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Impact of Bioenergy Crop Adoption on Total Crop Incomes of Farmers in Northern Ghana: The Case of *Jatropha Curcas*

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6.1 Introduction

Energy services have the potential to boost social and economic welfare of people. Access to energy is a crucial component of poverty alleviation, improving human welfare, and raising living standards (UNDESA 2005).

Most countries in sub-Saharan Africa rely on traditional biomass (crude oil, natural gas, and coal) as the primary energy source used and imported fossil fuels (IEA 2014). In the region, nearly 730 million people live in rural areas where they rely on traditional biomass for cooking (IEA 2014). In sub-Saharan Africa, energy demand grew by around 45%

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between 2000 and 2012. In Africa, over 80% of electricity generated is from fossil fuels; about 620 million people do not have access to electricity (IEA 2014). Energy demand is predicted to double from 500 million tonnes oil equivalent (Mtoe) in the year 2000 to 1000 Mtoe in 2030 (Denruyter et al. 2010).

The heavy reliance on fossil fuels raises serious environmental issues such as depletion of non-renewable resources, ozone depletion, and global warming. According to Intergovernmental Panel of Climate Change (IPCC) (2007), global Greenhouse Gas (GHG) emissions should be reduced by 50–80% by 2050 to slow down global warming. This means that the use of fossil fuels for energy generation should be restrained. Even though Africa's GHG emissions account for less than 4% of the global GHG emissions, the continent is the most vulnerable to climate change effects such as droughts and flooding (World Bank 2009). This is because Africa is exposed to climate risks such as extreme droughts, flooding, and storms. In addition, its low adaptive capacity worsens the situation because the continent is characterized by high rates of poverty, financial and technological constraints, and heavy reliance on rain-fed agriculture.

Biomass is the dominant source of energy supply in Ghana. The country depends entirely on imports in order to meet oil requirements. The production of oil started with a capacity of 85,000 barrels of oil per day in Jubilee field (Abdulai 2013). In 2007, biomass energy consumption (wood fuel and charcoal) was about 11.7 million tonnes (Ministry of Energy 2010). It is used mainly for cooking, employing traditional inefficient technologies. Less than 10% of people use modern cooking fuels (improved stoves, kerosene, or liquefied petroleum gas) in the country (Ahiataku-Togobo and Ofosu-Ahenkorah 2009). In 2007, petroleum products and electricity consumption accounted for 1.955 million tonnes and 6269 GWh respectively (Ministry of Energy 2010). Biomass (fuel-wood and charcoal) consumption in Ghana accounted for 64%. Petroleum products and electricity accounted for 27% and 9% respectively (Duku et al. 2011). However, according to IPCC (2007), combustion of fossil fuels contributes to global warming.

The energy sector faces some challenges in Ghana (Energy Commission 2006). These are related to the increase in energy demand, the potential imbalance between national energy production and indigenous sources of supply, inadequate investments in the energy sector, and overreliance on fuel imports and wood fuels. In order to address the issues of imbalance, low investments, and overreliance, *Jatropha* has been promoted as a panacea and promising feedstock for biofuels. However, *Jatropha* industry started in Ghana without any biofuel policies (Campion et al. 2012). In Ghana, prior to its introduction as a bioenergy crop, *Jatropha* was traditionally grown as gardens and a hedge or fence plant around homes in order to protect houses and fields against animals and sun exposure (Acheampong and Betey 2013). *Jatropha* was considered in Ghana for its ability to generate energy just recently, in 2005 (Boamah 2014). Its cultivation was promoted on marginal lands so as to not compromise food security (Boamah 2014). According to Brittain and Lualadio (2010), Ghana was predicted to be among the largest *Jatropha* producers in Africa by 2015. Projects related to *Jatropha* development started from 2005; by 2006, there were 17 biofuel projects in Ghana (Schoneveld et al. 2010). Several foreign companies (Agroils, Kimminic Estates, *Jatropha* Africa, Viram Plantation Limited, etc.) acquired large-scale land to produce both edible and non-edible crops for ethanol and biodiesel generation for exports (Dogbevi 2009). Large-scale *Jatropha* (100 hectares and more) development was highly criticized by Ghanaian NGOs for issues such as land grabbing and food insecurity as many of them were actually on fertile lands. Many of these large-scale *Jatropha* projects have failed. Of late, mainly participatory and small-scale *Jatropha* developments are ongoing in Ghana.

Jatropha seeds are not directly marketable in the open market. Farmers mostly sell their seeds to an NGO called New Energy. Previously, some farmers were selling the seeds to foreign investors under contract farming. However, these foreign investors are no more buying *Jatropha* seeds.

