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# The Impacts of Wage Employment on a Jatropha Plantation on Income and Food Security of Rural Households in Madagascar – A Panel Data Analysis

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## Abstract

Jatropha projects have been set up worldwide as solution to reduce competition between food and biofuel production. Jatropha is mostly produced on marginal land in developing countries and production is labour-intensive. The subject of this study is an existing Jatropha plantation in central Madagascar. The aims are to assess whether large-scale Jatropha plantations offer sufficient income possibilities to contribute to poverty alleviation and food security. The results show that incomes and food security improved in 2008 due to income generated on the plantation, but deteriorated between 2008 and 2010 mostly due to a decline in agricultural yields for climatic reasons. We find weak evidence that households working for the plantation experienced less reduction in incomes and expenditures than control households. The majority of households did not reduce agricultural production; plantation workers are mostly poorer farmers who need an additional income source.

**Keywords:** difference-in-difference, propensity score matching, income inequality, poverty reduction
**JEL:** C23, Q12, I32

## 1 Introduction

The production of biofuels is partly blamed for the large food price increases since 2008. One solution to lower competition between food and biofuel production is the use of marginal land; a crop suitable for this is Jatropha. It has become a potential energy crop due supposedly to its ability to grow on marginal land in semi-arid areas, its resistance to extreme climatic conditions and potential for controlling soil erosion and because it can contribute to local income and employment (VON BRAUN and PACHAURI, 2006). Therefore, international investors have started to establish Jatropha projects in several developing countries, such as Tanzania, Mozambique and also Madagascar. However, a number of projects have been terminated and concerns have

been raised. Specifically, are large-scale Jatropha plantations actually able to foster rural employment, reduce poverty and improve food security?

In order to assess the setting in question, the Department for Rural Development Theory and Policy at the University of Hohenheim cooperated with an existing Jatropha plantation in the region of Fianarantsoa in central Madagascar. Given the potential of Jatropha production and the large area of marginal land available in Madagascar, the Malagasy government has strong interests in leasing such land for energy production. JatroGreen SARL was founded as a joint venture by the German JatroSolutions GmbH and the Malagasy NGO Green Island Association and was allowed to set up a Jatropha plantation. Initiated in 2007, it covered 1,000 ha in 2010. Oil production had not yet started; wages are pre-financed by the German investor. The plantation area is not fit for the cultivation of food crops and therefore biofuel production does not directly hamper food production. Previously the land was very extensively used for grazing. Apart from research purposes and the sale of carbon dioxide certificates under the Clean Development Mechanism, Jatropha oil is intended for national sale (JATROSOLUTIONS, 2011). Rural households in the area surrounding the plantation benefit from the opportunity to generate income via the labour demands of the plantation.

The aims of the study are to examine whether plantation incomes contributed to poverty alleviation in the villages surrounding the plantation, whether they improved food security and diet diversity and whether income inequality has declined. Earlier studies suggest positive income effects and a contribution to poverty alleviation (BUENNER, 2009; GRASS and ZELLER, 2011). Based on these studies it is expected that the positive income effects have persisted over time and that the plantation offers a long-term potential for poverty reduction in the area. Based on the finding that mostly poorer households offer labour to the plantation, the gap between the very poor and the less poor is expected to have been reduced. The panel data this study is based on are expected to bring new facts to light. As the majority of households are net consumers, a positive impact on food security is expected. The baseline study (BUENNER, 2009) detected other positive effects on the communities in the vicinity of the plantation such as crime reduction.

## 2 Data and Methods

This study is based on quantitative and qualitative primary data. To assess the plantation's impact on surrounding communities, semi-structured interviews were conducted in three villages in 2008 and 2010 with village chiefs and representatives from different areas. These villages represent the majority of households working for

the plantation and the majority of people living within a distance of 10 km from the plantation. Quantitative data was collected via household surveys. The two standardized questionnaire surveys were carried out from December 2008 to March 2009 and from August to October 2010. Each survey captured a reference period of 12 months. The sample originally included 336 randomly selected households, which represent 50% of all households in each of the villages. Panel data are available for 315 households. The questionnaire covers demographic data of household members, household assets, plant and animal production, off-farm income sources, expenditure, food security (quantities consumed for major foods, home-produced consumption and acquisitions through the market) and diet diversity (HODDINOTT and YOHANNES, 2002; RUEL, 2003).

For the impact analysis, a treatment and a control group are identified. Households classified as treatment group have at least one member who worked on the plantation in the respective reference period of the past 12 months before the survey date (hereinafter called Jatropha households). Households belonging to the control group did not work on the plantation in the reference period. In order to estimate the effects on income, expenditures and food security over time, the main outcome variables of interest between the two groups are first compared between 2008 and 2010 with the help of a dependent and independent t-test. The propensity score matching method (PSM) is then used to compare outcome variables of the two groups, while dealing with the problem of selection bias. The selection bias is that households differ in socio-economic characteristics which influence their decision to work for the plantation or not. PSM matches the households based on these characteristics and guarantees that only households with similar factor endowment are compared (CALIENDO and KOPEINIG, 2008). A binary logit regression is applied to predict the probability of a household working on the plantation. Secondly, a panel data analysis uses the difference-in-difference method (DID) to reveal stronger evidence on changes in income, expenditures and food security over time. DID compares the outcome variables of the two groups at two different points in time using the results from propensity score matching (CALIENDO and KOPEINIG, 2008; RAVALLION, 2001).

