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Commercialization of Under-Utilized Plant Species in Zimbabwe: The Case of Jatropha (*Jatropha curcas*) in Mutoko District

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157- Commercialization of Under-Utilized Plant Species in Zimbabwe: The Case of Jatropha (*Jatropha curcas*) in Mutoko District.

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Abstract

Jatropha curcas L. (or physic nut), a previously underutilized tree species in smallholder farming systems, is fast gaining formal recognition as a very important tree crop in improving rural livelihoods. The Government of Zimbabwe is vigorously promoting the growing of Jatropha in marginal areas for bio-diesel production to save the country foreign currency in fuel imports. A study was carried out in 12 out of 19 wards of Mutoko district in 2007 to analyze the socio-economics of Jatropha commercial utilization by smallholder farmers in marginal areas as a livelihood improvement strategy. The analysis involved categorizing farming households according to socio-economic characteristics and finding the effects they have on commercial utilization of Jatropha. The study employed binary logistic (Logit) and Tobit regression analyses in meeting the research objectives. Size of landholding, household's wealth status and perception about the price were the socio-economic factors found to be significant in influencing decision by households to adopt (or not adopt) commercial utilization of Jatropha. The concludes by recommending that For successful Jatropha commercialization to be realized and the smallholder farmers' livelihoods improved, there is need for the government to put in place a complete package of incentives that will stimulate optimal exploitation of the Jatropha plant, including adjusting the selling price to viable levels.

Key Words*: Socio-economic, Jatropha, commercialization, Logit, Tobit*

INTRODUCTION

Jatropha curcas (physic nut/mujirimono) has been known to exist in Zimbabwe for over six decades, mostly in smallholder farming areas where it has been domesticated as a hedge or live fence around homesteads, gardens and crop fields to protect against invasion by roaming animals. The tree crop has become popular in the country through advocacy by the government as a potential solution to climate change and for improving livelihoods of the smallholder farmers in an environmentally sound and economically sustainable manner. The Government of Zimbabwe (GoZ) and some non-governmental organizations (NGOs) are promoting commercialization of Jatropha among smallholder farmers by encouraging massive propagation of the shrub for harvesting of seeds and marketing thereof to the country's bio-diesel project. The farmers and rural communities in these areas are also being encouraged, particularly by NGOs to process the Jatropha seeds into various marketable commodities such as soap, paraffin, and candles, etc. The promotion of Jatropha production among smallholder farmers in the marginal (drier) areas is being done to meet 10 percent of the country's diesel fuel requirements by 2017. The GoZ already specified Jatropha in 2005 and banned its export in line with its objective of extensively developing it and hopes to save foreign currency in petroleum fuel (diesel) imports. However, the Jatropha (bio-diesel) project is being advocated for by politicians and policy makers without full information on the socioeconomic and livelihood implications on the producers. Although Jatropha has now received formal recognition, its growers are still unable to achieve optimum economic benefits from the plant especially for all its various uses due to various social and economic constraints.

In spite of low returns to land, labour and capital, smallholder farmers in dry land and marginal areas have long maintained indigenous strategies and options to manage risk and to deal with poor overall productivity (SIRDC, 1998). Agroforestry is one of the options that have been adopted by these farmers as a dynamic, ecologically-based, natural resource management system that, through integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits (WAC, 2006). Plant species like Jatropha that can grow well on lands that may not be attractive for agriculture and supply raw materials for industry, fuels for basic energy requirements and improve the environment are therefore a promising option that needs careful and comprehensive assessment.

The oil plant Jatropha is a multi-purpose and drought-resistant large shrub or small tree that is a native of tropical America but now thriving well throughout Africa and Asia. The wood and fruit of Jatropha can be used for numerous purposes including generation of biodiesel. The shelled seeds of Jatropha contain a viscous oil (up to 35% by weight), which can be used for the manufacturing of candles, wax polish and soaps, in the cosmetics industry, for heating and lighting on its own as a diesel/paraffin substitute or as a blend (SIRDC, 1998). This latter use has important implications for meeting the demand for rural energy services and also exploring practical substitutes for fossil fuels to counter greenhouse gas accumulation in the atmosphere thereby mitigating the scourge of climate change. Various parts of the Jatropha plant are also of medicinal value, its bark contains tannin, and its flowers attract bees thus, making the plant a potential hub for honey production. Though Jatropha is not browsed by animals because of its toxic leaves and stems, after treatment, the seeds or seedcake can be used as animal feed and being rich in nitrogen, the seedcake is good source of plant nutrients (Henning, 1996).

