, S; Kalyebara, R (2007) 'Elements of the conceptual framework and sample survey design', in Smale, M; Tushemereirewe, WK (eds) *An Economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania*, International Food Policy Research Institute, Washington, DC, pp. 12-24

Smith, DJ; Schulman, C; Current, D; Easter, KW (2011) 'Willingness of agricultural landowners to supply perennial energy crops', Paper Presented at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24- 26, 2011

Song, F; Zhao, J; Swinton, SM (2009) 'Switching to perennial energy crops under uncertainty and costly reversibility', Staff Paper, Department of Agricultural Food and Resource Economics, Michagan State University

Strauss, J (1986) 'The theory and comparative statics of agricultural household models: a general approach', in Singh, I; Squire, L; Strauss, J (eds) *Agricultural Household Models: Extensions, Applications and Policy*, Baltimore: Johns Hopkins University Press, pp. 71-91

Suhendar (1997) 'Faktor-Faktor Sosial Ekonomi dan Budaya yang Mempengaruhi Adopsi Teknologi Padi Gogo Pada Suku Baduy Luar di Lebak', (Penelitian Skripsi S–1), Fakultas Pertanian UGM

TERI (2005) *Liquid Biofuels for Transportation: India Country Study on Potential and Implications for Sustainable Agriculture and Energy*, German Technical Cooperation. Available at: http://www.gtz.de/de/dokumente/en-biofuels-for-transportation-in-india-2005.pdf [Accessed on 5th July 2009]

Uzmay, A; Isin, F; Isin, S (2009) 'Farmers' views on the effects on agriculture sector of Turkey's accession membership into the European Union: case study of cotton farmers in Aegean Region, Turkey', *Journal of Food, Agriculture & Environment* 7(3-4): 609-614

Velandia, M; Lambert, DM; Fox, J; Walton, JC; Sanford, EK; Roberts, R (2010) 'Intent to continue growing switchgrass as a dedicated energy crop: a survey of switchgrass producers in East Tennessee', *European Journal of Social Sciences* 15(3): 299-312

Walburger, AM; Roy, DL; Koushik, KK; Klein, KK (2006) 'Policies to stimulate biofuel production in Canada: a lesson from Europe and United States', A BIOCAP Research Integrated Programme Synthesis Paper. Available at http://www.biocap.ca/rif/report/Walburger_A.pdf [Accessed on 15th February 2011]

Wanjiku, J; Ackello-Ogutu, C; Kimenye, LN; Place, F (2003) 'Socio-economic factors influencing the intensity of use of bio mass transfer in food crop production in western Kenya', *African Crop Science Conference Proceedings* 6: 661-667

Wastelands Atlas of India (2011) *Categorywise and Districtwise Wasteland Area*, Ministry of Rural Development and National Remote Sensing Agency, Government of India. Available at http://www.dolr.nic.in/WastelandsAtlas2011/Wastelands_Atlas_2011.pdf. [Accessed on 28th September 2012]

Welch, F (1978), 'The role of investment in human capital in agriculture', in Schultz, TW (ed) *Distortion of Agricultural Incentives*, Bloomington: Indiana University Press.

Wiersum, KF (1994) 'Farmer adoption of contour hedgerow intercropping, a case study from East Indonesia', *Agrogorestry Systems* 27(2): 163-182

Wendland, KJ; Sills, EO (2008) 'Dissemination of food crops with nutritional benefits: adoption and disadoption of soybeans in Togo and Benin', *Natural Resources Forum* 32(1): 39–52

Wilkinson, J; Herrera, S (2010) 'Biofuels in Brazil: debates and impacts', *The Journal of Peasant Studies* 37: 749–768

Wubeneh, N (2003) *Farm Level of Adoption of New Sorghum Technologies in Tigray Region, Ethiopia*, Unpublished M. Sc. Thesis, Department of Agricultural Economics, Purdue University, Indiana, U.S.A. Available at: http://pdf.usaid.gov/pdf_docs/PNADT031.pdf [Accessed on 10th October 2011]

Tables

Table 1a: Descriptive Statistics of the Factors Used in the Probit Models

Factors	Unit of Measurement	Current-farmers			Previous-farmers			Non-grower			Expected Sign
		Mean (Std. Dev.)	Min.	Max.	Mean (Std.Dev.)	Min	Max.	Mean (Std.Dev.)	Min.	Max.	
Personal Factors											
Age	Year	41.19 (12.39)	18	74	41.39 (12.06)	18	75	37.46 (11.33)	18	66	Positive
Education	Year	7.44 (4.92)	0	17	7.50 (5.10)	0	17	7.290 (5.03)	0	18	Positive
Primary Occupation	1 for farmer and 0 for otherwise	0.61 (0.49)	0	1	0.50 (0.50)	0	1	0.55 (0.50)	0	1	Positive
Knowledge about *Jatropha*	1 for yes and 0 for no	0.68 (0.47)	0	1	0.26 (0.44)	0	1	0.25 (0.43)	0	1	Positive
Physical Factors											
Cultivable Land	Hectare	3.09 (2.94)	0.6	22.67	NA	NA	NA	1.99 (2.32)	0	16	Positive
Availability of Unemployed Family Member	1 for available and 0 for not available	0.42 (0.50)	0	1	0.23 (0.43)	0	1	0.37 (0.48)	0	1	Positive
Labor Shortage	1 for yes and 0 for no	0.53 (0.50)	0	1	0.82 (0.38)	0	1	0.49 (0.50)	0	1	Negative
Distance to Nearest Market	Kilometer	12.83 (9.07)	1.5	28	12.33 (9.16)	1.5	28	12.72 (9.04)	1.5	28	Negative
Slope of Land under *Jatropha*	Degree	7.78 (8.47)	0	50	8.45 (8.71)	0	45	NA	NA	NA	Negative
Average Time to Reach the Plantation Site	Minute	14.12 (11.26)	0	60	26.51 (17.62)	2	90	NA	NA	NA	Negative
Rainfall	1000 milimiter	2.84 (0.58)	2.18	3.51	2.90 (0.58)	2.18	3.51	2.87 (0.58)	2.18	3.51	Negative

