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Article

Economic and Social Sustainability Performance of Jatropha Projects: Results from Field Surveys in Mozambique, Tanzania and Mali

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Abstract: This paper presents results from comprehensive field surveys of jatropha projects in Mozambique, Tanzania and Mali in 2012. The article singles out the salient economic and social impact results and derives lessons. The results clearly demonstrate the weak business case for jatropha biofuel production at this time. Plantations were found to be unviable because of insurmountable up-front capital requirements in combination with slow and unreliable crop maturation, inefficient oil pressing owing to a lack of scale and experience, inadequate utilization of by-products, and competitively-priced fossil diesel and palm oil. For smallholders, jatropha only has limited value as a hedge crop in environmentally and economically disadvantaged areas. Better prospects have to wait for the advent of improved jatropha varieties. Social impacts from the perspective of project managers were rather mixed: overall, food security perceptions were positive and no massive forced human displacements were noted so far, though some disputes over land access and compensation were reported. Labor legislation was apparently respected on plantations, and positive gender effects, regional income/employment effects and better public facilities were also reported. The projects generated considerable employment, albeit mostly of a temporary nature, as lack of economic viability had caused many projects to close down again. When introducing next-generation biofuel projects, better

monitoring by various actor groups is recommended, as well as long-term investment plans that include integral exit strategies.

Keywords: jatropha; biofuel; bioenergy; social development; economic development

1. Introduction

The high hopes that the international biomass industry had for jatropha (*Jatropha curcas* L.) as a bioenergy crop have led to a large number of projects, implemented in various countries, with the aim to develop a viable bioenergy cropping system. Underlying these projects was the understanding that the tropical woody perennial shrub may survive in harsh climates and under poor soil conditions [1,2].

Over the years, however, it became clear that there is a lack of knowledge of not only the agronomic, socio-economic and technical aspects of the jatropha value chain, but also of the implications that these aspects of jatropha cultivation have on the sustainable livelihoods of local communities [3,4].

This brought three Dutch knowledge institutions (Utrecht University/Copernicus Institute for sustainable development, Eindhoven University of Technology (TU/e) and Wageningen University/Plant Research International (WUR/PRI).) to undertake a comparative review of existing jatropha studies worldwide; this was finalized in January 2011 [1,5]. Covering several hundred publications, the assessment identified three main issues:

(1) No **comparable results** can be obtained from the various projects since no standardized assessment methods exist. This problem concerns:
   (a) cultivation of the crop (density, hedges, rows, mixed systems, impact of inputs on yield),
   (b) knowledge of environmental factors that influence growth and production (soil, rainfall, temperature, *etc.*), and
   (c) the way in which yield growth and biofuel production is being measured (fresh weight *versus* dry weight, filtered *versus* unfiltered oil, and so on).

(2) There is a lack of knowledge about the **business case**; about which key factors affect the economic feasibility of jatropha production, and which business models are most promising in economic terms.

(3) There is a lack of knowledge of major **social aspects** (working conditions, food security impacts, implications for access to land and complementary resources, gender issues, *etc.*).

These issues are also acknowledged by other sources. For example, Hodbod and Tomei [3] identify a lack of studies that analyze social impacts at the local level. Other authors likewise warn against possible negative socio-economic impacts on smallholders [6,7], and also indicate a lack of empirical field data. To close these knowledge gaps, the three universities began a follow-up project, based on the design of a standardized set of questionnaires that should enable a uniform way of new primary data collection from jatropha projects funded by Dutch government programs, and possibly others. Surveys using these questionnaires were held among jatropha projects in Tanzania, Mali and Mozambique in 2012. With the help of local organizations, the research team covered and analyzed

more than 70 sustainability aspects linked to agronomic, economic, social and some ecological issues to arrive at a better understanding of the functioning and impacts of projects, from which lessons for policy were extracted and recommendations for better business practices disseminated. The focus of this paper is on the results from the analysis of important economic and social sustainability performance dimensions of this research.

2. Methodology

A questionnaire was developed in order to arrive at a standardized overall sustainability measurement of the projects. The topics that were included on the social aspects followed the main sustainability criteria of several initiatives such as the Roundtable of Sustainable Biofuels (RSB) [8] and the Global Bioenergy Partnership (GBEP) [9]; these topics are also described in van Eijck *et al.* [10]. The questionnaire is included in Supplementary I.