The difference-in-difference estimator is given by

$$DID = [E(Yt(1)|D = 1) - E(Yt'(0)\ |D = 1)] - [E(Yt(0)|D = 0) - E(Yt'(0)|D = 0)],$$

and is based on the assumption

$$E[Yt(0) - Yt'(0)|P(X), D=1] = E[Yt(0) - Yt'(0)|P(X), D=0],$$

where t denotes the post-treatment period, t' the pre-treatment period, D = 1 the treatment group, D = 0 the control group, Yt(1) the post-treatment outcome of a

household who receives treatment and Yt'(0) the pre-treatment outcome (CALIENDO and KOPEINIG, 2008).

In order to compare levels of inequality over time, the Gini coefficient is used. The decomposition of the coefficient by income sources allows estimating the contribution of the plantation income to income inequality (LÓPEZ-FELDMANN, 2006). The national poverty line is used as indicator for poverty (INSTAT, 2010).

## 3 Results

In the following three sections, the descriptive statistics, results from group interviews and changes in agricultural production are presented.

### 3.1 Descriptive Results

The number of households working for the plantation in the sample increased from 2008 to 2010, as 24.3% of the households that were part of the control group during the first survey later became plantation workers. The control group consequently diminished in size. Nearly 40% of households had at least one member working on the plantation in both periods. Only 7.6% of the households stopped working for JatroGreen after the first survey. 29% of households never worked for the plantation. From the sample 517 persons worked between 6 and 308 days on the plantation in 2010. Mean working days per person decreased from 111 in 2008 to 103 in 2010. 46.7% of the workers were women, 53.3% men. Workers were between 14 and 65 years old, mean age was 30.2 years. Plantation workers earned an average daily wage of 3,000 Ariary, which was slightly lower than the mean wage for agricultural wage work with 3,473 Ariary per day in 2010. However, labour demand for other occupations is low, agricultural wage work is mostly done by household or family members and is limited to the rainy season. Plantation work does not require special skills and offers a more regular employment. It therefore represents a lucrative income source especially for low-skilled labour.

### 3.2 Results from Group Interviews

Among the population, the plantation is largely viewed positively. The main benefit according to the participants of the group interviews is the opportunity for income generation and the resultant higher living standard of households. Furthermore, harvest thefts, which were committed especially in the lean season, declined because of the possibility to work on the plantation. Given the low yields in 2010, harvest thefts have increased again.

JatroGreen has done some necessary and appreciated investments in the villages, for example in upgrading schools and building wells in each village, although people stated that investment was not enough. With the help of a chi-square test, it can be seen that the wells were used by a significantly higher percentage of Jatropha households compared to control group households. Jatropha workers furthermore now have the possibility to get credit at the market. In one village, participants of the group interview stated that due to the presence of people from outside, especially the JatroGreen management, morale has improved and villagers have become more tolerant and open to changes and innovations.

Participants of the group interviews stated their weak position in relationship to the plantation owners and management, as the populace does not feel their complaints are heard. In the household survey 11% of households said they fear an expansion of the plantation and a resulting loss of their fields. One reason for this relative large number may be insufficient communication between plantation management and the farmers. Households who did not trust the plantation management were mainly control households or households from Maroilo. Control households have poor contact to the management; in Maroilo the management is not as present as in the other two villages. Another issue is that team leaders are given the responsibility of contracting workers, but have no clear hiring criteria, which creates tension among households. Few cases of minors working and school interruptions were noted. Furthermore, people stated an increase in thefts from houses and shops during the periods of interruption of plantation work, perhaps due to the increasing arrival of people from other villages searching for plantation work. A concern for households who employ agricultural wage workers was having to pay more than the usual wage of 3,000 Ariary as the same can be earned on the plantation on a more stable basis. Looking at the data, the average wage paid for agricultural work amounted to 3,473 Ariary. The concern is therefore justified, as plantation work is preferred as it provides longer-term employment.

### 3.3 Changes in Agricultural Production

Despite the high share of households offering labour to the plantation, households still consider agriculture as their main occupation and income source. Very few households rely on plantation work as their main source of income. When explicitly asked about the reduction of agricultural work due to the work on the plantation, only two households answered that they had reduced their farming activities. Households tended to increase total working hours and make better use of an otherwise idle workforce. One of the earlier studies showed that a small number of households increased farming activities as a consequence of the improved access to inputs (BUENNER, 2009). Our analysis of the use of plantation income by Jatropha households confirms this hypothesis;

some of the money earned at the plantation in both survey periods is invested in agriculture and livestock.

Farmers stated in the group interviews that due to insufficient rain in the season 2009/2010, they cultivated on average only 75% of their farmland and yields declined on average by 40%. Results from the household survey show a mean reduction of 62% in the production of the five most important crops (rice, cassava, maize, beans and groundnuts), compared to the average production in the preceding five years. Therefore, it is not obvious whether under normal conditions there would not have been any reductions due to the work on the plantation. Lost income from agriculture as well as from other income sources in the case of nonexistence of the plantation is considered as negligible, due to the limited production and limited alternative income sources.

# 4 Empirical Results

## 4.1 Income and Expenditures over Time

The villages under study are located in a remote area with limited market access and limited income sources other than agriculture. The arrival of the plantation now provides many job opportunities with daily wages comparable to average agricultural wage levels. Total income is therefore expected to have increased since the opening of the plantation.