Income constitutes a key determinant of food security for poor people in rural areas since adequate income can help them afford appropriate food for their nutritional diet (FAO 2010; Faaij 2008). *Jatropha* can provide new income sources for farmers through *Jatropha*-generated activities such as seed selling. This supplementary income from *Jatropha*

can impact the food security status of farmers helping them to afford food. According to the Government of Ghana (2010), the investment in land is predominant in the northern part of Ghana due to their high prevalence of food insecurity, poverty, and illiteracy. In addition, Northern Ghana agriculture accounts for more than 90% of household incomes and employs more than 70% of the population in the region.

The objective of this chapter is to measure the impact of *Jatropha Curcas* adoption on total crop incomes of farmers in Northern Ghana. Section 6.2 presents the theoretical framework and estimation technique. Section 6.3 provides data and descriptive analysis. Section 6.4 presents the empirical results. Finally, Sect. 6.5 provides the conclusions.

6.2 Theoretical Framework and Estimation Technique

6.2.1 Theoretical Framework: The Random Utility Framework

Following Hoque et al. (2015), a household's decision to adopt a bioenergy crop can be analyzed within a random utility framework. Let U_{hA} be the utility obtained by a household h from adopting *Jatropha* and U_{hN} the utility of non-adoption. Let Z_h be a vector of farm and household characteristics affecting bioenergy crop-adoption decisions and ε_h be the error term. According to the state of adoption, the household h utility is approximated as:

$$\begin{cases} U_{hA} = f(Z_h) + \varepsilon_{hA} \\ U_{hN} = f(Z_h) + \varepsilon_{hN} \end{cases} \quad (6.1)$$

A household will choose to adopt *Jatropha* only if the utility derived from adopting is greater than the utility from not adopting: $U_{hA} > U_{hN}$. Since these utilities are not observable, they can be expressed in the following latent structure model for adoption of bioenergy crop:

$$V_h^* = \beta Z_h + \varepsilon_h \quad (6.2)$$

$$V_h = \begin{cases} 1, V_h^* > 0 \\ 0, V_h^* < 0 \end{cases}$$

Where V_h is a binary indicator taking the value of 1 in the case the household adopts bioenergy crop and 0 otherwise.

The outcome variable (total crop incomes per hectare of the household) is considered as a linear function of the binary variable for bioenergy crop adoption along with a vector of some other explanatory variables (X):

$$Y_h = \lambda X_h + \gamma V_h + \mu_h \quad (6.3)$$

Where Y_h is the outcome variable, V_h is a binary variable for adoption, λ and γ are vectors of parameters to be estimated and μ is the error term. However, from Eq. 6.3, since γ measures the impact of bioenergy crop adoption (treatment variable) on total crop incomes per hectare (outcome variable), then, households should be randomly assigned to the group of adopters or non-adopters. However, technologies are rarely randomly assigned. Instead, new technology adoption usually occurs through self-selection. In other words, it translates the fact that in Eq. 6.3, μ is correlated with V or Z . Equation 6.2 which does not take into account the self-selection might lead to a biased estimation. The propensity score matching (PSM) is employed in this study in order to deal with selection bias.

6.2.2 Estimation Technique: Propensity Score Matching

Rosenbaum and Rubin (1983) defined the Average Treatment Effect (ATE) as follows:

$$ATE = Y_i^A - Y_i^N \quad (6.4)$$

where Y_i^A is the total crop income per hectare of household i that adopted and Y_i^N is the total crop income per hectare of household i that did not adopt. It is difficult to estimate the impact from Eq. 6.4. The issue is that

either Y_i^A or Y_i^N is normally observed but not both of them for each household. What is normally observed is expressed as follows:

$$Y_i = K_i Y_i^A + (1 - K_i) Y_i^N \quad K = 0, 1 \tag{6.5}$$

where $K = 1$ represents the situation when the household i adopts Jatropa and $K = 0$ is the situation when the household has not adopted Jatropa.

The ATE can be re-specified as follows:

$$\begin{aligned} \text{ATE} = & P \cdot \left[E(Y_i^A / K = 1) - E(Y_i^N / K = 1) \right] + \\ & (1 - P) \cdot \left[E(Y_i^N / K = 0) - E(Y_i^N / K = 0) \right] \end{aligned} \tag{6.6}$$

where P is the probability for a household to adopt Jatropa ($K = 1$).