Two different questionnaire modules were developed. One was directed specifically at jatropha "projects", *i.e.*, managers of integrated plantation companies, and of seed processing activities working with independent outgrower farmers; a second, shorter module contained a series of questions for (small-scale) cultivators ("outgrowers") themselves. The questionnaire module for project managers comprised 58 socio-economic questions in total. In addition to factual introductory questions about location, size, starting year, *etc.*, a range of economic questions covered actual and estimated investment and operational costs of cultivation and/or processing, actual and expected revenues, and other benefits. The social aspects included observed impacts on food security, local prosperity, and company policy in relation to working conditions, land ownership and land rights, and gender. Furthermore, there were questions on the environmental aspects of biodiversity and the managers' expectations of their project and jatropha in general.

The smallholder questionnaire module (including agronomic aspects) included 49 questions. The economic aspects overlapped partly with the agronomic aspects and included mode of cultivation (field *versus* hedge plantings; interplanting arrangements; planting density; age of the crop; crop management; labor, water, fertilizer and other resource requirements and their estimated costs), incidence of pests and diseases, yield patterns, and sales prices and other contract conditions. For the social aspects, the smallholders were mainly asked about their food security situation, specifically about effects from jatropha on their food production.

Drafts of the two questionnaire modules were reviewed by external jatropha experts from different disciplines and backgrounds, and they were adjusted according to their comments and advice. A detailed field test was done in Tanzania at one project and at a few of its associated outgrowers. The questionnaires underwent further adjustment and were finalised after this round. In all three countries, local research partners undertook the data collection. In Tanzania and Mozambique representatives from the Dutch consortium assisted with and coordinated the data collection and trained the interviewers.

The use of standardized questionnaires for data collection was expected to have two main advantages: (a) ability to reach a high number of projects and outgrowers with limited time input from researchers; and (b) yielding standardized information on many issues, that could thus be compared across projects and outgrower activities. However, the amount of data collected and its quality varied to some extent, depending on the willingness of respondents to spend time to answer all the questions,

their level of literacy, recall ability, and general understanding. Moreover, great variety was encountered in smallholder crop cultivation conditions and management arrangements in practice—even in the same local area. This meant that expectations of quantitative cross-case comparisons had to be scaled down eventually.

Data were collected from a total of 23 jatropha projects: 10 in Tanzania, 7 in Mali and 6 in Mozambique. A total of 35 questionnaires were administered to smallholder cultivators in Tanzania, 40 in Mali, and 5 in Mozambique. The low number in Mozambique is explained by the fact that there was only one outgrower-based project operating in that country, and very few of its outgrowers had a long enough history with jatropha to be able to furnish sufficient information for this research. Large plantation projects constituted the dominant business model in Mozambique, unlike in Tanzania and Mali. A wider range of local stakeholders of the large Mozambican plantations (such as government officials) were therefore also consulted on selected issues, to enable some degree of independent verification of some of the plantation managers' answers on sensitive topics, e.g., employees' food security situation and land rights impacts. These interviews had a supplementary status. A semi-structured format was adopted for some questions, while other parts were conducted as free-flowing informal conversations. The stakeholders included local village leaders, 2–5 local community members (in two cases), 4–5 plantation employees (in five cases), and 1–2 local authorities (in four cases). For full sampling details see [11,12]. This work was done with the help of a translator.

In all three countries the number of project respondents was quite high compared to the total number of active jatropha projects in early 2012. As far as information was provided, 10 projects were then active in Tanzania, 9 in Mali, and 12 in Mozambique. Only one project in Tanzania refused to collaborate. However, one interview could be held with a representative from an already defunct project who was still available on site, so the total number of project interviews in Tanzania is still 10. A more detailed breakdown per country of the 23 projects is given in Supplementary I.

The projects and outgrowers were anonymized by coding them with a system indicating their country of location (Mo, Ta or Ma), followed by a code for type of activity (Pl for plantation, Pr for processor, and O for outgrower). The interviews within each of these three categories were assigned a (random) sequence number, separately for each country. Thus, for example, Mo_Pl4 indicates Mozambican plantation firm nr 4, while Ta_O7 denotes Tanzanian outgrower nr 7. This reference system is used throughout the following text and in the supporting tables.