As shown in Table 1 through use of a dependent t-test, income per capita has declined significantly from 2008 to 2010, despite the additional earnings from the work on the plantation. Table 2 shows that the sharp decline is the result of a considerable and significant decrease in farm income due to the above mentioned climatic conditions. For the same reason, agricultural wage work outside of the Jatropha plantation has decreased. Furthermore, people employed in public and military service have stated irregularities in payment or staff reduction due to political reasons. Off-farm income therefore has decreased significantly, but plantation income has not changed significantly. Given the unchanged income and at the same time a higher number of households working on the plantation, more households are benefitting, but at a lower level. The share of plantation income in total income has increased from 16% in 2008 to 43% in 2010 and plantation work is now the most important income source.

**Table 1. Differences in main outcome variables over time**

| Variable (Monetary variables are given in Ariary) | N | Mean 2008 | Mean 2010 | Mean difference | P (sign. level)[1] |
|---|---|---|---|---|---|
| **Income per capita** | 296 | 405,413 | 134,026 | -271,387 | **0.000** |
| **% income on national poverty line[2]** | 299 | 99.50 | 28.59 | -70.91 | **0.000** |
| Food expenditures per capita (without home-produced consumption)[3] | 308 | 110,715 | 106,734 | -3,981 | 0.474 |
| **Total expenditures per capita (without home-produced consumption)[3]** | 314 | 228,732 | 170,847 | -57,885 | **0.000** |
| **Diet diversity (number of different foods)** | 312 | 19.96 | 24.29 | 4.34 | **0.000** |
| Meals with rice (7 days before) | 306 | 14.00 | 14.32 | 0.32 | 0.384 |
| **Meals with vegetables (7 days before)** | 306 | 9.17 | 14.32 | 5.15 | **0.000** |
| Meat consumption (7 days before) | 306 | 0.75 | 0.87 | 0.11 | 0.351 |
| **Days not enough to eat (30 days before)** | 306 | 7.23 | 3.40 | -3.83 | **0.000** |
| **Months less than 3 meals per day (year before)** | 306 | 1.16 | 0.23 | -0.94 | **0.000** |

[1] P gives the significance level of a t-test testing the null hypothesis of no differences between the years
[2] Poverty line 2010: 468,800 Ariary (INSTAT, 2010); 2008: 407,433 Ariary (GRASS, 2011)
[3] Inflation-adjusted (Inflation in 2009 was 8.4% and in 2010 8.1% (WORLD BANK, 2011)

Source: own data (household surveys 2008 and 2010); INSTAT (2010); GRASS and ZELLER (2011); WORLD BANK (2011)

**Table 2. Differences in incomes over time**

| Income (in Ariary and per capita) | N | Mean 2008 | Mean 2010 | Mean difference | P (sign. level)[1] |
|---|---|---|---|---|---|
| Farm (without home-prod. consumption) | 309 | 256,788 | 20,672 | -236,116 | **0.000** |
| Livestock (without home-prod. consumption) | 314 | 23,895 | 29,498 | 5,604 | 0.180 |
| Plantation | 309 | 65,244 | 56,929 | -8,315 | 0.155 |
| Off-farm | 309 | 71,695 | 17,436 | -54,259 | **0.000** |
| Total | 296 | 405,413 | 134,026 | -271,387 | **0.000** |
| Share of plantation income | | 16% | 43% | 27% | |

[1] P gives the significance level of a t-test testing the null hypothesis of no differences between the years

Source: own data, household surveys (2008 and 2010)

The reduction in expenditures as seen in Table 3 confirms the decrease in income. An examination of individual expenditures (food, necessities, clothing, schooling, social obligations and luxury goods), shows that expenditures for all items decreased significantly except for food. Mean expenditures in 2010 exceed mean incomes and in

2008 were below income, which shows that households are able to smooth food consumption over time. Total expenditures can be restricted, but food expenditures do not fall under a certain minimum.

**Table 3. Differences in expenditures over time**

| Expenditures (in Ariary and per capita) | N | Mean 2008 | Mean 2010 | Mean difference | P (sign. level)[1] |
|---|---|---|---|---|---|
| Food (without home-produced cons.) | 308 | 110,715 | 106,734 | -3,981 | 0.474 |
| Necessities | 308 | 11,276 | 10,157 | -1,119 | **0.086** |
| Clothes | 316 | 19,407 | 11,025 | -8,382 | **0.000** |
| Social obligations | 287 | 12,140 | 5,163 | -6,978 | **0.005** |
| Luxury | 308 | 74,911 | 35,522 | -39,389 | **0.000** |
| School | 313 | 5,499 | 3,064 | -2,435 | **0.010** |
| Total | 314 | 228,732 | 170,847 | -57,885 | **0.000** |
| Share of food on total expenditures | | 48.4% | 62.5% | 14.1% | |

All variables are inflation-adjusted (2009: 8.4% and 2010: 8.1%, WORLD BANK, 2011)
[1] P gives the significance level of a t-test testing the null hypothesis of no differences between the years.
Source: own data, household surveys (2008 and 2010), WORLD BANK (2011)

## 4.2 Diet Diversity and Food Security over Time

The most prevalent problems in Madagascar in terms of food security are the reduction in food consumption during the lean season (DOSTIE et al., 2002) and an unbalanced diet due to the abundance of rice (IFPRI, 2010). The lean season is characterized by inadequate supply of food as households run out of stocks and market prices of staple foods are often very high. Participants of the group interviews stated that the diversity of foods available at the market has increased considerably since the creation of the plantation and that the provision of food in the lean season has improved. Diet diversity reflects the number of different foods consumed by a household throughout the year. Short and long-term food security is reflected in the days and months a household has to consume less than three meals per day.