Currently, Jatropha oil has become an important product from the plant for meeting the cooking and lighting needs of the rural population, or as a viable substitute for diesel. Substitution of firewood by plant oil for household cooking in rural areas will not only alleviate the problems of deforestation but also improve the health of rural women who are subjected to the indoor smoke pollution from cooking using inefficient fuel and stoves in poorly ventilated space. This positive attribute of Jatropha, if fully tapped, may help save time for rural women of Zimbabwe who spend most of their time fetching firewood for household use, to perform other productive tasks. The Jatropha system is characterized by many positive ecologically economic aspects that are attached to the commercial exploitation of this plant.

DEFINITION OF KEY CONCEPTS: *A REVIEW OF LITERATURE*

What is Jatropha?

Jatropha curcas L. (Jatropha or JC) is a multipurpose and drought resistant large deciduous shrub or small tree that grows up to a height of 3-5 metres and has a productive life of up to 50 years (Tigere, 2006, SIRDC 1998). Although a native of tropical America, it now thrives throughout Africa and Asia. The common English name for Jatropha is *physic nut* (Villancio, 2006). It is a member of the *Euphorbiaceae* family and plant of Latin American origin which is now widespread throughout arid and semiarid tropical regions of the world (Henning, 1999). A close relative to the castor plant, its oil has the same medical properties. Jatropha seeds contain about 35% of non-edible oil (Dove, 2007; Eijck and Romijn, 2006; Villancio, 2006; Benge 2006; Tigere, 2006; Henning, 1999; SIRDC, 1998). Jatropha can be incorporated into the farming system as agroforestry. The World Agroforestry Centre (WAC, 2006) defines agroforestry as a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscapes, diversifies and sustains production for increased social, economic and environmental benefits for land users. According to SIRDC (1998), Jatropha is easy to establish, grows relatively quickly and is hardy. Being drought tolerant, it can be used to reclaim eroded areas, be grown as a boundary fence or live hedge for keeping out animals from crops.

Jatropha Commercialization

Commercialization (or simply commercial utilization) of Jatropha refers to the derivation of economic and financial benefits from Jatropha hedges through marketing of Jatropha seeds or products derived from them. Where farmers are harvesting and processing the seeds into products for household consumption and not for sale, it is *subsistence* and not commercial utilization. The concept of Jatropha commercialization was initially introduced in Zimbabwe by two plant oil projects, in 1996, by two NGOs, Binga Trees Trust (BTT) and Biomass Users Network (BUN) in Binga and Mutoko districts respectively following the discovery that the plant was abundant in these areas (Dove, 2007, WSU, 2002). This was followed by the introduction of the National Bio-diesel Project (NBP) by the government in 2004 to encourage massive production of Jatropha for the project. The aims of the projects were to help farmers in these areas, build up cash incomes from tree products, Jatropha among them since the areas experience poor rains and have poor soil and mineral resources. The NGOs used to buy the seeds from the farmers, extract the oil from the seeds via mechanical extraction and retail it to small-scale soap makers and make soap. Most sales were within Zimbabwe to final consumers, and retailers. The major draw back to Jatropha commercialization has been that the general economic climate prevailing in Zimbabwe does not encourage investment and exports, thereby scaring away potential investors who may bring in the much needed competition for the enterprise to be viable to farmers. Besides the economic climate, the organizations found their Jatropha enterprises considerably hampered by long distances from main population centers.

Promotion of commercial utilization of the tree crop in Zimbabwe can be traced back to 1992 when a group of large scale commercial farmers (LSCF) formed the Plant Oil Producers Association (POPA) with the objective of producing Jatropha on a large scale (Dove, 2007). The activities of POPA slowed down when the farmers discovered that profit margins concerning Jatropha oil as fuel were not as big as they expected, especially because there was no possibility for mechanical harvesting of the seeds. In 1996, a Jatropha plant oil project was introduced by BUN-Zimbabwe in Makosa ward of Mutoko District with an objective to promote commercial exploitation of Jatropha, which is in abundance in the area as a live fence, to produce oil for use as fuel (Dove, 2007). In 2004, the GoZ declared the Jatropha shrub as a specified plant which should be promoted to harvest seed for processing into oil for bio-diesel generation. This has resulted in the massive promotion of the growing of the shrub across the whole country particularly by smallholder farmers, as a live fence around homesteads, crop fields and gardens. Before the declaration of Jatropha as a specified plant, interest in its production had been limited to the smallholder farming sector, now the large scale commercial farmers are also venturing in Jatropha production (Tigere *et al*, 2006).

