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What drives Adoption of Biofuel (*Jatropha Curcas*) Production in Central Eastern Malawi?

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Abstract
There is increased interest in production of Jatropha Curcas as a biodiesel feedstock by both local and international companies. The increased interest is due to problems associated with major energy sources such as diesel and petro and their availability. This study aims at providing an understanding of the socioeconomic factors that influence farmers' adoption of Jatropha Curcas production as a biofuel technology. The study uses data from 70 Jatropha Curcas farmers in Salima district in Malawi. The results indicated that positive and significant determinants of adoption of Jatropha Curcas production by small scale farmers are gender of the household head, plot size and education level of the household head. Based on extent of adoption, the results show that plot size and education level of the household head are the only significant factors that explain the extent of adoption while marriage status negatively influenced extentof adoption. The study recommends that if Malawi government would like to promote the cultivation of Jatropha crop on commercial basis, consideration for land allocated to Jatropha should be a priority. Promotion may be suitable for large commercial farmers who have lots of land.
Keywords: Jatropha Curcas production, adoption, Malawi

I. INTRODUCTION

Demand for fossil fuel is very high at International level, with China, India and Brazil representing three of the top ten energy consuming nations in the world and their share in total consumption will certainly increase (Toylar et al., 2008). Malawi as one of the developing countries also faces increasing local demand for crude fuel, for instance, diesel and petrol. The demand is intense in most sectors not sparing agricultural sector which is now using a lot machinery to improve productivity (FEWS NET, 2012). The increased local demand for crude fuel coupled with inadequate fuel reserves has led to increased fuel prices due to mismatch between demand and supply. Increasing petroleum prices coupled with limited supply of foreign currency makes the Malawian economy to remain unstable hence making it difficult for producers to import essential commodities, such as fuel and fertilizer (FEWS NET, 2012).

Environmental, health and economic problems accrued to the use of gasoline have stirred public policy debates on evaluating alternative sources of energy that are both renewable and environmentally acceptable. Many initiatives are being developed on choosing the best alternative source of energy while ethanol has been widely recognized as acceptable substitute for gasoline or as an additive to gasoline (Brittaine, 2010). While ethanol is produced from sugar-based crops such as sugar cane, sweet sorghum, and starch-based crops such as maize, cassava, or any type of grain or tuber biodiesel on the other hand is produced from most vegetable oils including: oil palm, rapeseed, soybeans, sunflower and tree seeds such as Jatropha Curcas, Moringa (Moringa oleifera) and Castor plant (Ricinus communis) (Takavarasha *et al*., 2005). Since ethanol and biodiesel are produced from plants, their uses enhance the natural cycling of carbon dioxide resulting in little or no net addition of carbon dioxide to the atmosphere (Mapemba *et al*., 2006).

Research has shown that Jatropha Curcas is a potential source of biodiesel production, and income among poor farmers. Currently, Jatropha Curcas is being grown in many districts but mainly along the Lake Shore and lower shire districts such as Nsanje, Chikhwawa, Mangochi, Salima, Nkhotakota, Nkhata-Bay and Karongain Malawi (Nalivata et al., 2010). So far there are about 18 million trees of Jatropha Curcas that have been planted in the country and more companies are showing increasing interest to invest more in the sector (GoM, 2010). The Jatropha Curcas crop is grown as hedges by smallholder farmers hence cannot compete with other cash crops in the country. Although, there have been increasing investment decisions and increased rate of adoption of Jatropha Curcas production on small scale and commercial production, there is no information on driving factors behind adoption of Jatropha Curcas production by farmers. The investment and production decisions have been based on little evidence-based information (Brittaine et al., 2010). The thrust of this study therefore is twofold; firstly to determine the factors that affect adoption of Jatropha Curcas production as a biodiesel feedstock and secondly, to assess factors that influence extent of adoption of production of Jatropha Curcas as a biodiesel feedstock.

II. METHODOLOGY

Data and Sampling Design

The survey was conducted in Salima district in Malawi among Jatropha Curcas smallholder farmers. All the sampled households in the study had at least one tree. The implementing organization (BERL), under which the producing farmers were, defined an adopter as farmer with more than 200 trees and every farmer with trees less than 200 was considered non adopter. However, the minimum number of the trees for a farmer to be qualified as an adopter varied from district to district that grew Jatropha Curcas and was based on the average household land size for the particular district. The study interviewed 70 randomly selected households from Salima Agricultural Development Division. Both primary and secondary data were used in implementing the analysis. Primary data were collected using semi-structured questionnaire as it is said to be an effective tool for minimizing bias and random error according to Fowler (1998). All data were analyzed using Statistical Analysis (STATA) package.