Diet diversity has increased significantly from 2008 to 2010, as shown in Table 1. Rice and meat consumption have not changed significantly whereas vegetable consumption has increased significantly. On average, households' consumption from home-produced production amounted to 44% of their total food consumption. No data on the value of home-produced consumption from 2008 is available. Therefore, it is not possible to assess possible reductions or increases in home-produced consumption. Furthermore, the prevalent reduction in food intake during the lean period decreased significantly.

These results are consistent with the results from the group interviews. According to the statements, household food security has improved especially in the lean period before harvest. Village residents observed a greater variety of food (for example meat and vegetables) and a greater number of suppliers on the market in Fenoarivo, which is the major source of food for the villages under study other than self-supply. Households working for the plantation spend a large share of their new income at the market and farmers and sellers benefit from this new demand.

The 2008 survey took place from January to March, shortly before the harvesting period, compared to August to October for the 2010 survey. Although the lean season in 2010 started earlier than usual, the food security situation of households might still have been better in 2010 compared to 2008. In the group interviews, people stated to be worse off in terms of food security in 2010. In 2008, 74% of the households reported at the time of the survey that their rice stocks were depleted. Stocks on average ran out in October; households with stocks remaining had on average 107 kg left. In 2010 44% of households depleted their rice stocks. Stocks on average ran out in June, 4 months earlier than in 2008. Households with stocks remaining had on average 51.43 kg left. Interviews held in 2010 were conducted 5 months later than in 2008, showing that the availability of food was considerably lower than in 2008. These numbers only reflect food availability in the villages and not households' actual consumption. Households often start economizing before and buy on the market when prices are still low and keep the rest of the stocks for the lean period.

According to the group interviews, the impact of the plantation on food security may be underestimated for climatic reasons. The lean season in 2010 started on average two to four months earlier than usual. Since the plantation started operating, plantation work has become the most common coping strategy of households to provide themselves with income to purchase food at the markets during this period. However, as yields declined not only in the three villages, but also in the greater area, prices started increasing earlier as well. Producers do not benefit from the higher prices, as they sell their yields shortly after harvest when prices are low. Consumer prices almost doubled compared to the year before, especially for the most important staple – rice.

### 4.3 Socio-economic Differences between Jatropha and Control Households

As mentioned in the introduction, households differ in socio-economic characteristics which influence their decision to work for the plantation or not. In this section we describe the results of an independent t-test comparing Jatropha and control households (see Table 4).

**Table 4. Socio-economic differences Jatropha and control group 2010**

| Socio-economic characteristics | N Control[1] | N Treated[2] | Mean C | Mean T | Mean total sample | Mean difference T-C | P (sign. level)[3] |
|---|---|---|---|---|---|---|---|
| Formation of HH | 172 | 301 | 1989.8 | 1993.6 | 1992.2 | 3.8 | **0.011** |
| HH size | 173 | 301 | 5.28 | 5.70 | 5.52 | 0.42 | **0.093** |
| Age of HH head | 171 | 296 | 45.08 | 41.96 | 43.10 | -3.12 | **0.027** |
| Value of HH assets (in 1,000 Ariary) | 172 | 301 | 1,018 | 671 | 797 | -347 | **0.007** |
| Value agricultural assets | 172 | 301 | 246,805 | 154,357 | 187,975 | -92,448 | **0.006** |
| Total value HH and agri-cultural assets per capita | 172 | 301 | 261,398 | 143,132 | 186,138 | -118,265 | **0.000** |
| Area cultivated ($m^2$) | 161 | 294 | 18,316 | 15,121 | 16,252 | -3,194 | **0.025** |
| Size of area per workforce ($m^2$) | 159 | 294 | 6769 | 5374 | 5864 | -1,395 | **0.010** |
| Total yield 09/10[4] | 160 | 284 | 1,586 | 1,177 | 1,324 | 409 | **0.018** |
| Average total yield[4] | 161 | 294 | 4,247 | 3,452 | 3,733 | 795 | **0.029** |
| Rice stocked | 171 | 300 | 434 | 336 | 98 | -371 | **0.092** |
| Dummy own business | 172 | 301 | 0.46 | 0.24 | 0.32 | -0.21 | **0.000** |
| Dummy public or military service | 172 | 301 | 0.06 | 0.02 | 0.04 | -0.04 | **0.050** |
| Dummy agricultural wage work | 172 | 301 | 0.40 | 0.26 | 0.31 | -0.14 | **0.004** |

[1] Control group: households with no member working for the plantation.
[2] Treatment group: households with at least one member working for the plantation.
[3] P gives the significance level of a t-test testing the null hypothesis of no differences between the groups.
[4] Total yields for the five most important crops (Rice, cassava, maize, beans and groundnut).
All monetary variables are given in Ariary, all yield variables in kg.

Source: own data, household survey (2010)

Jatropha households in 2010 had a significant lower household size, younger household heads and a more recent household formation. They also stated a lower value of household and agricultural assets as well as agricultural land, both on a household and on a per capita basis as well as at the workforce level. Jatropha households had less access to off-farm income sources, namely agricultural wage work, self-employment or public and military service. Furthermore, Jatropha households had less total yields on average and also for the 09/10 season, which is consistent with the lower amount of rice stocked. There are significantly more households from the control group which have superior roofing and private latrines than Jatropha households. Reduction in yields showed no significant difference between the two groups. This confirms the

hypothesis that Jatropha households did not reduce their food production due to the work on the plantation. At the same time it suggests that the reduction in farm income brings the two groups more closely together in terms of income, as climatic conditions hit both groups equally while plantation income remained constant.