Table 1b: Descriptive Statistics of the Factors Used in the Probit Models

Factors	Unit of Measurement	Current-farmers			Previous-farmers			Non-grower			Expected Sign
		Mean (Std.Dev.)	Min.	Max.	Mean (Std. Dev.)	Min.	Max.	Mean (Std.Dev)	Min.	Max.	
Economic Factors											
Non-farm Employment Opportunity	1 for yes and 0 for no	0.47 (0.501)	0	1	0.75 (0.43)	0	1	0.64 (0.48)	0	1	Negative
Alternative Use of Land under *Jatropha*	1 for yes and 0 for no	0.61 (0.49)	0	1	0.85 (0.35)	0	1	NA	NA	NA	Negative
Minimum Expected Income to Continue with *Jatropha*	Rs. 000 per hectare	14.36 (8.14)	1	48.2	20.49 (9.84)	3.75	56.25	NA	NA	NA	Negative
Expected Price of *Jatropha* Seed	Rupees	20.94 (7.74)	12	50	26.69 (9.88)	10	55	NA	NA	NA	Negative
Expected Payback Period	Year	15.68 (6.98)	5	50	24.43 (10.66)	7	60	NA	NA	NA	Negative
Institutional Factors											
Availability of/Access to Credit for *Jatropha* Plantation	1 for yes and 0 for no	0.38 (0.49)	0	1	0.34 (0.47)	0	1	NA	NA	NA	Positive
Technical Help in Pruning and Planting	1 for yes and 0 for no	0.55 (0.50)	0	1	0.23 (0.42)	0	1	NA	NA	NA	Positive
Extension Service	1 for yes and 0 for no	0.68 (0.47)	0	1	0.60 (0.49)	0	1	0.60 (0.49)	0	1	Positive
Risk and Uncertainty Factors											
Risk	1 for risk taker and 0 for risk averter	0.58 (0.50)	0	1	0.28 (0.45)	0	1	0.43 (0.50)	0	1	Positive
Pests and Disease Attack	1 for yes and 0 for no	0.51 (0.50)	0	1	0.56 (0.45)	0	1	NA	NA	NA	Negative

Note: i) Figures in parentheses show standard deviation; ii) NA = Not applicable

Table 2: Independent Sample Mean Test and McNemar's Chi2 Test across Categories of Farmers

Factors	Independent Sample Mean Test Significance Level		McNemar's Chi2 Test			
	Current-farmers vs. Non-grower	Current-farmers vs. Previous-farmers	Current-farmers vs. Non-grower		Current-farmers vs. Previous-farmers	
			Prob>chi2	Exact McNemar Sig Prob.	Prob>chi2	Exact McNemar Sig Prob.
Personal factors						
Age	0.008	0.895	-	-	-	-
Education	0.801	0.922	-	-	-	-
Primary Occupation	-	-	0.0478	0.058	-	-
Knowledge about *Jatropha*	-	-	0.270	0.3203	0.269	0.320
Farming Experience	0.292	-	-	-	-	-
Physical Factors						
Cultivable Land	0.000	-	-	-	-	-
Availability of Unemployed Family Member	-	-	0.010	0.013	0.000	0.000
Labor Shortage	-	-	0.734	0.799	0.001	0.001
Distance to Nearest Market	0.921	0.645	-	-	-	-
Slope of Land under *Jatropha*	-	0.520	-	-	-	
Average Time to Reach Plantation Site	-	0.000	-	-	-	-
Economic Factors						
Non-farm Employment Opportunity	-	-	0.220	0.250	0.053	0.062
Alternative Use of Land under *Jatropha*	-	-	-	-	0.000	0.000
Minimum Expected Income to Continue with *Jatropha*	-	0.000	-	-	-	-
Expected Price of *Jatropha* Seed	-	0.000	-	-	-	-
Expected Payback Period	-	0.000	-	-	-	-
Institutional Factors						
Availability of/Access to Credit for *Jatropha* Plantation	-	-	0.000	0.000	0.000	0.000
Technical Help in Pruning and Planting	-	-	-	-	0.001	0.001
Extension Service	-	-	0.000	0.001	0.002	0.002
Risk and Uncertainty						
Risk	-	-	0.787	0.857	0.035	0.044
Pests and Disease Attack	-	-	-	-	0.622	0.681