Equation 6.6 is based on the assumption that the unobserved counterfactual of adopters if they had not adopted, $E(Y_i^N / K = 1)$, can be approximated by the one of non-adopters $E(Y_i^N / K = 0)$. Without that assumption, the estimation of Eq. 6.4 representing the ATE cannot be done because $E(Y_i^N / K = 1)$ is not observed. However, that procedure might highly result in a biased estimation because of the issue of selection bias. Indeed, the treated group (adopters) might not be statistically similar to the control group (non-adopters). Fortunately, the PSM approach of Rosenbaum and Rubin (1983) first reduces the pre-treatment characteristics of each household into one variable. Secondly, PSM uses the propensity score to match households with similar characteristics. Rosenbaum and Rubin (1983) defined ‘propensity score’ as the conditional probability of receiving a treatment given pre-treatment characteristics:

$$p(X) \equiv \Pr\{K = 1 / X\} = E\{K / X\}; \quad p(X) = F\{h(X_i)\} \tag{6.7}$$

where $F\{\cdot\}$ is a normal or logistic cumulative distribution and X a vector of pre-treatment characteristics. An estimation of the propensity of

Jatropha adoption is run taking into account the restriction of the region of common support. After computing the propensity scores, the Average Treatment effect on the Treated (ATT) is estimated as follows:

$$\begin{aligned} \text{ATT} &= E\{Y_i^A - Y_i^N / K = 1\} \\ &= E\left[E\{Y_i^A - Y_i^N / K = 1, p(X)\}\right] \\ &= E\left[E\{Y_i^A / K = 1, p(X)\} - E\{Y_i^N / K = 0, p(X)\} / K = 1\right] \end{aligned} \quad (6.8)$$

ATT is performed using a single matching algorithm named Nearest Neighbor Matching with replacement. When there are few comparison units, matching with replacement allows one comparison unit to be matched more than once with each nearest treatment unit. However, matching without replacement forces the matching between the treatment group and the comparison group that is quite different in propensity scores. This enhances the likelihood of bad matches (increase the bias of the estimator). The quality of the matching is undertaken using a balance test called the mean absolute standardized bias. For each variable, the mean standardized difference is computed before and after matching as follows:

$$B(X) = 100 \frac{\overline{X}_T - \overline{X}_C}{\sqrt{\frac{V_T(X) + V_C(X)}{2}}} \quad (6.9)$$

where \overline{X}_T and \overline{X}_C are the sample means for the treated and control groups, $V_T(X)$ and $V_C(X)$ are the associated sample variances (Lee 2006). The bias reduction can be generated as follows:

$$BR = 100 \left(1 - \frac{B_{\text{after}}}{B_{\text{before}}} \right) \quad (6.10)$$

Rosenbaum and Rubin (1985) recommended that the mean standardized bias after matching greater than 20% is perceived as an indicator of failed matching. In addition, according to Sianesi (2004), the balance test can be done comparing the pseudo R^2 and p-values from the propensity scores estimated before and after matching. After matching, there should not be any systematic differences in the distribution of covariates between adopters and non-adopters. As a result, the pseudo R^2 should be low. The test should be rejected after matching and not before.

6.3 Data and Descriptive Statistics

Data used in this study were collected from 400 farmers in the West Mamprusi and Mion districts of Northern Ghana using a questionnaire from September to October 2015. These districts were selected because of their involvement in *Jatropha* production. These districts are among the poorest in Ghana; hence, issues of innovation, crop diversification, or technology adoption for wealth creation which *Jatropha* promises become pertinent. For the purpose of this study, adopters are classified as farmers who planted *Jatropha* and still have it in their plots, while non-adopters refer to farmers who did not cultivate *Jatropha*. Focus group discussions consisted of meeting with community leaders and some *Jatropha* farmers in each district to gather preliminary information on the number of *Jatropha* growers in the communities and the size of their *Jatropha* plot. The survey used a structured questionnaire to collect data from the households on socioeconomic characteristics of households and information on *Jatropha*. From the preliminary study, the estimated number of *Jatropha* farmers in these two districts was 344 (256 farmers in West Mamprusi District and 88 farmers in Mion District). This information was used to calculate the minimum sample size.

Yamane's formula of sample size is used (Yamane 1967):

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size, and e is the error term. Assuming an error of 5% and a confidence interval

of 95%, the following is obtained: $n = \frac{344}{1 + 344(0.05)^2} = 184.94$. The

number of Jatropha adopters was increased to 200.

A stratified random sampling technique consisting of dividing the population into groups called strata and proceeding with a simple randomization was used to select the list of Jatropha farmers to be surveyed. The stratification was done at the district level. The first stage involved purposive selection of Jatropha growing districts in Northern Ghana. These are West Mamprusi District and Mion District. A total of 120 Jatropha farmers were randomly selected in West Mamprusi District and 80 in Mion District in order to have a fair representation of farmers in both districts based on the preliminary study.