Insights from empirical studies

Tigere *et al* (2006) carried out a study in Makosa Ward of Mutoko district to elicit smallholder farmers' perceptions on the agronomy and utilization of Jatropha and identify possible areas for its exploitation, promotion and research. They used descriptive statistics to present results of the study. The study finds out that majority (83%) of the farmers mainly utilize Jatropha as a live fence, while utilization of Jatropha seeds (oil pressing) for soap and candle making is being undertaken by 43% of the farmers. Seed is harvested during non peak labour periods and seed yields of up to 400g per shrub per harvest can be achieved, depending on management. The use of Jatropha as a live fence has helped in reducing fencing costs where barbed wire or security fence and fencing posts could be used, and the level of deforestation is also reduced. Despite its various advantages, Tigere *et al* (2006) reports that, one of the main limitations of Jatropha is its seed toxicity to both humans and livestock as reported by 51% of the farmers. A relatively large proportion of farmers (42%) also mentioned that Jatropha lacks a woody stem which renders it unsuitable for use as firewood. This is one of the major limitations in communal areas where the major source of fuel is firewood.

Dove (2007) carried out an exploratory survey of Jatropha activities in Zimbabwe and found four organizations; BUN Zimbabwe, Binga Tree Project, Environment of Africa and POPA to be involved in promotion of Jatropha commercial utilization. Its findings were that the projects were promoting Jatropha as a source of oil for use as fuel (domestic and industrial use), use of press cake as organic fertilizer and use of oil for lighting purposes. The activities of POPA, an organization of large scale commercial farmers wanting to produce Jatropha oil on a large scale basis, were however, found to be slowing down after discovery that the profit margins from Jatropha oil as fuel were not as big as initially anticipated and also that there was no possibility for mechanical harvesting of the seeds.

WSU (2002) carried out an industry and market study of natural plant products with the purpose of identifying production and marketing opportunities for small and medium scale producers and distributors with a view to promoting both income generation and improved natural resource management. Jatropha was one of the main plants that were studied and the findings in Zimbabwe were that the plant was introduced in the country around the 1940s and has gained slow but steady acceptance by rural people as live fence. The Jatropha industry was found to be at a very early stage of development with some firms that had expressed interest becoming dormant due to the difficult economic environment. The markets for Jatropha were found to be generally confined to the areas were the plant grows with pricing being a matter of individual arrangements between processors and suppliers of the seed. The study also discovered three organizations that were actively involved in Jatropha promotion namely; BTT, BUN, and POPA.

A marketing opportunity that remains unexploited was identified by WSU (2002) in which Olivine Industries, Zimbabwe’s largest producer of edible oil and soap manufacturer had expressed interest in substituting imported tallow with Jatropha oil in their soap manufacture but, indicated it would only do so if ensured of a weekly supply of 2000 litres of the oil. Production levels in the country have never reached even closer to this level. There is need for encouraging such corporates as Olivine Industries to enter into contract farming arrangements with Jatropha producers to be guaranteed of constant and reliable supply. The study also found that bio-diesel from Jatropha does not have a significant price advantage over petroleum diesel but somewhat expensive given that the price of petroleum diesel was subsidized. The study, however, recommends that Jatropha production and processing be promoted from the point of view of both protecting the environment and income generation for the producers.

Benge (2006) noted that there is a growing interest in Jatropha as a bio-diesel “miracle tree” to help alleviate the energy crisis and generate income in rural areas of developing countries. He argues that forgotten perhaps is that a greater proportion of the farmers in developing countries only have access through some form of limited tenure to a very small plot of land needed to grow food crops. He asserts that marginal yields are obtained from plants grown on marginal lands. To be economical as a bio-diesel fuel, Jatropha must be produced in volume, and those who stand to profit the most are the processors, retailers and the "middle-men;" the latter have a history of exploiting vulnerable small producers by paying only a fraction of the actual value of their product.

Dove (2007) carried out economic analyses of Jatropha projects across Africa and their findings are as follows. In Mali, a Jatropha processing project was analysed in which the only investment was a hand-operated oil press which costs US$150. Findings were that extraction of 12kg of seed gives 3 litres of oil which transformed into soap giving 28 pieces of 170g each which are then sold at US$4.20 and the press cake also sold at US$0.27 bringing total revenue to US4.47. Total input cost was US$3.04 and the net profit for processing 12 kg of Jatropha US$1.43 in a day which is more than the daily average wage for workers in Mali. The analysis has the weakness that it only considered labour used in processing and ignored costing labour used in growing and harvesting the Jatropha. Including these costs would significantly reduce the profit margin.

In another study, Dove (2007) did an economic evaluation of a Jatropha project in Katute, Tanzania and found that Jatropha seed harvesting and marketing gives a profit margin of US$0.29 per hour. Oil extraction from 5kg of seed gives a profit of US$1.09 in one hour while soap production gives value added for 1 hour’s work of US$2.82. While collection and marketing costs are included, establishment costs have not.