3. The Economics of Jatropha Activities

The key question here is how the projects have been faring in financial terms, using managers' information about investments, operating costs and estimates of revenues. We tried to find explanations for the financial performance patterns seen in the data and to address the financial future outlook for jatropha projects. The analysis is done separately for large plantations that are primarily based on monocropping and involve large-scale land lease transactions of thousands of hectares; outgrower farmers cultivating jatropha according to some kind of verbal or written contractual arrangement for a seed processor; and seed processors, which specialize mainly in oil extraction and associated activities from their external seed suppliers—such as producing cooking briquettes and pellets from seedcake.

3.1. Large Plantations

Large plantations were only found in Mozambique where they constituted the dominant jatropha business model. Whereas Tanzania also had several large jatropha plantations until recently [10,13–15], our survey was unable to locate any that were still operational, implying that all Tanzania's large plantations had folded in the period 2008–2012. (The only remaining large scheme in Tanzania is the plantation of the former Sun Biofuels in Kisarawe, which sold its accessions to Thirty Degrees East, a holding based in Mauritius. This company is still undecided whether or not to continue with jatropha, so all activities have been put on hold.) In Mali there were never any large mono-plantation schemes. Its jatropha activities are centered around smallholder production and small farmer cooperatives.

Of the five large Mozambican plantation firms covered by the survey, the oldest ones started activities in 2007, and the two most recent ones around 2010. Their projected full size is indeed very large, ranging between 5000 ha and 50,000 ha. In comparison, the areas that had been planted up with jatropha at the time of our survey were small. The two oldest projects had 2311 and 1500 ha under jatropha, respectively. The areas planted up in the three more recent projects ranged from just 165 to 250 ha. Not surprisingly, the breakeven points were projected quite far into the future. The smallest project of 5000 ha is expected to need seven more years to break even, whereas the others expected to need a full ten years or more.

Large plantations have high up-front capital requirements for land clearing and land preparation, otherwise the planting of jatropha cannot proceed apace. Delays in planting are costly since jatropha begins to yield commercially interesting quantities of seeds only after 5–6 years. The investment data given by four projects (Table 1) indicate that the smallest investment outlay so far was in the region of US$ 2 million, but the respondent indicated that additional equipment investment was still to take place. More realistic investment requirements are probably US$ 4.8 and US$ 5 million as quoted by two other projects. Project Mo_Pl3 even quoted US$ 12 million.

Although adequate equipment investment pays off in the longer term, it does lead to extremely high initial costs per ha. This is illustrated by the column labelled "Investment costs per planted-up ha, by 2011" in Table 2.

In the projects that started only very recently, the investment per ha is as high as US$ 10,000 and US$ 20,000. Even in the two oldest projects, the amounts are still a formidable US$ 3333 and US$ 5193, respectively. The respondents indicate that these costs should decrease to around US$ 1000 and US$ 1200 per ha at full size. High fixed costs could thus be quite a burden in the initial years of operation.

Table 1. Data for financial analysis of large plantations (part I).

Company id. nr	Starting Year of Jatropha Activities	Turnover 2011 (US$)	Area Planted up by 2011 (ha)	Projected Full Size (ha)	Projected Breakeven Year	Expected NPV (US$ m)	Expected IRR	Actual Seed Yield 2011 (t/ha/year)	Projected Mature Seed Yield (t/ha/year)
Mo_Pl1	2009	0	200	10,000 [a]	2020	Net CF: $10.9 m/year (=$600/t SVO) [b]	50%	0.24 t [c]	Approx. 5.5–6 t [m]
Mo_Pl2	2007	0	1500	5000 [d]	2015	Not given	26%	0.45 t [e]	3 t
Mo_Pl3	2007	18,000	2311	2311 [f]	2014	$15.9 m [g]	7% [h]	0.50 t	N.A.
Mo_Pl4	2010	0	165	Approx. 15,000	2020	Not given	N.A.	0.06 t [i]	N.A.
Mo_Pl5	~2010	0	240	50,000 [k]	2020	Not given	N.A.	0.06 t	1–2 t [l]

[a]: by 2017; [b]: without by-products or carbon credits; [c]: from 1st productive 25 ha; [d]: by 2014; [e]: from 1st productive 60 ha; [f]: down from original 10,000; [g]: with a 40 y. horizon, and discount rate of 5%; [h]: by 2016; [i]: from 1st productive 78 ha; [k]: but awaiting better varieties; [l]: originally 5 t seeds, later reduced to 1–2 t; [m]: derived from estimate of 1500 SVO/L.