The study needed a counterfactual to evaluate the effect of Jatropha farming adoption on key outcomes such as income. An equal sample size of 200 non-Jatropha farmers was used. The procedure to survey the non-Jatropha farmers was as follows: In each community where the Jatropha farmers were surveyed the equal number of non-Jatropha farmers was also surveyed. To choose a non-Jatropha farmer, a sample list of some non-Jatropha farmers in the community was collected from community leaders. A random list with three back-ups was then formed for each community to survey the non-Jatropha farmers.

Table 6.1 shows the distribution of respondents per district and community.

Figure 6.1 shows the map of the study area.

Table 6.2 describes the variables used in the study.

Table 6.3 shows the descriptive statistics of continuous variables used in the econometric models for the entire sample and the two sub-samples of non-adopters and adopters indicating the variable means and standard deviations. Adopters are distinguishable in terms of household characteristics such as age, farming experience, number of visits by extension services officers, and number of man-days labor hired.

On average, adopters allocate half a hectare to Jatropha cultivation. The mean age of farmers interviewed was about 43 years old. There is a significant difference in the age of adopters and non-adopters. On average,

Table 6.1 Distribution of respondents per district and community

District	Community	Adopters	Non-adopters
West Mamprusi District	Zagsilari	20	20
	Nasia	19	19
	Boamasa	20	20
	Janga	20	20
	Wungu	20	20
	Loagri	21	21
Mion District	Jimle	47	47
	Kpachaa	30	30
	Tuya	03	03
Total		200	200

Source: Authors

adopters are 45 years old while non-adopters are 41 years old. There is no statistically significant difference in the number of adult members in the household of both adopters and non-adopters. On average, the number of adult members in the household is five. There is no statistically significant difference in the years of education for farmers both adopters and non-adopters. On average, farmers spent two years of education. There is a significant difference in the years of farming experience at the level of 5% between the two groups. On average, *Jatropha* adopters have been farming for about 26 years while non-adopters for about 23 years. There is no statistical difference in farm size between the two groups and the average farm size is 3.75 hectares. On average, farmers own 3.45 hectares of land. There is no statistically significant difference in distance from the nearest agricultural market for the full sample. On average, the distance from home to the nearest agricultural market is 8.3 kilometers. There is a statistically significant difference at the level of 1% in the number of times farmers had access to extension services. Adopters had more access to extension services than non-adopters. On average, adopters had access to extension services 0.49 times compared to 0.29 for non-adopters during the 2014 cropping season. Adopters hired more labor than non-adopters. The mean number of hired man-days for adopters is 125 compared to 79.16 man-days for non-adopters. The difference is significant at the level of 5%. There is no statistical difference in the degree of risk attitude of the farmers. On average, the degree of risk attitude is 5.73.