Table 3a: Results of the Probit Model of Adoption of *Jatropha* Plantation

Factors	Without Fixed Effect (First Model)			With Fixed Effect (Second Model)		
	Coefficient	Robust Std Error	Marginal Effects	Coefficient	Robust Std Error	Marginal Effects
Personal Factors						
Age	0.0512	0.0423	0.020	0.045	0.043	0.018
Age Square	-0.0003	0.0005	0.000	0.000	0.001	0.000
Education	0.0001	0.0201	0.000	0.012	0.024	0.005
Primary Occupation	-0.1563	0.2133	-0.062	-0.345	0.246	-0.137
Farming Experience	-0.0153	0.0096	-0.006	-0.012	0.010	-0.005
Physical Factors						
Cultivable Land	0.1050**	0.0527	0.042	0.114**	0.057	0.046
Distance to Nearest Market	0.0005	0.0170	0.000	0.038	0.043	0.015
Availability of Unemployed Family Member	0.1062	0.1696	0.042	0.117	0.185	0.047
Labor Shortage	0.0388	0.1624	0.015	0.124	0.181	0.049
Location	-0.8716***	0.3324	-0.326	-0.270	0.790	-0.107
Rainfall	-0.8287**	0.3321	-0.331	-5.717***	0.351	-2.276
Economic Factors						
Non -farm Employment Opportunity	-0.6191***	0.2150	-0.243	-0.817***	0.236	-0.317
Institutional Factors						
Credit Availability	1.3331***	0.2928	0.486	2.273***	0.477	0.723
Extension Service	0.3743*	0.2206	0.148	1.255**	0.575	0.458
Risk and Uncertainty Factors						
Risk Behavior	0.3684**	0.1698	0.146	0.370**	0.181	0.146
Constant	1.0544	1.3923	-	16.639	-	-
Number of Observations = 289 Wald Chi^2 (15) = 54.52 Prob > Chi^2 < 0.001 Pearson Chi^2 (273) = 286.50 Prob > Chi^2 = 0.275 Pseudo R^2 = 0.150 Log Pseudo Likelihood = -170.355 Area under ROC Curve = 0.744				Number of Observations = 289 LR Chi^2 (39) = 79.58 Prob > Chi^2 < 0.001 Pearson Chi^2 () = 276.86 Prob > Chi^2 < 0.109 Pseudo R^2 = 0.199 Log Pseudo Likelihood = -160.526 Area under ROC Curve = 0.777		

Note: *** =1%, ** = 5% , and * =10% level of significance are considered. dy/dx is for discrete change of dummy variable from 0 to 1.

Table 3b: Specification Test of the Probit Model of Adoption of *Jatropha* Plantation

Factors	Without Fixed Effect (First Model)				With Fixed Effect (Second Model)			
	Coefficient	Standard Error	z	P>z	Coefficient	Standard Error	z	P>z
_hat	1.054	0.159	6.620	0.000	1.023	0.148	6.890	0.000
_hatsq	-0.211	0.145	-1.450	0.146	-0.109	0.136	-0.800	0.422
Constant	0.060	0.089	0.670	0.500	0.035	0.092	0.380	0.701
No. of Observations = 289 LR Chi^2 (2) = 61.96 Prob > Chi^2 < 0.001 Pseudo R^2 = 0.155 Log Pseudo Likelihood = -169.339					No. of Observations = 289 LR Chi^2 (2) = 80.22 Prob > Chi^2 < 0.001 Pseudo R^2 = 0.200 Log Pseudo Likelihood = -160.210			

Table 4a: Results of the Probit Model of Continuation with *Jatropha* Plantation

Factors	Without Fixed Effect (First Model)			With Fixed Effect (Second Model)		
	Coefficient	Robust Std Error	Marginal Effects	Coefficient	Robust Std Error	Marginal Effects
Personal Factors						
Age	0.017	0.061	0.007	0.007	0.062	0.003
Age Square	0.000	0.001	0.000	0.000	0.001	0.000
Education	-0.058**	0.029	-0.023	-0.023	0.035	-0.009
Knowledge about *Jatropha*	0.776***	0.276	0.302	0.952***	0.295	0.364
Physical Factors						
Availability of Unemployed Family Labor	0.199	0.244	0.079	0.121	0.264	0.048
Labor Shortage	-0.731***	0.243	-0.284	-0.524*	0.276	-0.206
Distance to Nearest Market	-0.030	0.021	-0.012	0.924***	0.062	0.365
Slope of Land under *Jatropha*	-0.012	0.022	-0.005	-0.024	0.023	-0.009
Average Time to Reach Plantation Site	-0.045***	0.009	-0.018	-0.046***	0.010	-0.018
Location	0.112	0.490	0.044	-0.531	0.825	-0.209
Rainfall	-0.208	0.457	-0.083	-3.741***	0.447	-1.479
Economic Factors						
Non-farm Employment Opportunity	-0.874***	0.270	-0.337	-1.000***	0.309	-0.383
Alternative Use of the Land	-0.957***	0.291	-0.362	-1.040***	0.294	-0.395
Minimum Expected Income to Continue with *Jatropha*	-0.027*	0.015	-0.011	-0.025	0.017	-0.010
Expected Market Price	0.007	0.015	0.003	-0.010	0.015	-0.004
Expected Payback Period	-0.085***	0.019	-0.034	-0.102***	0.026	-0.040
Institutional Factors						
Access to Credit	0.735*	0.405	0.286	1.179***	0.445	0.444
Technical Help in Planting and Pruning	0.235	0.279	0.094	0.233	0.299	0.092
Extension Services	0.234	0.317	0.093	-0.127	0.744	-0.050
Risk and Uncertainty Factors						
Risk Behavior	1.188***	0.238	0.447	1.367***	0.286	0.505
Ant and Pests Attack	0.159	0.255	0.063	0.078	0.299	0.031
Constant	4.405	-	-	13.477	-	-
Number of Observations = 281 Wald Chi Square (21) = 115.97 Prob > Chi^2 < 0.001 Pearson Chi^2 (259) = 196.31 Prob > Chi^2 = 0.998 Pseudo R^2 = 0.563 Log Pseudo Likelihood = -85.054 Area under ROC Curver = 0.943				Number of Observations = 281 LR Chi^2 (46) = 240.11 Prob > Chi^2 < 0.001 Pearson Chi^2 (234) = 191.28 Prob > Chi^2 = 0.957 Pseudo R^2 = 0.617 Log Pseudo Likelihood = -74.594 Area under ROC Curver = 0.957		