The differences in socio-economic characteristics of the groups are consistent with the findings from GRASS and ZELLER (2011). When comparing treatment and control group in 2008, mean differences show that households working for the plantation have significant lower incomes, a bigger household size, less land per workforce, less livestock and are less involved in wage work and own business activities (GRASS and ZELLER, 2011). This shows that socio-economic differences between Jatropha and control households did not change over time, suggesting that determinants for working on the plantation have not changed either.

### 4.4 Determinants for Working on the Plantation

To predict the probability of a household working on the plantation, a binary logit regression has been applied. In this section we present the results of the regression, as shown in Table 5.

**Table 5. Determinants of household decision to work for the plantation in 2008**

| Variables | Coefficient | Significance | Marginal effect | 95% confidence interval | |
|---|---|---|---|---|---|
| Sum workforce | 0.2653 | 0.016 | **0.0661** | 0.0125 | 0.1197 |
| Land per worker | -0.2142 | 0.018 | **-0.0534** | -0.0978 | -0.0090 |
| Dummy Sakafia | 1.6337 | 0.001 | **0.3544** | 0.1988 | 0.5099 |
| Dummy Maroilo | -2.7453 | 0.000 | **-0.5631** | -0.6642 | -0.4620 |
| Own business | -0.6794 | 0.027 | **-0.1682** | -0.3143 | -0.0220 |
| Public service | -1.5417 | 0.019 | **-0.3411** | -0.5571 | -0.1251 |
| Year of household formation | 0.0222 | 0.034 | **0.0055** | 0.0004 | 0.0106 |
| Dummy Zebu | -0.6330 | 0.049 | **-0.1569** | -0.3101 | -0.0037 |
| Constant | -46.586 | 0.036 | | | |
| N | 336 | | | | |

Pseudo $R^2$: 0.2970, Chi square: 0.0000,
Pos. predictive value: 75.94%, Neg. pred. value: 84.68%, Correctly classified: 79.17%.

Source: own calculations, based on household survey (2008)

The distance to the plantation is a major determinant for the decision of a household whether to work on the plantation or not. If a household is located in Sakafia, a village close to the plantation, the probability that one of its members will work on the plantation is 35% higher than for households living in the other two villages. If a household is located in Maroilo, a village which is located farer away from the plantation, this probability decreases by 56% compared to the other two villages. The village head of Maroilo stated that only young strong men who are able to deal with the long commute and hard labour are able to work for JatroGreen. Furthermore, the decision to seek plantation work is also determined by the number of household members between 17 and 65 and the available land per household member. As agriculture is the main income source and the area is characterized by few employment possibilities other than agriculture, it is therefore reasonable that workers who are not needed for cultivation will work on the plantation. Having a lot of cattle is a symbol of wealth and requires more workforce than crop farming and therefore decreases the probability of plantation work. Households with more than two zebus have significant higher incomes per person than households with no cattle. Households having their own business or working in public or military service had significant higher income per capita in the reference period than those households with no access to these incomes. This decreases the need for an additional income source and therefore significantly the probability that a member will work at the plantation. The year of household formation indicates that newly established households are more open to new employment and income sources, as well as the age of the household members. Younger people are more likely to work on the plantation; in 2010 the mean age of plantation workers was 30.2.

### 4.5 Comparison of Main Outcome Variables Jatropha and Control Group

In order to see if differences in outcome variables between Jatropha and control households persisted over time, this section presents results from an independent t-test comparing income, expenditures and food security situation of the two groups in 2010.

No significant differences in total income per capita can be found when comparing Jatropha and control households. The comparison of the different income sources illustrated in Table 7 shows that Jatropha households have lower levels of farm and off-farm incomes. Given the determinants for working on the plantation, Jatropha households have lower access to off-farm employment and less agricultural production. The reduction in farm and off-farm incomes and relative importance of plantation incomes in 2010 therefore brings the two groups closer together.

## Table 6. Differences in outcome variables in 2010

| Outcome variables | N control[1] | N treated[2] | Mean C | Mean T | Mean total sample | Mean difference T-C | P (sign. level)[3] |
|---|---|---|---|---|---|---|---|
| Income per capita | 97 | 199 | 116,369 | 142,633 | 134,026 | 26,246 | 0.120 |
| % income poverty line[4] | 97 | 199 | 24.82 | 30.43 | 28.59 | 5.60 | 0.120 |
| Food expenditures[5] | 171 | 301 | 214,357 | 186,694 | 196,716 | -27,663 | **0.017** |
| Value of home-prod. consumption | 171 | 301 | 96,882 | 80,455 | 86,406 | 16,427 | **0.060** |
| Total expenditures[5] | 170 | 300 | 312,939 | 282,638 | 293,597 | -30,301 | **0.033** |
| Diet diversity (number of single foods) | 171 | 300 | 24.10 | 24.36 | 24.27 | 0.26 | 0.400 |
| Rice cons. (week before) | 171 | 300 | 14.99 | 14.02 | 14.37 | -0.97 | **0.040** |
| Vegetable cons. (week before) | 171 | 300 | 14.02 | 14.55 | 14.36 | 0.52 | 0.212 |
| Meat cons. (week before) | 171 | 300 | 0.95 | 0.77 | 0.83 | -0.18 | 0.111 |
| Days not enough to eat (month before) | 171 | 300 | 2.45 | 3.91 | 3.38 | 1.46 | **0.007** |
| Months less than 3 meals per day (year before) | 171 | 300 | 0.08 | 0.35 | 0.25 | 0.27 | **0.001** |