Table 2. Data for financial analysis of large plantations [a] (part II).

Company id. nr	Total Investment Costs so Far (US$)	Total Investment Costs per ha for Planted-up Area by 2011 (US$/ha)	Projected Total Investment Costs per ha at Full Size (US$/ha)	Total Production Costs per ha by 2011 (US $/ha/year)	Projected Total Production Costs per ha at Full Size (US$/ha/year)	Estim. Oil Content of Seeds	Intended Selling Price (US$/t SVO)	Intended Selling Price (US$/L SVO)	Local Fossil Diesel Price (US$ /L)
Mo_Pl1	$2,000,000	$10,000	Not given	$1000–1500 (=$2041/t SVO)	$500–750	35%	$600–650 [b]	$0.63	$1.27
Mo_Pl2	$5,000,000	$3333	$1000	$667 (=$690/t SVO)	Not given	31%–42%	$850	$0.85	$1.17
Mo_Pl3	$12,000,000	$5193	$1200 [c]	$176 (=$417/t SVO)	Not given	30%	$1193 [b]	$1.19	$1.27
Mo_Pl4	Not given	Not given	Not given	No production yet	Not given	18%	Not yet determined [d]	Not yet determined [d]	$1.27
Mo_Pl5	$4,800,000	$20,000	Not given	$480	$272–300	40%	Not yet determined [d]	Not yet determined [d]	$1.33

[a]: All local prices were converted into US$ at the rate of 30 Mtc ± 1 US$; [b]: equals the world price of palm oil crude according to the respondent; [c]: according to the original investment plan, later revised; [d]: no sales realized yet.

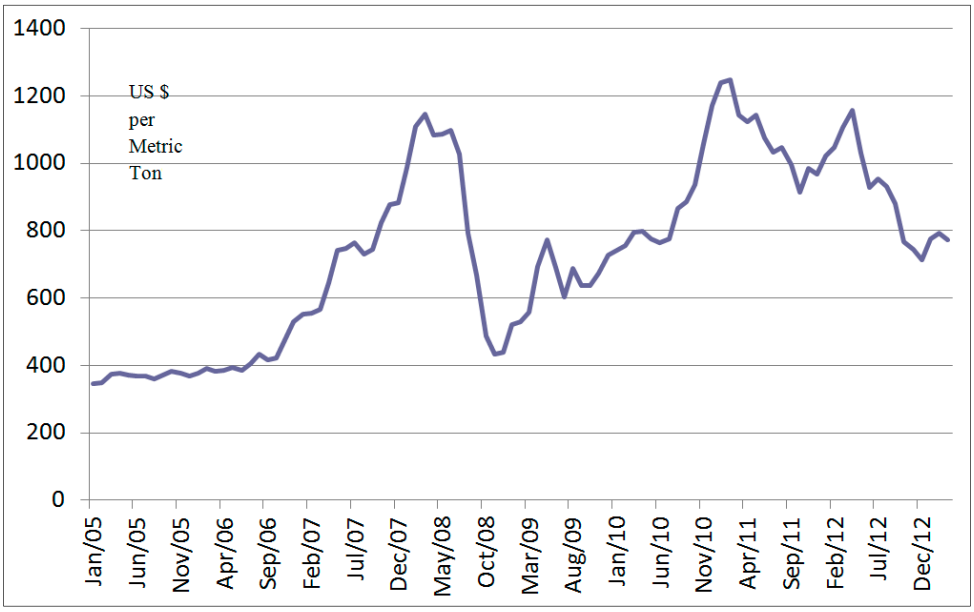
The slow maturation of the jatropha plant significantly aggravates the initial cash flow problems deriving from high initial capital requirements. In the two oldest projects, the yield data quoted were 450 kg and 500 kg dry seeds per ha for approximately 4–5 year old jatropha (*i.e.*, pertaining to the oldest sections of the plantations). The respondent from the 2009 plantation indicated to have obtained 240 kg/ha from its first productive 25 ha. In the two projects that were started in/around 2010 the reported yields were still only 60 kg per ha. When we compare this to the estimates for dry seed yields from mature jatropha given by three respondents, there is still a big gap to be overcome: they projected 1–2 tonnes, 3 tonnes, and 1500 L Straight Vegetable Oil (SVO) (equivalent to about 5.5–6 tonnes of seeds). While the last estimate seems rather unrealistic to obtain, 2–3 tonnes seed per ha may be achievable for mature jatropha with sound agronomical practices, professional management and reasonably good soil and climatic conditions. At the same time, we can say that this is only just the sheer minimum yield required in order to ensure long-term break even (further details below).