Note: *** =1%, ** =5%, and * =10% level of significance are considered. dy/dx is for discrete change of dummy variable from 0 to 1.

Table 4b: Specification Test of the Probit Model of Continuation with *Jatropha* Plantation

	Without Fixed Effect (First Model)				**With Fixed Effect (Second Model)**			
Factors	**Coef.**	**Standard Error**	**z**	**P>z**	**Coef.**	**Standard Error**	**z**	**P>z**
_hat	1.007	0.109	9.230	0.000	1.017	0.114	8.940	0.000
_hatsq	0.049	0.079	0.620	0.534	0.058	0.024	2.430	0.015
Constant	-0.051	0.137	-0.370	0.712	-0.064	0.120	-0.540	0.592
No. of Observations = 281 LR Chi^2 (2) = 219.63 Prob > Chi^2 < 0.001 Pseudo R^2 = 0.564 Log Pseudo Likelihood = -84.873					No. of Observations = 281 LR Chi^2 (2) = 241.06 Prob > Chi^2 < 0.001 Pseudo R^2 = 0.619 Log Pseudo Likelihood = -74.156			

Figures

Figure 1: Conceptual Framework Related to Farmers' Adoption and Continuation with *Jatropha* Plantation

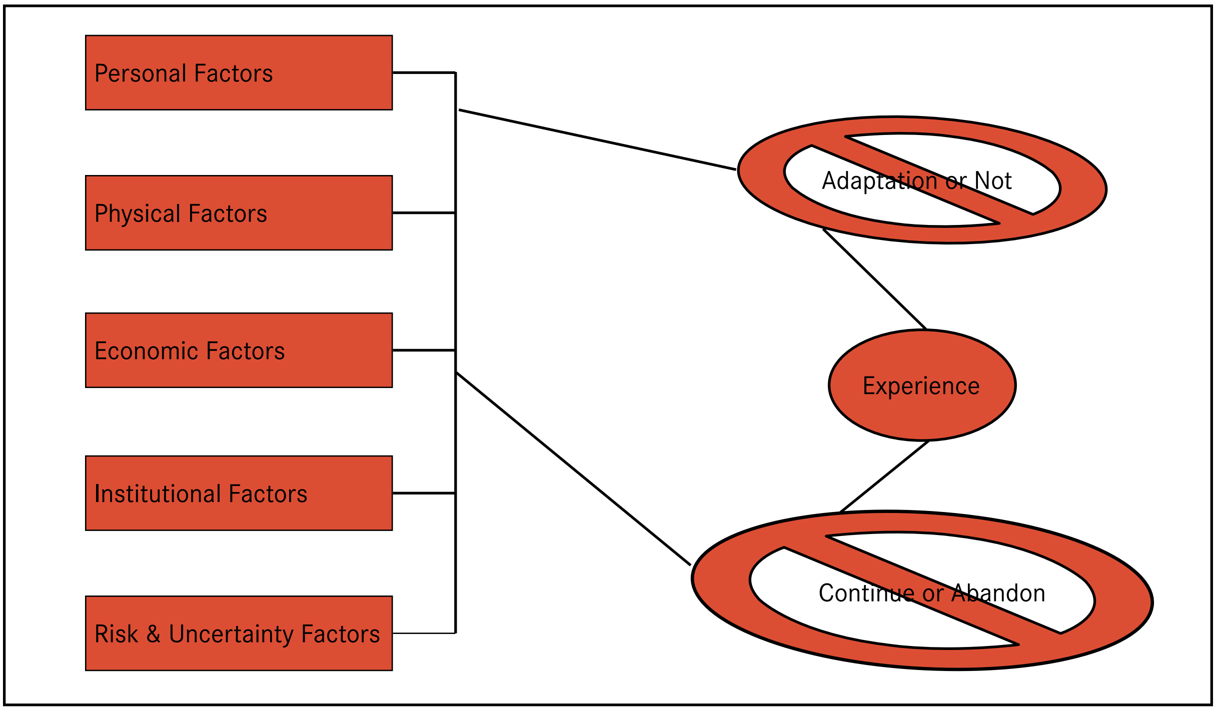


Figure 2: A comparison of Current, Previous, and non *Jatropha* growers

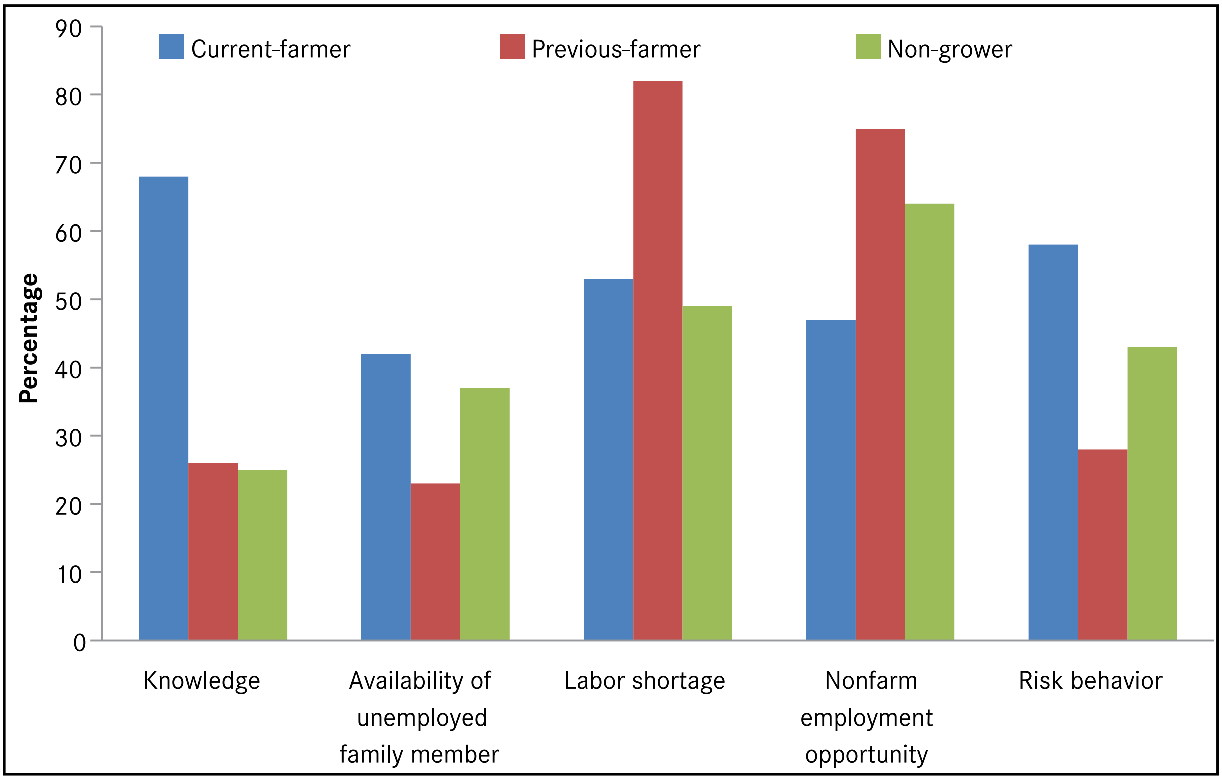


Figure 3: Farmers' reasons for abandoning *Jatropha* plantion

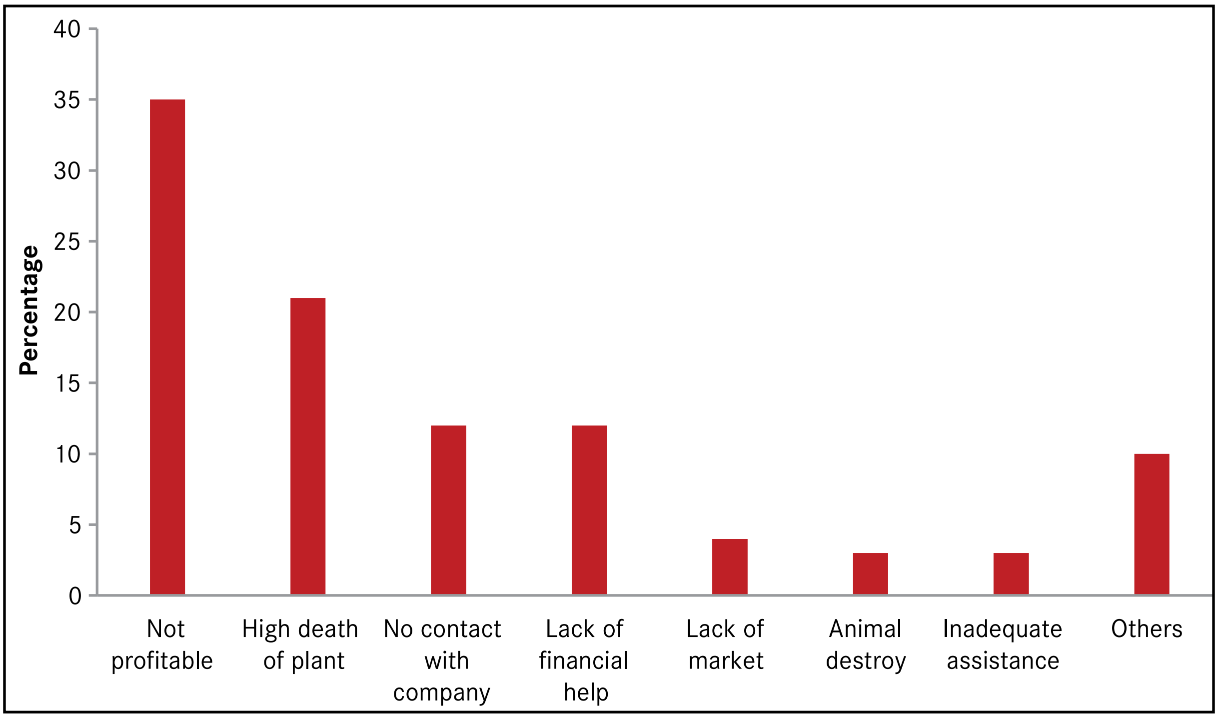
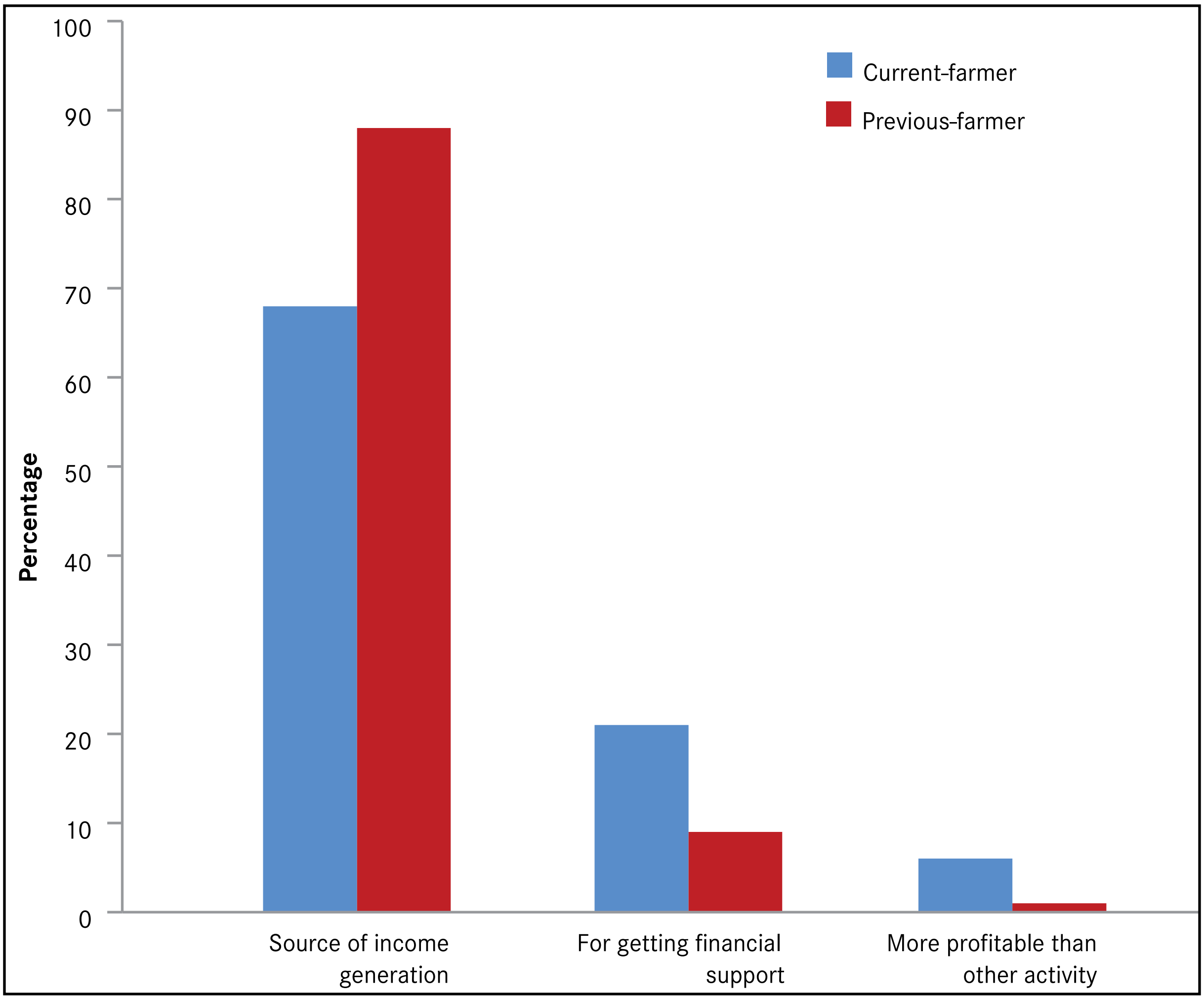
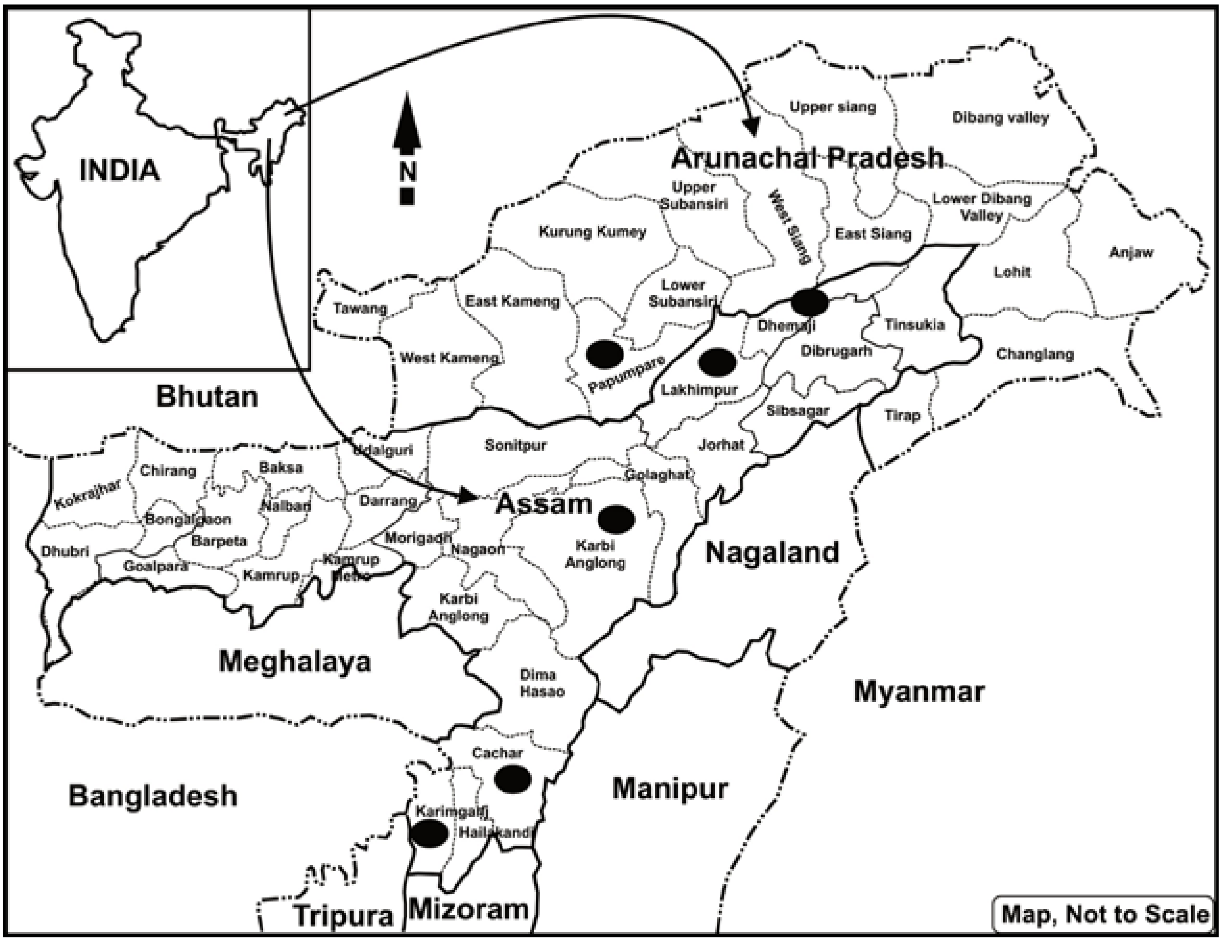