[1] Control group: households with no member working for the plantation.
[2] Treatment group: households with at least one member working for the plantation.
[3] P gives the significance level of a t-test testing the null hypothesis of no differences between the two groups.
[4] National poverty line 2010: 468.800 Ariary (INSTAT, 2010).
[5] Expenditures with home-produced consumption.
All monetary variables are given in Ariary and per capita.
Source: own data, household survey (2010), INSTAT (2010)

## Table 7. Differences in income sources Jatropha and control group 2010

| Income (in Ariary and per capita) | N control[1] | N treated[2] | Mean C | Mean T | Mean total sample | Mean difference T-C | P (sign. level)[3] |
|---|---|---|---|---|---|---|---|
| Total | 97 | 199 | 116,369 | 142,633 | 134,026 | 26,246 | 0.120 |
| Farm | 116 | 199 | 29,227 | 16,088 | 20,927 | -13,138 | **0.077** |
| Livestock | 115 | 199 | 38,933 | 24,046 | 29,498 | -14,887 | 0.185 |
| Plantation | 116 | 198 | 0 | 92,477 | 58,378 | 92,477 | **0.000** |
| Off-farm | 116 | 199 | 29,484 | 10,092 | 17,233 | -19,392 | **0.000** |

[1] Control group: households with no member working for the plantation.
[2] Treatment group: households with at least one member working for the plantation.
[3] P gives the significance level of a t-test testing the null hypothesis of no differences between the two groups.
Source: own data, household survey (2010)

Jatropha households had significantly lower food as well as total expenditures and a lower value for home-produced consumption. There were no significant differences in market purchases between the two groups. The significantly lower number of meals with rice can be partly explained with the fact that poorer households substitute rice with cassava, especially in the lean period. Jatropha households also had significantly higher levels of food reduction in the short term (7 and 30 days) as well as long term (12 months). A comparison of socio-economic characteristics provides a more detailed explanation. When examining the amount of rice paddy stocked after harvest, a significant difference can be found: Jatropha households had lower rice stocks than control households in both years. There was no significant difference in the stock left at the time of the interview and the date when the stocks ran out.

### 4.6 Results from the Difference-in-Difference Analysis

This section attempts to assess the impact of plantation work on incomes, expenditures and food security of the households. The difference-in-difference analysis computes two differences, between Jatropha and control households and between 2008 and 2010. As shown in Table 8, households working for the plantation experienced less income reduction than control households between 2008 and 2010. In the sub-sample of households with incomes below the median, households had to reduce their expenditures less than control households. The only two significant variables show that control households had to reduce their food consumption less than Jatropha households in the period from 2008 to 2010. Control households in the full sample had more success than Jatropha households in reducing the months with not enough food. Control households in the sub-sample could improve short-term food security more than Jatropha households.

### 4.7 Changes in Inequality

As demonstrated by the logit regression in chapter 4.4, mostly poorer households work for the plantation. In this paragraph we test the hypothesis that plantation income has an equalizing effect on the income distribution in the villages.

Table 9 shows the Gini coefficients computed for the research area. Numbers are slightly higher than the official numbers from the Malagasy federal office of statistics which estimated the Gini coefficient at 0.37 for rural regions in 2010. When plantation income is ignored, the Gini coefficient is 5 percentage points higher than the actual value in 2008 and 14 percentage points higher in 2010. Looking at expenditures, inequalities between households have decreased significantly from 2008 to 2010.

## Table 8. Difference-in-difference results

| | Full sample (N=285) | Subsample (N=142) |
|---|---|---|
| **Δ Income per capita** | | |
| Treated | -245,605 | -81,674 |
| Controls | -361,134 | -48,156 |
| **DID estimate** | **115,530** | **-33,581** |
| **Δ% Poverty line** | | |
| Treated | -64.64 | -74.9 |
| Controls | -93.88 | -78.1 |
| **DID estimate** | **29.24** | **3.2** |
| **Δ Expenditures per capita** | | |
| Treated | 3,758 | -16,465 |
| Controls | 17,060 | -75,426 |
| **DID estimate** | **-13,302** | **58,961** |
| **Δ Food expenditures per capita** | | |
| Treated | -15,418 | 741.67 |
| Controls | -1,843 | -30.820 |
| **DID estimate** | **-13,576** | **31,562** |
| **Δ Diet diversity (12 months)** | | |
| Treated | 3.61 | 3.78 |
| Controls | 5.41 | 7.07 |
| **DID estimate** | **-1.94** | **-3.29** |
| **Δ Rice consumption (7 days)** | | |
| Treated | 0.62 | 0.95 |
| Controls | -3.29 | -4.05 |
| **DID estimate** | **3.90** | **5.0** |
| **Δ Vegetable consumption (7 days)** | | |
| Treated | 5.7 | 6.42 |
| Controls | 5.8 | 9.20 |
| **DID estimate** | **-0.1** | **-2.78** |
| **Δ Meat consumption (7 days)** | | |
| Treated | 0.25 | 0.24 |
| Controls | -0.07 | -0.58 |
| **DID estimate** | **0.32** | **0.82** |
| **Δ Not enough to eat (30 days)** | | |
| Treated | -2.83 | -2.25 |
| Controls | -4.31 | -5.40 |
| **DID estimate** | **1.48** | **3.15*** ** |
| **Δ Not enough to eat (12 months)** | | |
| Treated | -0.74 | -0.76 |
| Controls | -0.88 | -0.93 |
| **DID estimate** | **0.14*** ** | **0.17** |

*, **, *** significant at 1, 5 and 10% respectively, significance levels calculated with bootstrap standard errors. All monetary variables are given in Ariary and per capita.