Eijck and Romijn (2006) conducted a study of five Jatropha projects in Tanzania and used cost-benefit analysis (CBA). The results of the CBA show internal rate of returns (IRR) ranging from 0 to 384%. Reliability of the results is questionable since a lot of assumptions, some of which may not apply, have been used. For example, a total yield of 4 to 10 kg per tree is assumed. This yield is very difficult to achieve, especially when no external inputs are used.

An economic analysis of Jatropha seed production in a plantation situation was done by Villancio (2006) in Philippine. His findings from gross margin and cost-benefit analyses (GMA and CBA) of a commercial plantation are that returns are realisable from the third year after establishment. Initial gross margin of PhP3,000 and net benefit of PhP11,000 are realised in year 3 but peaks to PhP75,000 and PhP22,000 respectively in year 7 and remain constant thereafter. Careful analysis of this situation show that seed yield of 5 tonnes per ha and below are not profitable; profitability improves when yields increase to 7.5 tonnes per ha. His costing does not consider (ignored) management costs given that all the other calculations are based on plantation production.

Benge's (2006) observation was that in many calculations of projected profitability, one or more of the costs of establishment, harvesting, transport, processing and marketability may not be included, while the over-valued speculation of selling carbon credits is; therefore, a somewhat distorted view of bottom-line economics. He argues that to optimize oil extraction from Jatropha seeds and to produce a quality of oil that will maximize profits (e.g., a diesel oil substitute) requires: equipment, some quite expensive; chemicals, such as methanol and caustic soda, that are highly flammable, toxic and dangerous to use and are somewhat costly and not readily available; and infrastructure and trained personnel that must be in place in a timely manner. He goes to argue that the use of refined Jatropha oil as a substitute for diesel fuel and for soap production may have the potential to improve the livelihood of the people in rural areas by providing additional income; but only if the right conditions exist. He also noted that some of the biggest advocates for Jatropha are those who are selling seeds (of unknown genetic potential), who stand to make profits in the near term.

RESEARCH METHODOLOGY

Data Collection and Management

Both primary and secondary data on Jatropha production and utilization were sought and analyzed in this study. A socio-economic survey was conducted (120 household questionnaires) to generate household socio-economic data as primary data for the research. A focus group discussion (FGD) as well as interviews and discussions with key informants who have vested interest, knowledge and experience in the Jatropha system were also conducted to generate both socio-economic data and other information on economic, technical, social and political aspects of the Jatropha system. The key informants included local community leaders (e.g. village heads), resident Agricultural and Forestry Conservation extension personnel and NGO field officers working with communities in the area. The community leaders were asked to provide information on issues of land tenure, gender and access to resources. The extension personnel and NGO field officers were asked to inform on current technologies and practices in the Jatropha system; its production and utilization as well as the level of adoption of these technologies in the area. The discussions with the key informants sought information on the history, current work and future plans on the Jatropha system in the area. Secondary data were collected through literature study of various articles (both published and unpublished) on Jatropha and the Jatropha system, specifically on previous studies from the region and the rest of the world. The literature study sought information from journal articles and other working papers on:

- History and distribution of Jatropha in the country and the rest of the world,
- List and type of by-products from the Jatropha system, and
- Economic evaluation of the Jatropha system.

Analytical Framework

The research study adopted regression analysis as the analytical tool for the study.

Regression Analysis

Regression analysis is a multivariate analysis type which involves examining multiple variables while at the same time investigating the relationship between dependent variable with variation in one independent variable *ceteris paribus* (Chiputwa, 2006). In this study, two types of regression analysis have been used namely the binary logistic (logit) and Tobit multiple linear regression models.

The Binary Logistic (Logit) Model

This study uses the binary logistic regression model (logit) which is more or less similar to a linear regression model only that it is applicable to models where the dependent variable is dichotomous. Probit and logit estimations are used when the outcome variable takes two possible states, hence the name binary models. These models have been used in economic literature to gauge the probability of choosing one option over another (Chiputwa 2006, Lemchi *et al* 2005, Jera 2004, Muhammad and Muhammad 2003, Bacha *et al* 2001, Lwayo and Maritim n.d). The binary logistic regression (logit) model is used because the dependent variable is a dichotomy (e.g. yes or no) and the independent variables are continuous and/or categorical. Following Long (1997), the model is generally presented as:

$$\Pr(y_i = 1 | x_i) = \frac{\exp(x_i\beta)}{1+\exp(x_i\beta)} = \frac{1}{1+\exp(-x_i\beta)}$$

Where:

$\Pr(y_i = 1 | x_i)$ represents the probability of an event happening if the dependent variable takes a value of 1 given an independent variable x_i.

x_i represents all vectors of the independent variables and their explanatory power can be explained by the intercept.