Figure 4: Farmers' reasons for adopting *Jatropha* plantion



Map 1: District Map of Arunachal Pradesh and Assam



Source: http://www.mapsofindia.com/maps/india/india-political-map.htm

Note: ● indicates sample districts

Annexes

Annex I: Selected Literature on Methodology of Adoption Behavior Based on Logit and Probit Models

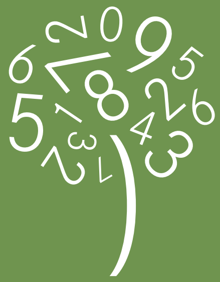
Author	Title	Dependent Variable	Model
Adesina et al., 2000	Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon	Factors affecting farmers' adoption of alley farming	Logit model
Finco and Doppler, 2011	Biodiesel and social inclusion: a fuzzy set and regression analysis in the north of Brazil	Adoption of oil seeds	Probit model
Iqbal et al., 1999	Factors affecting the adoption of hybrid maize varieties in the irrigated Punjab	Adoption of hybrid varieties of maize	LPM, Logit and Probit models
Gregg, 2009	Non-adoption of improved maize varieties in East Timor	Adoption of maize variety	Probit model
Iqbal et al., 2006	A logistic analysis of the factors determining the decision of smallholder farmers to intercrop: A case study involving rubber–tea intercropping in Sri Lanka	Adoption of rubber–tea intercropping	Logit model and correlation analysis
Mazuze, 2005	Analysis of adoption and production of orange-fleshed sweet potatoes: The case study of Gaza province in Mozambique	Adoption of sweet potatoes	Probit model
Mercer and Pattanayak, 2003	Agroforestry Adoption by Smallholders	Agroforestry adoption	Logit and Probit models
Mponela et al., 2011	Determinants and extent of land allocation for *Jatropha curcas L*. cultivation among smallholder farmers in Malawi	Household decisions to plant *Jatropha curcas* and extent of *Jatropha* plantation	Logit and Tobit models
Mujeyi, 2009	Socio-economics of commercial utilization of *Jatropha* (*Jatropha curcas*) in Mutoko district, Zimbabwe	Commercial utilization or non-commercial utilization of *Jatropha*	Logit and Tobit models
Ndongo et al., 2010	Socio-economic determinants of the adoption of budded planting materials in rubber smallholdings of the South West region, Cameroon	Adoption of budded planting material	Logit model
Neill and Lee, 2001	Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in Northern Honduras	Adoption and abandonment of maize- mucuna system	Bivariate Probit model
Nkamleu and Manyong, 2005	Factors affecting the adoption of agroforestry practices by farmers in Cameroon	Adoption of agroforestry	Logit model
Paulrud and Laitila, 2010	Farmers' attitudes about growing energy crops: a choice experiment approach	Willingness of farmers to grow energy crops	Logit model
Posthumus, 2005	Adoption of terraces in the Peruvian Andes	Soil conservation	Probit model
Qualls et al., 2011	Analysis of factors affecting farmers' willingness to adopt switchgrass production	Interest in growing switchgrass and acres that farmers would be willing to convert to switchgrass	Probit and Tobit models
Sheikh et al., 2003	Logit models for identifying the factors that influence the uptake of new 'no-tillage' technologies by farmers in the rice–wheat and the cotton–wheat farming systems of Pakistan's Punjab	Uptake of new 'no-tillage' technologies	Logit models
Wendland and Sills, 2008	Dissemination of food crops with nutritional benefits: adoption and disadoption of soybeans in Togo and Benin	Adoption and disadoption of soybeans	Probit model