Source: own calculations, computed in Stata with PSMATCH2; LEUVEN and SIANESI (2003)

**Table 9. Gini coefficients over time**

| | 2008 | 2010 | Δ |
|---|---|---|---|
| Gini coefficient (based on total income per capita) | 0.43 | 0.47 | 0.04 |
| Gini coefficient (total income per capita without plantation income) | 0.48 | 0.61 | 0.13*** |
| Gini coefficient (based on expenditures per capita) | 0.48 | 0.30 | 0.18*** |

*** significant at the 0.01 level, significance estimated with jackknife procedure

Source: own data, computed in STATA with Fastgini

Table 10 shows the breakdown of the Gini coefficient and the marginal changes by which an increase in one income source has on inequality. The results show that a 1% increase in plantation income will slightly decrease the Gini coefficient for total income, in 2008 by 0.05% and in 2010 by 0.04%. The Gini correlation between plantation income and total income in 2008 is low (0.39), showing that plantation incomes favour the poor more than the other income sources. In 2010, given the higher share of plantation income in total income, this correlation is higher. An increase in plantation incomes as well as in agricultural incomes would nevertheless lead to a slightly lower Gini coefficient.

**Table 10. Decomposition of the Gini coefficient by income source**

| | 2008 | | | | | 2010 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sk | Gk | Rk | Share | %Δ | Sk | Gk | Rk | Share | %Δ |
| **Income source** | | | | | | | | | | |
| Farm | 0.61 | 0.52 | 0.85 | 0.63 | 0.02 | 0.16 | 0.76 | 0.60 | 0.16 | -0.00 |
| Livestock | 0.06 | 0.82 | 0.56 | 0.06 | 0.00 | 0.23 | 0.86 | 0.77 | 0.33 | 0.10 |
| Off-farm | 0.17 | 0.80 | 0.62 | 0.20 | 0.03 | 0.14 | 0.83 | 0.36 | 0.09 | -0.05 |
| Plantation | 0.16 | 0.76 | 0.39 | 0.11 | -0.05 | 0.46 | 0.65 | 0.67 | 0.42 | -0.04 |
| **Total** | **1.00** | **0.43** | | | | **1.00** | **0.47** | | | |

Sk: share of income source on total income, Gk: Gini coefficient for each income source,
Rk: the Gini correlation of income from source k with the distribution of total income share: share of each income source in total inequality,
%Δ: refers to the impact that a 1% change in the respective income source will have on inequality.

Source: own data, computed in STATA with the descogini module

In order to see the contribution of plantation incomes to the Gini coefficient, it is split into the various income sources (LÓPEZ-FELDMANN, 2006). Income sources are divided into farm income, livestock income, plantation income and other off-farm income.

### 4.8 Development of Poverty

In this section we show the development of poverty, using the national poverty line as well as survey data for household income and expenditures.

**Table 11. Development of poverty**

| | 2008 | 2010 |
|---|---|---|
| Poverty line (in Ariary, per capita) | 407,433 | 468,800 |
| % of households below (based on income) | 70.2 (N=315) | 97.6 (N=315) |
| Number of households below | 217 | 289 |
| Mean % income on poverty line | 99.50 | 28.59 |
| % of households below (based on expenditures) | not available | 89.6 (N=470) |
| Mean % expenditures on poverty line | not available | 37.38 |

Source: GRASS and ZELLER (2011), INSTAT (2010), own data, household surveys (2008 and 2010)

The official poverty levels for rural areas in Madagascar were 73.5% in 2005 and 82.2% in 2010. Poverty levels for the Fianarantsoa region were 77.6% and 88.2% for the two years of the study, regardless of rural or urban regions. Compared to these numbers, households in the study area were doing better in 2008 and worse in 2010. Employment on the plantation started in late 2007 and by 2008 plantation income had already become the second most important income source and represented about 16% of total income. As shown in the dependent t-test, plantation income did not change significantly from 2008 to 2010 and could therefore not absorb the significant decrease in agricultural income. In 2010 plantation income represented about 43% of total income in the sample. The percentage of households below the poverty line as well as the severity of poverty increased considerably. Nevertheless, it can be concluded that the situation would have been much worse without the plantation and that the plantation therefore contributed to poverty reduction.

Considering expenditures as a proxy for incomes, households are slightly better off. Fewer are found to be below the poverty line or slightly closer to the line. For 2008 no value estimates of home-produced consumption are available therefore only values for 2010 are listed in Table 2. The estimated figure of 89.6% of households below the poverty line is very close to the poverty level estimated by INSTAT (2010). As the figure of 88.2% was estimated for the whole region of Fianarantsoa and poverty in rural areas is higher than in urban areas, the figure of 89.6% seems very close to official estimations.

## 5 Discussion of Results

The hypothesis that Jatropha households have higher incomes and higher levels of food security than similar control households over time could not be proved. Data may have been insufficient for a difference-in-difference analysis. All outcome variables in 2008 had already been influenced by the plantation. 2008 incomes as well as expenditures were already on a higher level and the additional income and higher purchasing power of Jatropha households stimulated the demand on the market. Therefore, the impact of the plantation is likely underestimated.

Mean incomes from the plantation decreased due to the slightly reduced offer of work and the higher number of households already working on the plantation. This may have weakened the impacts in 2010. Furthermore, the creation of the plantation resulted in spillover effects. Households not working on the plantation benefited in various ways such as selling organic fertilizer to the plantation, offering goods and services as well as exploiting the higher purchasing power of Jatropha households. Furthermore, incomes show a high variance. Working days as well as daily wages differ among households, for example team leaders earn a regular income.