The model has the advantage that its regression coefficients can be used to depict odds ratios (the probability of success relative to failure) for each independent variable in the model. An odds ratio that is greater than 1 implies that a unit increase in the continuous variable or discrete change in the categorical variable among the independent variables leads to a decrease in the odds of a household being an adopter versus being a non-adopter. The Logit model is simple to understand and its parameter estimates are asymptotically consistent and efficient (Long, 1997).

The other advantage of using the BRM is that it does not necessarily require the variables to be normally distributed. The model's appropriateness to data can be detected using the model Chi-square or F-test just like the OLS regression model. The model has its limitations in that it cannot analyze the intensity of adoption or utilization of a given practice. It is very sensitive to model specification thereby requiring larger sample sizes for the estimates to be efficient.

Tobit Regression Model

It is often the case that in adoption studies we do not only want to know probability that a farmer has adopted a technology but also the extent of use of the technology after adoption. To simultaneously explain probability of adoption, and intensity of use of the technology, the use of a Tobit model is appropriate (Langyintuo and Mekuria, 2005). Direct application of the Tobit estimation sufficiently provides the needed information on adoption probability and the intensity of use of Jatropha commercialization or subsistence utilization.

The Tobit model can be specified as:

$$t_i = x_i\beta + u_i: \qquad \text{If } x_i\beta + u_i > 0$$

$$= 0 \qquad \text{If } x_i\beta + u_i \leq 0$$

$$i = 1,2,....n$$

Where:

t_i is the technology (commercial utilization in this case).

X_i represents the vector of independent variables.

u_i: is the disturbance or error term

The model assumes that there is an unobserved latent variable which is positive $(X_i\,\beta + u_i > 0)$ in that case there is adoption of the technology and negative or zero $(X_i\,\beta + u_i \leq 0)$ in the case of non-adoption (Baidu-Forson, 1999).

Finding the effect of an independent variable on the expected value of a dependent variable E_t for all cases requires examining the formula for the first-order partial derivative of Tobit model equation such that:

$$\frac{\delta E_t}{\delta X_k} = F(z) \times \frac{\delta Et*}{\delta X_k} + E_t * \times \frac{\delta F(z)}{\delta X_k}$$

Where:

E_t^* is the expected value of t for cases above the limit (adopters or commercializers).

$\frac{\delta Et^*}{\delta X_k}$ tells how the intensity of adoption will change due to a change in a specific independent variable.

$\frac{\delta F(z)}{\delta X_k}$ tells the effect of a particular independent variable on the probability of adopting.

RESULTS AND DISCUSSION

Commercial Utilization of Jatropha

Commercialization in the context of this study, refers to derivation of financial benefits from the Jatropha hedges through selling or processing of Jatropha into various consumer products used at home as substitutes of the rest. Commercialization (marketing and value addition) has been encouraged by the introduction of the plant oil and bio-diesel projects in the area, which uses Jatropha seeds in manufacturing bio-fuels such as diesel and paraffin. The projects have also introduced techniques of processing Jatropha into various household commodities such as soap, candles, and floor polish as away of improving rural livelihoods. Most of these products are produced for home consumption while some are sold on the local market. Either way, households benefit from the extra income generated from Jatropha product marketing or from reducing consumption expenditure on the farm.

Value addition on Jatropha is still a relatively new concept needing extensive promotion through farmer training and education. Only 9.5 percent of the households are involved in processing of Jatropha into household commodities. A greater proportion (55%) of the Jatropha processing households (or 5.3% of Jatropha producers) indicated to have sold some of the commodities they produce but generally value addition is done on products meant for domestic consumption only since the farmers still lack capacity in terms of working capital, appropriate technology (machinery) and technical know how. Marketing of Jatropha and/or its products is being undertaken by 64.7 percent of the Jatropha producing households to generate supplementary income. This study considers those households that have sold Jatropha and/or processed Jatropha products more than once, as *commercializing*, otherwise, they are *non-commercializers*.

Socio-economic Characteristics and Level of Participation in Jatropha

The characterization of farmers according to their socio-economic status was done to determine the level of heterogeneity among the farmers and relating it to their level of participation in the Jatropha system. The majority (78.4%) of Jatropha producing households are male-headed. Female-headed households comprise 21.6% of Jatropha producers but none of them (female headed households) are involved in processing of Jatropha products. A greater proportion (56%)

of the female-headed household Jatropha producers is involved in production and marketing of Jatropha while 44% have the trees but are not harvesting. The Pearson's Chi-square test of association between gender and farmer's level of participation in the Jatropha system (4.813) suggests no significant relationship. The same Pearson's Chi-square test on the relationship between age of household head and their level of participation in the Jatropha system (19.764) suggests a strong relationship at the 95% confidence interval. This means that a household's level of participation in Jatropha is influenced by the age of the head of that particular household.