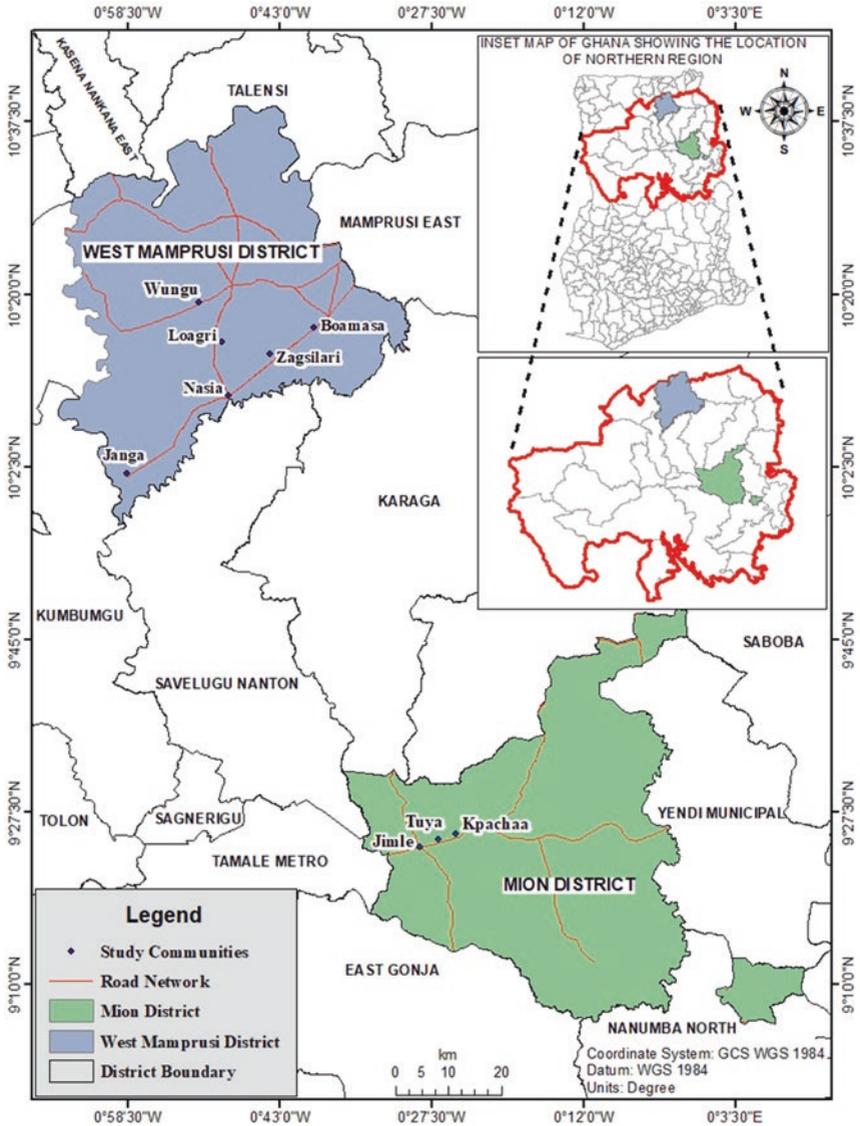


Fig. 6.1 Map of study area. Source: Authors

Table 6.2 Variables definition for Jatropha adoption

Variable	Type	Definition and measurement	Expected signs
<i>Treatment variable</i>			
Adopter	Dummy	1 = Grows Jatropha, 0 = Does not grow Jatropha	
<i>Outcome variable</i>			
Total crop incomes per hectare	Continuous	Income from all crops including Jatropha per hectare (in Ghana cedis)	
<i>Independent variables</i>			
Gender	Dummy	Gender of the head of household 0 = male, 1 = female	-
Age	Continuous	Age of the head of household (in years)	-
Education	Continuous	Level of education of the head of household in years	+
Number of adults	Continuous	Number of adult members of the household (count units)	+
Farming experience	Continuous	Farming experience of the head of household (years)	+
Farm size	Continuous	Farm size (hectares)	+
Extension services	Continuous	Number of times the household had access to extension services	+
Off-farm activities	Dummy	Engagement in off-farm activities 0 = No, 1 = yes	+
Livestock	Dummy	Livestock ownership 0 = No, 1 = yes	-
FBO	Dummy	Farmer based organization membership 0 = No, 1 = yes	+
District	Dummy	0 = Mion, 1 = West Mamprusi	-
Credit access	Dummy	Access to credit 0 = No, 1 = yes	+
Distance to market	Continuous	Distance from home to the nearest agricultural market (in km)	-
Size of land owned	Continuous	Size of land owned (in hectares)	+
Hired labor	Continuous	Number of man-days hired during 2014 cropping season	+
Irrigation	Dummy	Practice of irrigation 0 = No, 1 = yes	+
Risk attitude	Continuous	Degree of Risk attitude	+
Discount factor	Dummy	1 = preference for present, 0 otherwise	+

Source: Authors

Table 6.3 Descriptive statistics for continuous variables

Variables	Adopters		Non-adopters		Total		t-value
	Mean	SD	Mean	SD	Mean	SD	
Age	45.13	15.25	41.06	13.76	43.09	14.65	-2.80***
Number of adults	5.81	5.54	5.21	3.86	5.51	4.78	-1.25
Farming experience	26.46	15.53	23.32	14.20	24.90	14.94	-2.11**
Farm size	3.79	2.65	3.70	0.19	3.75	2.68	-0.32
Education	2.17	4.24	1.68	3.80	1.93	4.03	-1.20
Distance to market	8.11	7.08	8.47	7.32	8.30	7.19	0.51
Extension services	0.29	0.46	0.15	0.36	0.22	0.42	-3.39***
Size of land owned	3.56	2.46	3.35	2.61	3.45	2.53	-0.86
Hired labor	125.71	240.71	79.16	142.01	102.43	198.74	-2.35**
Risk attitude	5.93	2.69	5.53	2.66	5.73	2.68	-1.49

Source: Authors

Note: ** * show significance at 5% and 1% levels, respectively

Table 6.4 shows the descriptive statistics of categorical variables used in the econometric models for the entire sample and the two sub-samples of non-adopters and adopters indicating the frequencies and percentages.