Other elements contributing to an initially unfavorable cost/revenue situation include oil pressing inefficiencies, inadequate utilization of oil by-products and unfavorable prices for the oil. Although our interviews with processors in Tanzania established that pressing efficiency and productive utilization of by-products are of major influence on the costs per liter of SVO, and we pressed for information about these parameters in Mozambique as well, none of the Mozambican projects reported any data about this. The main reason is that none except Mo_Pl3 had actually been pressing any seeds so far. The latter had realized a commercial turnover of US$ 18,000 from domestic sales of SVO so far. No significant export of jatropha oil had taken place by 2012. Low oil content of the seeds is also an issue contributing to low financial returns in some cases. The four Mozambican plantation managers who gave information about this reported a wide range, from 30% to 42%, depending on batch and area (Table 2). (A fifth reported 18%. This is most likely due to its practice of harvesting ripe and green seeds together, which is uncommon)

The data about total production costs (Table 2) are highly variable between projects, and hard to compare. Unlike the investment data discussed above, it is difficult to make sense of them. The two oldest projects report values of US$ 667 per ha/year and US$ 176 per ha/year, respectively, which suggests big differences between them. However, the difference in terms of tonnes SVO is much smaller: US$ 690 and US$ 417, respectively. This could suggest substantial differences in the firms' cost structures that are hidden from our view. The firm that started in 2009 predictably reports a higher figure of US$ 1000–1500 per ha/year (or US$ 2041/tonne SVO), but indicates that this should ultimately decrease to US$ 500–750/ha. The figure of US$ 400 per ha/year quoted by one of the most recent projects seems low, and in any case it is probably too preliminary to attach much importance to.

The three oldest projects also gave their views on their prospective competitive position in the international bio-oil market (Table 2), by comparing their product to palm oil crude and fossil crude. These two commodities are the two closest substitutes for jatropha oil, hence their prices constitute the lead sales prices for jatropha SVO suppliers who aim for the international market (which is the case with almost all large plantation projects). As Figure 1 shows, palm oil crude has experienced large price swings since 2008, similarly to petroleum crude. The unpredictability of the palm oil and fossil oil prices creates much uncertainty about the future economic feasibility of the plantation projects as the business case of jatropha is extremely sensitive to prices of the competing oils.

Figure 1. Palm oil monthly price—January 2005–March 2013 [16].



All three respondents ultimately did expect to be able to sell below the local fossil diesel price of Mtc 35–38 per liter (2012). Their intended local SVO selling price ranged from US$ 600–1200 per tonne (Mtc 18.75–35.80 per liter). The lower bound in this range seems a realistic price to aim for, given the fact that the feasible domestic price closely follows the international fossil and palm oil prices. The international palm oil price fluctuated between roughly US$ 400–1200 per tonne between 2005 and March 2013 (see Figure 1) and it should be considered highly unlikely that the world price of palm oil crude will sink below US$ 600 for prolonged periods of time within the coming decades, even in spite of the prolonged recessionary conditions in Europe. However, the upper bound in the quoted price range seems too optimistic on the part of the respondent. The average monthly price of palm oil crude over the period July 2007 (*i.e.*, at the end of the era of low prices) to March 2013 was US$ 868 (Own calculation based on data from [16] well below US$ 1200.

In van Eijck *et al.* [10] implications for profitability were estimated for the case of a large Tanzanian plantation which is based on yield curves and cost and revenue parameters similar to the Mozambican plantation projects discussed in this article, using cost-benefit analysis. This yielded an Internal Rate of Return very close to the real interest rate of 8%, implying an almost zero net profit over the project's 20 year lifespan. In combination with a high risk profile for this new crop, plantation projects like these need higher oil prices, and seed yields higher than 2–3 tons/ha in order to attain economic viability.