The majority of both high-resource and low-resource households are involved in Jatropha production for marketing only. Pearson's Chi-squared test of association suggests significantly strong relationships between household size and level of participation in Jatropha (99% significance level), and wealth ranking and level of participation in Jatropha (95% significance level) respectively (Table 1). Most female household heads tend to be widows and are not well educated compared to their male counterparts.

Table 1: Level of Participation with Respect to Household Size and Wealth Ranking

Household Head Characteristic	**Level of Participation in the JC System**				**Total, N (%)**	**Pearson's Chi-square Test, χ^2**
	Tree Raising without Harvesting	***Production and Processing for Consumption***	***Production and Marketing Only***	***Production, Processing and Marketing of Products***		
Household Size						
< 3 members	4	0	5	0	9 (7.7)	21.654***
3 - 5 members	16	3	31	1	51 (44.0%)	
6 -10 members	16	2	33	4	55 (47.4%)	
>10 members	0	0	0	1	1 (0.9%)	
Total	**36 (31.0%)**	**5 (4.3%)**	**69 (59.5%)**	**6 (5.2%)**	**116 (100%)**	
Wealth Ranking						
High-resource	6	1	29	4	40 (34.5%)	10.012**
Low-resource	30	4	40	2	76 (66.5%)	
Total	**36 (31.0%)**	**5 (4.3%)**	**69 (59.5%)**	**6 (5.2%)**	**116 (100%)**	

(*** = significance at 99% level) **Source**: Household Survey Data - Mutoko District, (2007)

Table 2 below summarizes the patterns in farm resource ownership according to farmers' levels of participation in Jatropha. The resources include size of land holding, livestock numbers and quantities of farm implements owned by the farmers. There is generally sufficient evidence to suggest strong association between farmers' wealth level and farm resource endowments as indicated by Pearson's Chi-square test results shown. Relationships exist between farmer's level of participation and ownership of the following resources; land, all types of livestock except pigs, and farm implements such as harrow and wheel barrow.

Table 2: Level of Participation with Respect to Farm Resource Endowments

Farm Resource	Level of Participation in the JC System				Total, N (%)	Pearson's Chi-square Test, χ^2
	Tree Raising without Harvesting	*Production and Processing for Consumption*	*Production and Marketing Only*	*Production, Processing and Marketing of Products*		
Landholdings						
Less than 1 ha	15	3	35	2	55 (47.5%)	28.306***
1 to 3 ha	20	1	31	1	53 (45.7%)	
3.1 to 5 ha	1	1	1	1	4 (3.4%)	
More than 5 ha	0	0	2	2	4 (3.4%)	
Livestock Ownership						
Cattle						
None	6	3	16	0	25 (21.6%)	50.589**
1 to 3 cattle	20	1	34	2	57 (49.1%)	
More than 3 cattle	10	1	19	4	34 (29.3%)	
Goats						
None	2		14	1	17 (14.7%)	42.256*
1 to 3 goats	22	3	34	2	61(52.5%)	
More than 3	12	2	21	3	38 (32.8%)	
Poultry						
None	0	0	3	0	3 (2.6)	86.923**
1 to 5	21	1	25	1	48 (41.4%)	
More than 5	15	4	41	5	65 (56.0%)	
Harrow						
None	36	5	66	4	111 (95.7%)	14.101**
One	0	0	3	2	5 (4.3%)	
Wheelbarrow						
None	31	5	50	4	90 (77.6%)	14.963**
One	2	0	19	2	23 (19.8%)	
More than 1	3	0	0	0	3 (2.6%)	
TOTAL	**36 (31.0%)**	**5 (4.3%)**	**69 (59.5%)**	**6 (5.2%)**	**116 (100%)**	

(**, *** = significant at 90%, 95% and 99%). **Source**: Household Survey Data - Mutoko District

Factors Influencing Jatropha Commercial Utilization

A number of previous studies have analyzed the effects of socio-economic variables on the decision by farmers to adopt agricultural technologies (Chiputwa 2006, Lemchi *et al* 2005, Jera 2004, Muhammad and Muhammad 2003, Bacha *et al* 2001, Lwayo and Maritim n.d.). Variables mainly considered in these studies include, gender, age, marital status, household size, level of education, landholding, and access to agricultural services such as extension and credit. Landholding or farm size has been commonly considered in most adoption studies and it seems that a certain threshold farm size has to be attained for a farmer to consider adopting a new concept. There are also other factors that have been considered in this analysis such as perception about market conditions (especially commodity price) and purpose for which Jatropha was initially planted to serve.