There is no statistically significant difference in gender of farmers between the two groups. On average, 85.5% farmers are male. Adopters are less engaged in off-farm activities (30%) compared to non-adopters (40.5%). There is a significant difference in farmer based organization (FBO) membership at 1%. The percentage of FBO membership is higher for adopters. A total of 45% of adopters are members of FBO compared to 22% for non-adopters. On average, 64% of respondents own livestock. There is no statistically significant difference in access to credit between both groups. On average, only 19% of farmers had access to credit. The same for the discount factor, about 76% of farmers have a preference for the present. There is no statistically significant difference in irrigation practice; only 2% of respondents practiced irrigation.

Table 6.5 shows the descriptive statistics for total crop incomes per hectare of farmers for the whole sample and for male and female-headed households. There is a statistically significant difference at the level of 1% for the level of total crop incomes per hectare between adopters and non-adopters. On average, adopters have GHC 641.92 per hectare as total crop incomes while non-adopters have GHC 1243.41 per hectare.

Table 6.4 Descriptive statistics for categorical variables

Variable	Category	Adopters		Non-adopters		Total		X ² value
		No.	%	No.	%	No.	%	
Gender	Male	166	83	176	88	342	85.5	2.02
	Female	34	17	24	12	58	14.5	
Off-farm act	Yes	60	30	81	40.5	141	35.25	4.83***
	No	140	70	119	59.5	259	64.75	
FBO	Yes	90	45	44	22	134	33.5	23.75***
	No	110	55	156	78	266	66.5	
Livestock	Yes	130	65	126	63	256	64	0.17
	No	70	35	74	37	144	36	
Credit access	Yes	38	19	38	19	74	19	0.00
	No	162	81	162	81	324	81	
Disc. factor	Yes	148	74	159	79.5	307	76.75	1.69
	No	52	26	41	20.5	93	23.25	
District	Mion	80	40	80	40	160	40	0.00
	WM ^a	120	60	120	60	240	60	
Irrigation	Yes	4	2	4	2	8	2	0.00
	No	196	98	196	98	192	98	

Source: Authors

Note: **, *** show significance at 5% and 1% levels, respectively

^aWest Mamprusi district

Table 6.5 Descriptive statistics for total crop incomes per hectare

Total crop incomes (GHC/ha)	Adopters		Non-Adopters		Total		t-value
	Mean	SD	Mean	SD	Mean	SD	
Whole sample	641.92	528.92	1243.41	1235.74	942.67	995.90	6.32***
Male	673.57	558.28	1206.98	1269.32	948.07	1024.18	4.98***
Female	487.39	314.68	1510.26	932.09	910.78	816.27	5.96***

Source: Authors

There is a statistically significant difference at the level of 1% for the level of total crop income for both male-headed and female-headed households. On average, male-headed household adopters have GHC 673.57 per hectare while male-headed household non-adopters have GHC 1206.98 per hectare. On average, female-headed household adopters have GHC 487.39 per hectare while female-headed household non-adopters have GHC 1510.26 per hectare.

Nonetheless, descriptive statistics cannot explain whether the observed difference in crop income per hectare between adopters and non-adopters

for the whole sample and by gender is due to *Jatropha* cultivation. The noted differences in total crop income per hectare depending on the adoption status of the household might not be the result of *Jatropha* adoption but rather might be due to other factors, farm and farmers' characteristics, for instance. The impact analysis of *Jatropha* adoption on total crop incomes per hectare is preceded by the determination of the propensity scores for the treatment variable (adoption status of *Jatropha*).

6.4 Empirical Results

The impact analysis of *Jatropha* adoption on total crop incomes per hectare is preceded by the determination of the propensity scores for the treatment variable (adoption status of *Jatropha*).

6.4.1 Estimation of the Propensity Scores

A probit model is used to predict the probability of adopting *Jatropha*. The results of the propensity scores are reported in Table 6.6.

Several variables are statistically significantly associated with adoption of *Jatropha*. The number of times of access to extension services, the number of man-days hired, the FBO's membership, and the risk attitude of the head of household are positively associated with adoption. Access to extension services could play an important role in *Jatropha* adoption in Northern Ghana, for instance, in educating farmers in land use decisions concerning *Jatropha*. *Jatropha* is known as labor intensive; the ability of farmers to hire labor could increase its adoption. The coefficient of the risk attitude variable shows that the greater the degree of risk loving, the higher the probability of adopting *Jatropha*. Membership of FBO significantly increases the likelihood of *Jatropha* adoption. Indeed, FBO might assist farmers to manage the crop, find a market, and get access to loans.