3.2. Outgrowers

In Mozambique, there is only one processor-outgrower project in the North, but in Tanzania and Mali the processor-outgrower model is the dominant one. In Mali, the seed trade and/or processing are often conducted cooperatively by organized groups of outgrowers. Some of these projects also claimed to cultivate fields that belong to their cooperative. There were also a few local/regional development projects with links to outgrowers, which tend to have broad social aims, such as providing agricultural

extension for increased food security, combating erosion, or building up local/regional energy supply from non-traditional sources. Similar developmentally-oriented ventures were found in Tanzania. In both countries we also found one or two larger, more commercially-oriented outgrower-processor arrangements in which the processors are owned by western foundations or private investors. Outgrowers cultivate jatropha in two basic arrangements: fields and hedges. Within each of these arrangements we can make a further distinction between those that intercrop with other types of plants, and those that don't.

Tables 3 and 4 give annual (2011) gross revenue from seed sales for outgrowers cultivating jatropha older than two years in hedges (standardized per 100 m. hedge) and on fields (standardized per ha), respectively. Many Malian outgrowers did not, or could not, provide any revenue information, therefore this analysis covers only 13 hedge cases and 13 field cases. The revenue data should be interpreted as gross value added (GVA, *i.e.*, net profit and labor costs). While detailed cost data about investment (tools, planting materials) and inputs other than labor (manure, fertilizers, water) were also gathered, these expenses proved to be negligible. No farm tools had been acquired specifically for jatropha cultivation, and planting material (seeds, cuttings, seedlings) usually had come virtually for free, while precious fertilizer and irrigation water were used only for food crops, not for jatropha. For most small farmers these inputs are hardly available in the first place. The opportunity costs of land and labor are the two dominant cost items of smallholder production by far. However, their value depends crucially on the specifics of the local situation, as detailed below.

Table 3. Revenue [a] data for jatropha hedge growers, 2011, all countries, $n = 13$.

Outgrower Id. Nr	Mono or Mixed Cropping	Total Length	Age of Jatropha (year)	Jatropha Revenue per 100 m Hedge Equivalent (US$)
Ma_O1	hedge, wide spacing, mono	1200 m	4	0.48
Ma_O26	hedge, mono	30 m	6	23.00
Ta_O1	hedge, mixed	80 m	11	11.75
Ta_O2	hedge, mono	163 m	3	0.99
Ta_O3	hedge, mono	203 m	11	1.54
Ta_O4	mainly hedge, mixed	80 m	11	11.75
Ta_O5	hedge, mixed	153 m	10	8.18
Ta_O6	hedge, mono	110 m	8	2.13
Ta_O7	hedge, mixed	140.5 m	4	50.04
Ta_O9	hedge, mono	111 m	4	5.00
Ta_O10	hedge, mono	261 m	12	51.72
Mo_O2	hedge, mono	600 m	3	4.17
Mo_O3	hedge, mono	600 m	3	4.67

[a]: Revenues from mixed hedges include only the proceeds from the jatropha crop.

Table 4. Revenue [a] data for jatropha field growers, 2011, all countries, $n = 13$.

Outgr Id. Nr	Mono or Mixed Cropping	Total Size	Age of Jatropha (year)	Jatropha Revenue per ha Equivalent (US$)
Ma_O5	field—intercrop	0.25 ha	4	29.2
Ma_O7	field—no intercrop	4.00 ha	11	2.73
Ma_O20	field—no intercrop	12.06 ha	3	0.61
Ta_O11	field—intercrop	0.81 ha	10	3.7
Ta_O12	field—intercrop	0.40 ha	8	7.03
Ta_O13	field—intercrop	0.20 ha	5	1.9
Ta_O19	field—intercrop	0.03 ha	2	15.67
Ta_O20	field—no intercrop	0.81 ha	3	2.32
Ta_O21	field—no intercrop	0.61 ha	4	27.67
Ta_O22	field—no intercrop	1.21 ha	7	23.25
Ta_O23	field—no intercrop	0.03 ha	3	15.67
Ta_O24	field—no intercrop	0.20 ha	4	56.25
Ta_O25	field—no intercrop	0.01 ha	4	46.89

[a]: Revenues from intercropped fields only include the proceeds from the jatropha crop.

The tables show much variability in terms of lengths of hedges and sizes of fields. The shortest hedge is 30 m, the longest 1200 m. The size of fields varies between 0.01 ha (basically just a few jatropha trees) and 12.06 ha. The survey data also indicated that cropping arrangements on fields are extremely diverse, both in terms of combinations of plant species as well as plant spacing, weeding, watering, and a nutrient and pest management regime. Fences are also diverse, ranging from 100% monocropped jatropha to highly diversified multipurpose hedgerows. Even in the hedges solely planted with jatropha, the planting distances are highly variable, with some farmers preferring 20–30 cm, while others adhere to 50 cm or an even wider arrangement, which leads to bigger bushes with a higher yield per bush but not necessarily a higher yield per meter hedge. Hence, a quantitative investigation of determinants of seed yield—and the GVA derived from this—proved impossible to conduct. Instead we make more basic observations around the data in the two tables.