Theoretical and Empirical Model

In this study we are faced with two regimes of analysis. In which case, the first regime involves modeling a dichotomy dependent variable (adoption) while in second regime we model a continuous variable of extent of adoption. Such data generation processes are best modeled by endogenous switching regression approach. More specifically, the two-stage switching regression model uses a probit model in the first stage to determine the relationship between adoption of Jatropha Curcas production and a vector of socio-economic factors. In the second stage, separate regression equations are used to model extent of adoption conditional on a specified criterion function.

Let the adoption of new technology be a dichotomous choice, where a farmer decides to adopt the new technology when there is a positive difference between the marginal net benefits of adopting the technology and not adopting the technology. Let this difference be denoted as I^* so that $I^*>0$ corresponds to the net benefit of adopting the technology exceeding that of not adopting the technology, and it is under this condition that the farmer decides to adopt the technology. However, I^* is not observable; what is observed is I, which represents the observed behavior of the farmer regarding adoption of the technology. This relationship can be expressed as

$$Y_n = X'\beta_n + \varepsilon_n \quad \text{if} \quad I = 1 \qquad [1]$$
$$Y_0 = X'\beta_0 + \varepsilon_0 \quad \text{if} \quad I = 0$$

Where, variable Y_n is intensity of technology use under adopters and variable Y_0 is intensity of technology use under non adopters. That is, only Y_n or Y_o is actually observed for any given household, depending on the value of the criterion function $I^* = Z'\alpha + \varepsilon_c$. This implies that ordinary least squares (OLS) estimates of β_n and β_o will suffer from sample selection bias: the error terms in Eq. (1), conditional on the sample selection criterion, have non-zero expected values (Lee 1978; Maddala 1983). Lee (1978) treats sample selection as a missing-variable problem. The error terms ε_c, ε_n, and ε_o are assumed to have a tri-variate normal distribution with zero mean and non-singular covariance matrix specified as

$$\operatorname{cov}(\varepsilon_n, \varepsilon_o, \varepsilon_c) = \begin{pmatrix} \sigma_n^2 & \sigma_{n0} & \sigma_{nc} \\ \sigma_{n0} & \sigma_0^2 & \sigma_{0c} \\ \sigma_{nc} & \sigma_{0c} & \sigma_c^2 \end{pmatrix} \qquad [2]$$

where σ_c^2 is the variance of the error term ε_c in the criterion equation (i.e., technology adoption); σ_n^2 is the variance of ε_n, σ_0^2 is the variance of ε_o, σ_{n0} is the covariance of ε_n and ε_o, σ_{nc} is the covariance of ε_n and ε_c, and σ_{0c} is the covariance of ε_o and ε_c.

The probit model used in this study was specified and estimated as

$$Y_i = F(\alpha + \sum \beta X_k) = F(Z_i) \qquad [3]$$

Where, Y is the discrete qualitative dependent variable presenting the net unobserved benefit to farmer i by planting over 200 Jatropha Curcas trees in their fields or homestead, F is the cumulative probability distribution

function, β is the vector of parameters, X is the vector of explanatory variables and Z is the Z-score of area under the normal curve.
The expected value of the qualitative dependent variable therefore becomes;

$$E(y|x) = 0[1 - F(x'\beta)] + [F(x'\beta)] = F(x'\beta) \quad [4]$$

The parameters (β) are estimated by maximum likelihood function and they are consistent, asymptotically normal and efficient.
As already alluded to, extent of adoption is measured by the number of technologies being adopted and in this case; it is the number of Jatropha trees planted. In order to grasp what really affects the extent of adoption, it is essential to analyze the factors that affect the number of trees that each farmer has. Separate extent of adoption functions for adopters (n) and non-adopters (o), of the following form, were specified and estimated jointly with the adoption equation.
Adoption Extent = *f*(Plot size, education, marital status,
household size, age, non-farm income, gender) [5]
All the variables used in the model are defined in this Table 1 below.