The variables district and off-farm activities membership are negatively associated with *Jatropha* adoption. Being located in West Mamprusi District significantly reduces the likelihood of adopting *Jatropha* compared to Mion District. This is likely due to greater access to a potential

Table 6.6 Probit estimates of the propensity to adopt *Jatropha*

Variables	Probit	
	Coefficient	Standard error
Gender	0.286	0.205
District	-0.345*	0.181
Education	0.028	0.018
Age	0.014	0.007
Number of adults	0.026	0.016
Farming experience	-0.001	0.007
Farm size	-0.112	0.076
Extension services	0.200***	0.072
Off-farm activities	-0.299**	0.146
Livestock	0.097	0.146
Credit access	0.042	0.187
Distance to market	-0.001	0.011
Hired labor	0.002***	0.000
Size of land owned	0.063	0.081
FBO	0.583***	0.155
Risk attitude	0.086***	0.029
Discount factor	-0.178	0.179
Irrigation	-0.043	0.461
Constant	-1.176	0.335
Pseudo R^2	0.1269	
Log-likelihood	-242.08	
Observations	400	

Source: Authors

Note: *, **, *** show significance at 10%, 5%, and 1% levels, respectively

market in Mion District. The NGO New Energy is buying the seeds from the farmers in Mion district. Engagement in off-farm activities has a negative influence on the probability of *Jatropha* adoption. The current result might be due to the fact that farmers engaged in off-farm activities have less time and resources to engage in *Jatropha* cultivation.

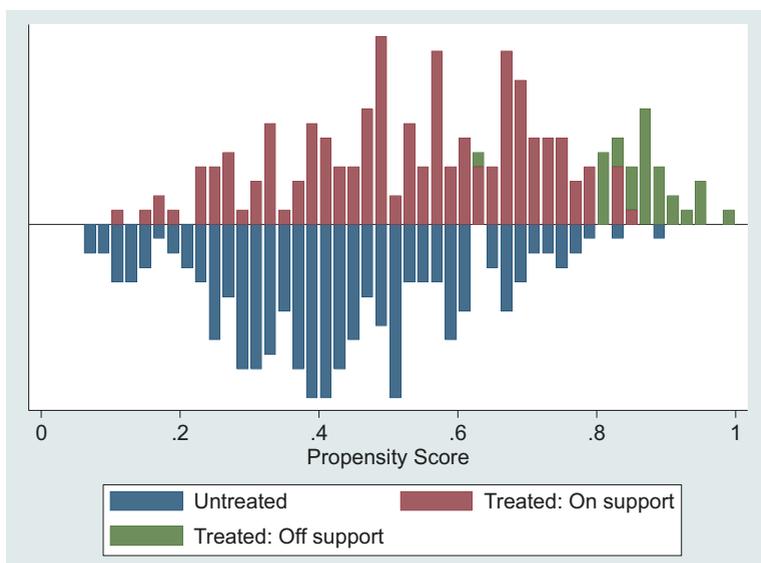
Table 6.7 provides the distribution of the propensity scores.

For adopters, the estimated propensity scores vary between 0.06356 and 0.98953 with a mean of 0.50168. For non-adopters, it varies between 0.06356 and 0.89317 with a mean of 0.42073. The results suggest that the region of common support is satisfied in the interval [0.06356, 0.89317]. The consequence of this restriction is that observations falling outside this range of the region will be discarded from the analysis. As a result, nine observations have been removed from the

Table 6.7 Estimated propensity scores

Sample	Observations	Mean	SD	Minimum	Maximum
Whole sample	400	0.50168	0.20187	0.06356	0.98953
Adopters	200	0.58263	0.19964	0.11644	0.98953
Non-adopters	200	0.42073	0.16935	0.06356	0.89317

Source: Authors

**Fig. 6.2** Propensity score distribution and common support for propensity score estimation. Source: Authors

analysis. The common support condition is imposed in the regression models by matching in the region of common support only.

The distribution of the propensity scores and the region of common support before and after matching are represented in Fig. 6.2.

6.4.2 Estimation of Average Adoption Effect: Matching Algorithms

Table 6.8 reports the estimates of the average adoption effects estimated by Nearest Neighbor Matching with replacement for the whole sample

Table 6.8 ATT of *Jatropha* adoption on crop income

Matching algorithm: Nearest neighbor				
Matching with replacement	Sample	ATT	Number of treated	Number of control
Whole sample	400	-385.23*** (-3.05)	170	200
Male	342	-293.22** (-2.48)	143	176
Female	58	-624.23*** (-3.76)	15	24

Source: Authors

Note: **, *** show significance at 5% and 1% levels, respectively

and for male and female. The analysis is based on the restriction of the region of common support.