In analyzing factors influencing the farmers' decision to adopt different concepts of Jatropha utilization, it may not be enough to only know the probability that a farmer will adopt commercial utilization of Jatropha but it is also critical to know the extent of continued commercial utilization after adoption. To simultaneously explain probability of adoption, and intensity of use of the technology, the use of the Tobit model is also appropriate.

The Logit can also be specified as:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \ldots\ldots\ldots\ldots + \beta_k X_k + e$$

where P_i = probability of adoption, β_i = coefficients, X_i = independent variables, and e = error term.

The dependent variable is the natural log of the probability of a household engaging in commercial utilization of Jatropha (P_i) divided by the probability of not engaging in commercial utilization of Jatropha ($1-P_i$).

Dependant variable: Commercial utilization or non-commercial utilization of Jatropha (If commercialized then 1, otherwise 0)

$$Commercialization = \beta_0 + \beta_1 Sex + \beta_2 Age + \beta_3 Hhsize + \beta_4 Literacy + \beta_5 Landsize + \beta_6 Wealthcat + \beta_7 Incomesorce + \beta_8 Credit + \beta_9 Extension + \beta_{10} Perceptn$$

where:

β_0	= denotes the intercept term
β1 - β12	= unknown parameters to be estimated
Commercialization	= commercialization of Jatropha (if commercialized =1, otherwise =0)
Sex	= sex of household head (if male = 1, otherwise = 0)
Age	= age of household head
Hhsize	= size of the household
Literacy	= household head's literacy level (None =0, Primary =1, Educated = 2)
Landsize	= size of total arable land
Wealthcat	= wealth category of household
Incomesorce	= major source of income (if on-farm = 1, otherwise = 0)
Credit	= access to agricultural credit (if having access = 1, otherwise = 0)
Extnadvc	= frequency of extension contact (none = 0, sometimes =1, always = 2)
JCppltn	= Number of Jatropha trees on the farm
Perceptn	= perception about selling price of Jatropha (if positive = 1, otherwise = 0)

The Logit and Tobit regression models are run first with Commercialization as the dependant variable and then with Subsistence Utilization as the dependant variable to determine the extent of both commercial and subsistence utilization of Jatropha. Table 4 below presents results of Logit and Tobit regression analyses of factors affecting Jatropha commercialization decision (commercialize or not commercialize) by households. The results show that three explanatory variables, namely size of land holding, wealth category, and perception about the selling price of Jatropha are significant in influencing the probability of commercializing (or not commercializing) Jatropha by households. The estimated coefficients of the Logit model represent a change in odds, or the ratio of the probability of adopting over the probability of non adoption while the marginal effects of the Tobit indicate adoption probability and use intensity in terms of post-harvest utilization of Jatropha.

The size of arable land that a farmer possesses has a negative and significant relationship with the probability of adopting commercial utilization of Jatropha. The probability of adopting any Jatropha utilization option decreases by a factor 0.11 for a unit increase in the size of landholdings.

Table 4: Logit and Tobit Analyses of Jatropha Commercial Utilization

Variable	**LOGIT**			**TOBIT**			
	Coefficient (β)	***Odds Ratio (expβ)***	***z*-value**	**Coefficient (β)**	***t*-value**	***Marginal Effects***	
						Adoption Probability	***Use Intensity***
Sex	0.8804784	0.2089403	1.64	0.4931256	1.79	.129578	.1308629
Age	0.0116667	0.0026364	0.71	0.0080159	0.97	.001517	.0017383
Household size	0.0190919	0.0043143	0.16	0.0120703	0.19	.004919	.0056357
Literacy	0.2244359	0.0507174	0.58	0.1483793	0.74	.032470	.037198
Total land size	-0.4960581	-0.1120977	2.83***	-0.2137496	-3.34***	-.076360***	-.08747***
Wealth Category	-1.067497	-0.2412298	1.98**	-0.5546075	-2.04**	-.136448*	-.1563148*
Major source of income	-0.4224473	-0.0954634	0.92	-0.2609535	-1.10	-.057970	-.0664104
Access to credit	1.043865	0.2034409	1.46	0.5469312	1.54	.120998	.1689672*
Frequency of extension contact	0.3283361	0.0741964	0.94	0.1378447	0.79	.038972	.0446472
No. of JC trees on farm	0.0068353	0.0015446	1.45	0.0033629	0.171	.000884	.0010136
Perception about Jatropha price	-1.463154	-0.3502619	1.66*	-0.7616603	-1.81	-.232752*	-.1999436
Cons	1.162787	-	0.58	1.38514	1.38	.289336	.331463
No. of obs	**116**			**116**			
LR Chi^2	**22.75**			**22.32**			
Prob>Chi^2	**0.0192**			**0.0220**			
Pseudo R^2	**0.1487**			**0.1015**			
Log likelihood	**-65.107677**			**-98.735506**			