Table 1: Operational Definitions of Variables

Variables	Description
Adoption	1=adopter, 0=non-adopter
Adoption extend	Number of Jatropha Curcas planted
Martial status	1=married, 0= not married
Gender	1=men, 0=female
Plot size	Acres of total owned land
Education	Number of school years completed by the household years
Marriage Status	Dummy Variable (1= Married, 0= Otherwise)
Household Size	Number of family members that eat from the same pot
Age	Number of years lived by the household head
Non-farm income	Other income sources apart from farming (1=Yes, 0=Otherwise)

III. EMPIRICAL FINDINGS AND DISCUSSION

Descriptive statistics

Age is the important aspect in technology adoption as it relates to farmers experience, ability and capacity to uptake new farming technology recommendations (Bonabana-Wabbi, 2002**)**. The results indicate that there is significant difference in ages between adopters and non-adopters. Mean age for adopters was 40 while that for non-adopters was 35 years old. Since Jatropha Curcas as a biofuel feedstock cover some space on the cultivatable farm size, farmer's land size was considered a factor of importance to this study so as to explore its influence on adoption decision of Jatropha Curcas production. Population pressure makes land a major limiting factor for agricultural production. The size of landholding impacts on the household`s land use decisions in terms of type and diversity of farm enterprises to grow on the farm (Fabiyi *et al*, 1991). Households with small land holding size (1 acrea) tend not to adopt, while an adopter had larger land holding size (about 3 acres). The findings tally with Smale (1993) who said that total land area per household is associated with the opportunity for technology adoption as it accommodates farmers to include different cropping patterns. Furthermore, adopters had a mean household size of 6 while non-adopters had a mean household size of 5. Sometimes access to innovation is also gender sensitive which deprives other gender category from adopting the technology (Smale, 1993). The study found that 40.6% female respondents and 59.4% of all male headed households adopted Jatropha Curcas production. About 88% of adopters were married, while 82% of the non adopters reported to be married.
Education is important for an informed society. Educated people act as pioneers in most innovation adoption. Education provides basic skills that facilitate transmission to technical knowledge and rational decision-making and also to see and understand the technologies in a proper perspective in relation to current circumstances (Pahuang, 2001).

Tables 3: Key descriptive statistics for variables

Variable	***Mean***	
	Adopter	*Non-adopter*
Age	*40*	*35*
Land size	*3*	*1*
Household size	*6*	*5*
	Percent	
Gender		
Male	59.4	60.5
Female	40.6	39.5
Marriage Status		
Married	*87.6*	*81.6*
Not married	*12.4*	*18.4*
Education		
No education	3.1	13.1
Adult literacy	0	2.6
Standard 1-5	28.1	42.1
Standard 6-8	37.5	31.6
Secondary	28.2	10.6
Tertiary	3.1	0
Occupation		
Casual labour	5.3	31.3
Business	21	9.4
Employed	0	6.3
Handcraft	15.9	3.0
Remittances	5.3	0
Agriculture	52.6	50

About 3.1% of the adopters obtained tertiary education with 28% attended secondary school education. On the other hand only 10.6% of the non-adopters attended secondary education and none of them obtained tertiary education. The study also showed that slightly over 50% of the adopters depend solely on farming.

Endogenous switching regression model Results

The results of the probit regression analysis presented in Table 3revealed that gender of the household head was a significant determinant of adoption of *Jatropha Curcas* production ($p<0.05$). The results entail that probability of adopting Jatropha Curcas by male headed households is higher than that for female headed households. The result may reflect the traditional bias against women in inheriting land or having secure land, or the inherent gender-bias in testing and demonstration of the technology. Other studies have found female farmers to less likely test new technologies (Masangano, 1996). But the field observations revealed that limitation of women in decision making process and participation in cash orientedcrops further reinforces their limited access to production of *Jatropha Curcas* as a biofuel feedstock.

Table 3: Probit model estimates of adoption of Jatropha Curcas

Variable	**Coefficient**	**Std error**	**p>|z|**
Plot size	0.1032*	0.0546	0.059
Marriage Status	-0.1748*	0.1030	0.090
Age of farmer	0.0045	0.0126	0.722
Education level	0.2111***	0.0576	0.000
Secondary incomes source	0.0017	0.0035	0.609
Gender of household head	0.0210***	0.0027	0.000
Plant spacing	-0.0146***	0.0019	0.000
Intercept	2.3970***	0.7866	0.002
Likelihood Ratio test	34.24***		
Wald chi2(6)	28.38***		