Table 6.8 shows that adoption of *Jatropha* significantly reduces total crop income per hectare of farmers. For the whole sample, the ATT estimate per hectare is negative (GHC -385.230). This is probably due to the fact that most farmers grow *Jatropha* on their fertile lands. *Jatropha* production is likely to compete for land with food production resulting in smaller areas cultivated and less food grown at the local level. The absence of an open market for *Jatropha* especially in the West Mamprusi district makes income generation from *Jatropha* very difficult. This results in reducing total crop incomes of farmers. The adoption of *Jatropha* significantly reduces the total crop income per hectare of both male-headed and female-headed households. The ATT estimate is GHC -293.22 for male and GHC -624.23 for female. Comparing the impact on male-headed and female-headed households, the results reveal that the participation in *Jatropha* cultivation affects more negatively female-headed than male-headed households. The reduction in total crop income per hectare is higher for female-headed than male-headed households. This can be explained by the fact that bioenergy crops such as *Jatropha* are inputs intensive (land, labor, water, fertilizers, and pesticides) and female farmers have traditionally limited access to inputs (Tauli-Corpuz and Tamang 2007). In Ghana, for instance, female farmers have very little access and control over resources due to patriarchy. They face challenges such as unequal access to land, finance and credit, and so on.

6.4.3 Indicators of Matching Quality Before Matching and After Matching

Table 6.9 provides the indicators of matching quality. It reveals the results of covariate balancing tests before and after matching. It can be seen that all indicators of matching quality before matching significantly exceed those after matching. After matching, the results show an insignificant likelihood ratio test supporting a rejection of the joint significance of covariates. In addition, after matching the results reveal a lower pseudo R^2 . Indeed, the pseudo R^2 dropped from 0.127 to 0.051 after matching. After matching, there is also a reduction in absolute bias for overall covariates used to estimate the propensity score. Table 9 also reveals a mean standardized bias lower than 20% after matching as recommended by Rosenbaum and Rubin (1985). The standardized mean difference for overall covariates used in the propensity score around 15% before matching is reduced to about 13.3% after matching. This leads to a substantial reduction of the total bias of 11.33% through matching. All these statistics suggest that the specification of the propensity score is fairly successful in balancing the distribution of covariates between adopters and non-adopters. These results can then be used to assess the impact of *Jatropha* adoption among groups of farmers having the same observed characteristics.

Table 6.9 Matching quality indicators before and after matching for the whole population

Matching quality indicators	Before matching	After matching
Pseudo R^2	0.127	0.051
LR χ^2	70.35	23.89
$p > \chi^2$	0.000	0.159
Mean standardized bias%	15.0	13.3
Total % bias reduction	11.33	

Source: Authors

6.5 Conclusions

This study examined the adoption of *Jatropha Curcas* and its impact on total crop incomes of farmers in two districts of Northern Ghana. The PSM method was used to account for selectivity bias. The results suggested the presence of bias in the distribution of covariates between groups of adopters and non-adopters, indicating that accounting for selection bias is a significant issue. The results showed that *Jatropha* adoption reduces the total crop incomes per hectare of farmers. The study also highlighted the potential gender-differentiated impacts of *Jatropha* adoption on total crop incomes per hectare of farmers. The impact is worse for female-headed households compared to male-headed households, though the impact is negative for both. The ATE on the Treated estimates are GHC −385.230 per hectare for the whole sample, GHC −624.23 per hectare for female-headed households, and GHC −293.22 for male-headed household. Therefore, *Jatropha* cultivation might constitute a threat to farmers' crop incomes. There are a couple of reasons that can justify this finding, but the primary reason is the fact that *Jatropha* is cultivated in most cases on fertile lands and therefore conflicting with household staple and cash crops. The lack of market for *Jatropha* seeds is another reason which is worthy to highlight in this context.

The study recommends that the promotion of *Jatropha* cultivation should be properly regulated to avoid the massive conversion of fertile land used for crop production for *Jatropha* cultivation. There is a need to develop appropriate strategies and a regulatory framework to harness the potential economic opportunities from *Jatropha* cultivation while protecting rural people from converting part of their fertile lands to *Jatropha* cultivation at the expense of food crops. In this view, the Energy Commission (Ministry of Energy) should present the final bioenergy policy for Ghana in order for the country to move a step forward in the biofuel sector. The policy support is needed for improving income generation from *Jatropha*. Pro-women *Jatropha* development such as the promotion of *Jatropha* by-products (traditional soap and fertilizers) should be encouraged.

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