*significant at 10% level, **significant at 5% level, ***significant at 1% level

Since Jatropha was traditionally being planted for the purpose of keeping out animals from crop fields and mainly grown along farm boundaries, it is most likely that farmers with smaller landholdings would choose to fence their plots since it is easier compared to fencing larger plots. In terms of harvesting, it becomes easier for a household to harvest on a smaller perimeter of hedges of a plot than on a larger one. The results from the Tobit model indicate reductions in both use intensity and adoption probability of 0.09 and 0.08 respectively when the size of land holding is increased by a single acre. Landholding or farm size is, therefore, critical in determining a farmer's decision to adopt or intensify post-harvest commercial utilization in the Jatropha system.

A significant negative relationship also exists between the household's wealth category and the probability of adopting Jatropha commercialization. The odds of adopting Jatropha commercial utilization increase by a factor of 0.24 for poorer (low resource) households. The adoption probability for non commercializing households and commercial utilization intensity of use decrease by 14 and 16 percentage points respectively when a household's wealth status improves from being poor (low-resource) to being rich(high-resource). This may be explained by the fact that Jatropha marketing is a low capital investment which makes it ideal for low resource farmers to venture into. The picking (harvesting) and selling of Jatropha does not require any machinery, capital or specialized skills to effect. There may be a possibility that, like most agroforestry options, Jatropha may be perceived by high resource farmers as inferior and a technology for poorer farmers.

The decision to adopt commercial utilization of Jatropha is also significantly influenced by the farmers' perception about the selling price of Jatropha. Results of the Logit analysis show that the perception of a farmer towards the selling price has a negative significant relationship with the probability of commercializing. The odds of adopting post-harvest commercial utilization of Jatropha decrease by a factor of 0.35 when the farmers perceive the selling price of Jatropha as too low and unattractive. This is a common expectation in the (micro)economics of the household or farm. Producer price of a commodity determines the level of supply to the market. Innovations that present desirable attributes and command good perception by the target group are known to command greater chances of adoption by the clientele (Lemchi *et al,* 2005). The adoption probability of non-commercializing households decreases by 23% when the selling price is perceived to be unattractive while the use intensity by commercializing households increases by 17% when access to credit is there.

A significant negative relationship exists between the household's access to credit and the probability of adopting Jatropha commercialization. The probability of adopting the Jatropha system decreases by a factor of 0.11 when the household has access to agricultural credit. If a household accesses credit it means its capital base has improved and the household can now afford investment in enterprises with higher returns. However, access to credit was not significant in influencing the adoption probability and use intensity in subsistence utilization.

This implies that a household’s decision to adopt or intensify subsistence utilization of Jatropha is not influenced by whether or not the household has access to credit.

CONCLUSION AND RECOMMENDATIONS

This paper examined the adoption profile of Jatropha utilization options and factors that have influenced them. Econometric analyses of factors driving the adoption process gave some levels of reliable statistical accuracy in that the factors considered were important in influencing the adoption decisions of the respondents. The strengths of the impacts of the individual variables included in the models, however, differed. The farm size, household size, wealth category, access to credit, Jatropha tree population and farmer’s perception about the selling price of Jatropha are the variables that were found to be significant in shaping the decisions of households on whether to commercialize or not. Statistically, the decision to adopt and intensify use of Jatropha utilization options is based on the wealth category of the farmer. Farmers considered to be poor are in that condition because they have fewer income generating options for improving their livelihoods, hence, they are likely to accept any new option that increases their income base or reduces expenditure.

For successful Jatropha commercialization to be realized and the smallholder farmers’ livelihoods improved, there is need for GoZ to put in place a complete package of incentives that will stimulate optimal exploitation of the Jatropha plant. These incentives should include among others adjusting the selling price to viable levels and promoting investment in Jatropha by private players so that there is competition and viability for the farmer. Value addition should also be promoted for the supply of cheaper and cost-saving household products. If, for example, soap production grows in the future, and demand for Jatropha seed along with it, some more plantations may become necessary. At that point the price for a kilogram of seed will have to be attractive relative to prices of other cash crops. Any increased demand for the output of live hedges will encourage their establishment and increase environmental benefits. Jatropha should not be taken as an alternative to conventional crop production but a necessary complement to it.

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