*, *** means significant at 10% and 5%, respectively

To the expectation, land holding size had also a positive and significant effect ($p<0.1$) on the adoption of Jatropha production. The probability of adoption was found to increase for each marginal increment in hectarage. By implication, this could be because farmers with large land holding size are willing to try different technologies and may not compete with the production of other crops since land is sufficiently large. The land holding size was used as a proxy for wealth and status and income levels of farmers hence the result showed a

positive relationship between adoption decision and land size.
Another positive and significant determinant of adoption of Jatropha Curcas production was education level of the household head ($p<0.05$). The result indicated that the probability of adoption increased for each additional school year of formal education completed by the household head. The results agreed with the priori that respondents' exposure to education increases his or her ability to comprehend and utilize information relevant to the adoption of biofuel technologies. The results corroborate that ofBaylin and Pahuang (2001) who observed that low education levels in rural farmers in Malawi, affect adoption rate to technologies and that technology efficacy in adoption gets reduced when illiteracy exists. Hossan (2000) also found something similar to the results by observing that formal education enhances farmers` decision-making power to see and understand the technology in a proper perceptive and its relevance to his/her situation that enhances technology adoption.
The last but not the least factor with a positive significant effect on the probability of adoption was plant spacing between Jatropha trees. Significant at 5%, *Jatropha Curcas* spacing was found to decrease probability of adopting production of *Jatropha Curcas*for each additional meter between the trees. Another factor found to significantly reduce the probability of adoption of *Jatropha Curcas* was marital status($p<10$). The result agreed with the priori expectation and explained that decision making process on adoption was faster for unmarried household head as there are few objections to any decisions made as compared to married ones.
Table 8 showsfactors that affect extent of adoption in *Jatropha Curcas* production. The results for adopters showed that land holding size has a positive influence ($p<0.1$) on the number of trees that a household can have. The results highlighted that increase in land size by 1 hectare would increase the adopters number of trees by 12. The land holding size is considered the first and probably the most important determinant of adoption in most empirical adoption literature and its effect on adoption is considered to be positive, negative or neutral (Bonabana-Wabbi,2002**)**. But based on field observation, most adopters planted the trees around their entire plots hence achieved the big number of trees per hectare.

Table 4: Full information maximum likelihood (FIML) estimates of the switching regression model

Variable	**FIML estimate**	
	Adopters	**Non-adopters**
Land size	11.5444 (3.4192)***	0.2952(3.7922)
Household size	23.1099 (16.799)	-3.3930 (3.2372)
Marital status	-27.8301(16.578)*	-9.8236 (7.1554)
Age	1.20978 (3.5139)	0.8241 (0.4626)*
Education level	58.7820 (15.432)***	7.1521 (5.1961)
Secondary income source	0.5079 (0.9784)	-.0721 (0.1827)
Intercept	477.7961 (210.591)**	45.1542 (39.213)

*, **, *** means significant at 10% , 5% and 1%, respectively

Other significant determinant of number of trees that adopters can have was education level of the household head. The education level was significant at 1% hence increasing number of school years of the household head by 1 would increase adopters number of trees by 59. Therefore, educated population is capable in adopting more bio fuel production than uneducated. The results agreed with the findings of Kanyama-Phiri et al. (1994), who said education has an essential aspect in technology adoption because it changes farmers` perception on culture, social and tradition hindrances to adoption hence the higher the education level attained the lower hindrances to adoption. The last factor affecting the adopter's number of trees significantly ($p<0.1$)was marital status of the household head. Marital status affected adoption negatively by reducing the number of adopted trees by 28 for married household head. Married people are firstly more concerned with sorting out food security problem in the household. Thus, priority for land is given to food production other than Jatropha carcus. On the side of non-adopters it can be concluded that gender of the household head is the only factor that significantly ($p<0.1$) affected the few number of Jatropha trees that characterized non adopters. The fact of having male headed household head increased the number of trees that non-adopter household had by 1 approximately. The results portrayed a common phenomenon in most technology adoption in Malawi where female farmers tend to be retrogressive in technology adoption (Smale, 1993).

Conclusion and Policy Implications

In summary, the main aim of this study was to provide an understanding of the socio-economic factors that influence farmers` decision to adopt Jatropha Curcas production as a biofuel feedstock. It specifically focused on determining the socio-economic factors that affect adoption of Jatropha Curcas as a biodiesel feedstock and assess the level of influence of these socio-economic factors on the extent of adoption of Jatropha Curcas as a biodiesel feedstock.
The results indicated that positive and significant determinants of adoption of Jatropha Curcas production by small scale farmers are gender of the household head, plot size and education level of the household head.