Annex II: Selected Literature on Methodology of Adoption Behavior Based on Tobit, Multiple Regression, and Other Models

Author	Title	Dependent Variable	Model
Adesina and Forson, 1995	Farmers’ perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa	Adoption of modern sorghum varieties and adoption of modern mangrove rice varieties	Tobit model
Choudhury and Gowswami, 2013	Determinants of expansion of area under *Jatropha* plantation in North East India: A Tobit analysis	Expansion of area under *Jatropha*	Tobit model
Fujisaka et al., 1994	Trees, grasses, and weeds: species choices in farmed-developed contour hedgerows	-	Decision tree model
Hipple and Duffy, 2002	Farmers’ motivations for adoption of switchgrass	-	Case study (descriptive analysis)
Jensen et al., 2007	Farmer willingness to grow switchgrass for energy production	Willingness to convert hectares to switchgrass	Tobit model
Manivong and Cramb, 2008	The adoption of smallholder rubber production by shifting cultivators in Northern Laos: a village case study	Number of rubber plantations	Multiple regression
Sadati et al., 2010	Survey of effective factors on adoption of crop insurance among farmers: a case study of Behbahan County	Adoption of crop insurance	Correlation analysis, stepwise regression analysis
Samiee et al., 2009	Factors influencing the adoption of integrated pest management (IPM) by wheat growers in Varamin County, Iran	Level of wheat growers’ adoption in IPM practices	Correlation analysis, Stepwise regression analysis
Smith et al., 2011	Willingness of agricultural landowners to supply perennial energy crops	Willingness to supply perennial grasses	Tobit, Truncated and Log normal hurdle, Exponential Type II Tobit models
Velandia et al., 2010	Intent to continue growing switchgrass as a dedicated energy crop: a survey of switchgrass producers in East	Relative importance of the components potentially affecting the formation of intentions to produce switchgrass	Spearman’s rank correlation coefficients
Wanjiki et al., 2003	Socio-economic factors influencing the intensity of use of bio mass transfer in food crop production in western Kenya	Intensity of adoption	Tobit model
Wiersum, 1994	Farmer adoption of contour hedgerow intercropping:a case study from east Indonesia	-	Tabular form explanation
Wubeneh, 2003	Farm level of adoption of new sorghum technologies in Tigray region, Ethiopia	Proportion of sorghum area under the new cultivars and proportion of land fertilized	Tobit model

Annex III: Distribution of Respondents across Districts and Categories of Farmers

State	District	Block	Village	Current-farmer	Previous-farmer	Non-Grower	Sample
Assam	Cachar	Binda Kandi	Didar Kush	5	6	5	16
			KailashPur	3	3	3	9
			Matinagar	6	7	5	18
		Narshingpur	Bishnupur	3	3	3	9
			Rajnagar	8	7	9	24
			Shyamacharanpur	14	17	17	48
	Karimganj	Badarpur	Adarkona	4	2	3	9
		Ramkrishna Nagar	Bhairab Nagar	4	3	4	11
		South Karimganj	Bagargool	2	3	2	7
			Madan Mohan	3	3	3	9
	Karbi Anglong	Rongkhang	Rongkimi	6	3	5	14
			Sadar Terong	7	3	5	15
	Dhemaji	Bordoloni	Naharbari	0	3	2	5
	North Lakhimpur	Boginadi	Dorgey	6	6	6	18
			Kali Gaon	5	4	4	13
			Namoni Dorgey	4	4	5	13
		Ghilamara	Alimur	6	6	6	18
			Bali Medok	2	2	3	7
			Bharat Suk	7	7	8	22
			Bogum	6	6	6	18
			Kalabari	4	3	4	11
			Kaman Chapari	13	10	10	33
Sub-total				**118**	**111**	**118**	**347**
Arunachal Pradesh	Papumpare	Balijan	Dipu	4	4	5	13
			Garung Karbi	6	6	5	17
			Garung Nishi	2	1	2	5
			Upper Balijan	6	6	6	18
		Kimin	Kakoi	4	5	5	14
			Lower Jumi	4	4	4	12
Sub-total				**26**	**26**	**27**	**79**
Total				**144**	**137**	**145**	**426**



SANDEE
P.O. Box 8975, E.P.C 1056, Lalitpur, Nepal
Street address: c/o ICIMOD, Khumaltar, Lalitpur, Nepal
Tel: 977 1 5003222, **Fax:** 977 1 5003299, **Email:** info@sandeeonline.org **Web:** www.sandeeonline.org

SANDEE Sponsors
ICIMOD
IDRC CRDI
Norad
Sida