Results might also have been stronger if more households with a high probability of working on the plantation had been found in the control group. The assumption of common support was not completely given, especially not for the subsample. Furthermore, 2010 incomes were apparently underestimated. Data collection was reduced to the most important income sources for the households. Yet, especially in 2010 when incomes from agriculture were considerably lower, additional income sources and remittances from family members might have proven important for the households. According to the income data obtained in 2010, poverty increased substantially, however expenditures did not decline to the same extent and proved to be a more reliable measure of household welfare.

Due to the reduction in agricultural production and incomes, households may not have been able to improve their food security. Earnings from the plantation could not compensate for this loss. Due to the remoteness of the area and low competitive markets, the impact of income on food security might have been overestimated; few households rely fully on the market to provide food. As control households possess more assets than Jatropha households, they might be better able to cope with income shocks. Furthermore, family and neighbourly help might have led to a higher distribution of the benefits. Less poor households are expected to support poorer households which might not be able to work on the plantation. One example of this is giving away or selling rice cheaply to people in need during the lean season or the increased consumption of milk, which is very rarely sold but usually given away to relatives or

people in need. Furthermore, the year and a half period between the two surveys might have been too short to reveal major significant changes in consumption patterns. Severe hunger could not be observed in the area and for some households demand for food may already be on the more elastic part of the demand curve, they are not willing to spent an equal share of the additional income on food. Social life and leisure-time possibilities have also increased between the two survey rounds. Expenditures on non-food consumable goods might be underestimated.

Plantation incomes have a small equalizing effect on income distribution. This is quite obvious given that mainly poor households work on the plantation. Due to the sharp decline in agricultural production in 2010, less poor households also worked on the plantation. This might have weakened the impact on incomes and expenditures for the subsample of poorer households.

## 6 Conclusions

The main research question was to assess the impact of the plantation on households' income and food security over time. Adverse weather conditions in the Fianarantsoa region and political problems in Madagascar have led to a reduction of incomes and a deterioration of the food security situation from 2008 to 2010. Households' consumption levels have declined since 2008; high inflation rates, scarcity of food in the region and high seasonal price volatility caused household purchasing power to decline. Against this background, plantation incomes remained constant and have therefore contributed to a stabilization of households' income and food security. There is weak evidence from the difference-in-difference analysis that households working for the plantation experienced a lower reduction in incomes and had to reduce their expenditures to a lesser extent than control households from 2008 to 2010. With regards to households' food security situation the picture is diffuse. Comparisons over time show higher levels of diet diversity, consumption of vegetables and a lower reduction of food intake in 2010 than in 2008.

The difference-in-difference analysis revealed a significant positive effect from plantation work in 2008 on diet diversity and on the provision of food in the lean period although these effects did not hold over time. In 2010 there were significant positive effects on short-term food security, though at the expense of long-term food security. There is a significant positive association between income and food security indicators. This reflects the fact that despite the prevalence of subsistence farming, the majority of households rely equally on the market for provision of food. As households working for the plantation are among those with less agricultural land, they have to purchase at the market and due to the scarcity of food in the region and the remote-

ness from other markets, plantation wages were not enough to secure a household's food security.

Determinants for working on the plantation have not changed over time. Households working for JatroGreen are among the poorest in the study area. The main determinants are the extent of agricultural activity, the access to off-farm income sources and the need for additional income sources. Key factors here are the wage level, the regularity of work and the high offer of wage work for unskilled labour in an area with low availability of other work. The wage level also plays a part in contributing to the maintaining of farming activities, which are more lucrative for households than working on the plantation (BURGER and PETERS, 2010). The number of households working for the plantation has increased from 2008 to 2010, showing the need as well as the acceptance of the plantation work as additional income source.

Despite the success of the plantation, the majority of households still rely on agriculture as the main income source. As market prices are subject to inflation, food availability and seasonal volatility, households relying on plantation wages for their purchases are worse off. The considerable reduction of agricultural production in the season 2009/10 did not allow estimating the true impact of plantation work on agricultural production.

In 2010 more households are found below the poverty line than in 2008. Nonetheless, the plantation has contributed to poverty alleviation. Given the limited agricultural production and the low availability of off-farm income sources, poverty would have increased to a higher extent without the plantation. Given that Jatropha households are among the poorest in the area, plantation incomes have also contributed to a higher equality in incomes and expenditures. This was proven with the help of the Gini coefficient. Here it has been able to show that income inequality would have been significantly higher without the additional income from the plantation. Equally, inequalities in expenditures have significantly decreased.

In conclusion it can be said that the plantation is widely accepted and appreciated as an additional income source. However, as the increase in harvest thefts reveal, its possibility of long-term poverty alleviation is substantial, but limited. Political, institutional and climatic factors must be included in the reduction of poverty.

Suggestions for the JatroGreen management are to strengthen communication to workers as well as non-working villagers to create more trust and increase participation, e.g. through establishing an additional outgrower scheme. On a national level, as more (foreign) investment in land is expected, monitoring of investments and the issue of land titles might be a solution to guarantee the rights of smallholders.

The focus of this study was on employment and food security impacts. Additional benefits of Jatropha production for households, e.g. local energy supply, have not been quantified, but might lead to further positive impacts for the population. Further research should therefore concentrate on these additional benefits as well as on the local and national market potential of Jatropha oil as substitute for fuel, wood and charcoal. Furthermore, the establishment of a value chain, the cost structure of oil production as well as economic and political factors on a national and international level will play a crucial role for the performance of the plantation.

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