Marital status and distance between the trees were found significant but negatively affecting adoption. Based on extent of adoption, the results showed that plot size and education level of the household head were the only significant factors that influenced the extent of adoption or number of trees that adopters have. Further, marital status was also found to be significant but negative factor influencing the number of trees for the adopters. However, age of the household head was only significant factor affecting the extent of adoption for non-adopters. The results show that the promotion of biofuel production in Malawi will entail that adoption of the crop on commercial basis will largely involve farmers who have large land holding sizes. Most farmers that will be involved in commercial farming of Jatropha would be highly literate. There is also gender dimension with the adoption of Jatropha with male farmers more likely to adopt the biofuel crop. The study recommends that if Malawi government would like to promote the cultivation of \ Jatropha crop on commercial basis, consideration for land to be allocated to Jatropha production should be a priority. Hence, promotion may be suitable for large commercial farmers who have lots of land.

REFERENCES

Baylin, A., and Pahuang, R. (2001). Some factors affecting the adoption of farming technologies, University of Sussex, UK.

Bonabana-Wabbi, J. (2002).Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda.Unpublished Msc. Thesis.Virginia Polytechnic Institute and State University.Accessed on 14th June 2012. Available online at http://www.lumiere.lib.vt.edu/sample_theses/submitted/trash/etd.../thesis1.pdf

Brittaine, R. and Lutaladio, N. (2010) Jatropha; A Smallholder Bioenergy Crop. The potential for Pro-poor Development. Intergrated Crop Management Vol. 8-2010. FAO, Rome Italy.

Fabiyi, Y.L., Idowu, E.O., andOguntale, A.E., (1991). Land tenure and management constraints to the adoption of alley farming by women in Oyo State of Nigeria.Agricultural Extension, 6 (1/2):40-60.

FEWSNET.(2012). Malawi Food Security Outlook.Accessed on 7th June 2012. Available online at http://www.fews.net/docs/Publications/Malawi_OL_2011_10.pdf

Fowler, T.J. (1998). Design and Evaluation of Survey Questions. In: L. Birkman&D.J. Rog (Eds.), Handbook of Applied Social Research Methods, (pp. 343-374). Thousand Oaks: Sage.

Government of Malawi (GoM).(2010)Minister of Finance Budget Speech for the Financial Year 2010/2011.Accessed on 18th June 2010.Available online at http://www.finance.gov.mw/budgetS2010.pdf.

Kanyama-Phiri, G. Y., K. Wellard, and J.B. Kamangira(1994).Preliminary findings on adoption of agroforestry technologies by smallholder farmers in Zomba RDP. Paper presented to agroforestry symposium held at Bvumbwe Agriculture Research Station (24-28 October, 1994)

Mapemba, L.D, Epplin, F.M. and Huhnke,R.L.(2006).Environmental Consequences of Ethanol from Corn Grain, Ethanol from Ligno cellulosic Biomass, and Conventional Gasoline. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, July 23-26, 2006, Long Beach, California.

Masangano, C., (1996). Diffusion of agroforestry technologies. Accesed on 22th June, 2012. Available online at URL.http://www.msu.edu/12user/masangn/agrof.html.

Nalivata, P. Kachamba, D.J. and Mtethiwa, A.H. (2011). Biofuel crops production in Malawi; Principles and crop Management Practices. A manual prepared with funding from `Small scale biofuels in Malawi` project in cooperation with Bioforsk Soil and Environmental Division. Bnda College of Agriculture, Lilongwe, Malawi.

Nalivata, P.C., and Mapemba, L.D. (2010).A Study on the Impact of Biofuels on Food Crops and Livestock Production in the Future. Final Report Submitted to CDM Head Office, Lilongwe Malawi.

Rooyen, C. and Swardt, S. (2002). Towards Understanding the Small Scale farmers. Draft final report, London, UK.

Smale, M.(1993). Maize is life: Maize research and smallholder production in Malawi. Case study of Malawi Research Impact in Africa (MARIA) Project, USAID.Accessed on 23rd June 2012. Available online at http://www.pdf.usaid.gov/pdf_docs/PNABZ963.pdf

Takavarasha, T.,Uppal, J. andHongo, H. (2005) Feasibility study for production and use of biofuel in the SADC region. SADC Secretariat, Gaborone, Botswana.

Toylar, P.R., Govinalajala, C. and Levin, J. (2008) Financing Energy Efficiency. World Bank. Lilongwe, Malawi.