As far as the 13 hedge cases (Table 3) are concerned, the average seed sales value (GVA) per 100 m. hedge is US$ 13.49 per annum. After excluding two dubious cases that are possibly outliers, the average comes down to a mere US$ 6.72. By all accounts, this is extremely modest, especially given the fact that it should compensate for labor effort. The labor requirements are estimated at 1–2 weeks per smallholder household per annum, including children and the elderly, for seed harvesting and shelling, and occasional weeding (in the first 2 years only) and pruning. With agricultural minimum wages for hired labor being in the region of US$ 1.5–3.0 per day, depending on location, it is clear that the revenues received from jatropha cannot match this. It would thus only make sense to engage in jatropha cultivation in periods when no other, more productive work for family labor can be found at all, and if the land cannot be used for some more productive purpose.

The low jatropha revenues are put in a broader perspective when we realize that in Tanzania and Mozambique, average family farm sizes are in the region of just one or a few acres, so the total length of their boundary hedges would be limited to a few hundred meters at the most. Their width and height also need to be controlled to greater or lesser degree, in order to avoid competition with food crops for

space and sunlight. The total income earning potential from such hedges is correspondingly limited. In Mali, average farm sizes are much bigger (20–30 ha), but so are the (extended) families who work those farms. (Information obtained from the Managing Director of Mali Biocarburant SA., 2012.)

It stands to reason that our survey registered many complaints from smallholders about low revenues from their hedge jatropha. Their complaints were associated primarily with agronomic conditions, such as poor soils, lack of rain, too much rain, or devastating pest and insect attacks. Low seed prices were also mentioned but appear to be of somewhat lesser importance, and only minor differences in seed prices were observed across locations, depending on the degree of remoteness of the smallholder in relation to the seed buyer. There were no notable complaints about sales contract conditions. The contracts were found to be similar across countries, involving guaranteed buying of all seed supply at a guaranteed minimum price which is adjusted upwards over time in accordance with inflation. Smallholder price risk is therefore minimal. By far the greatest risk observed in practice emanates from processor projects folding due to lack of economic viability. Smallholders seemed to understand this. Several said that they wished to receive higher seed prices in the future, but were willing to accept low prices as long as a viable value chain had not yet been established.

The level of (dis)satisfaction of the hedge farmers with jatropha is also not linearly related to the seed price they receive. In areas where more productive opportunities for labor and land exist, e.g., in Arusha region in Tanzania, farmers showed little interest in cultivating jatropha. This is because of more lucrative competing uses for their labor time and land. Even hedge/boundary land can have a positive opportunity cost. There are areas in which the soils and climate permit the growing of a variety of other hedge species that yield benefits that jatropha does not provide, such as medicine, fodder, wood for building timber and fuel, and nitrogen fixation. Hedges in these areas predominantly consist of mixed plantings. Thus, in more fertile areas with adequate rainfall, it should not be assumed—as has often been done—that jatropha would always be a good use of boundary land for small farmers, at least not in a monocropping hedge arrangement.

The situation in dryer, less fertile, eroded and geographically remote conditions can be quite different. In such areas, few alternative hedge crops for jatropha can thrive. In these areas there is great interest among the small farm populations to collect and sell jatropha seeds, even at revenues far below the local rural minimum wage. Whatever little cash the seed sales generate is still appreciated in view of the severely limited alternatives open to farmers—something is better than nothing. (Source: Interview with manager Ta_Pr1.) Moreover, in addition to its cash value, Jatropha is valued in such areas also for its suitability as a sturdy fence for homesteads and animal pens.

The GVA patterns of jatropha cultivation shown by the 13 field cultivation cases (Table 4) also show a low average and substantial variability; and just like in the hedge cases, there is no significant relation detectable between GVA and prevalence and intensity of intercropping. Averaging the per-ha normalized values results in US$ 17.91 (st. dev. US$ 18.07), with a wide range of US$ 56.25 to US$ 0.61. (It proved impossible to obtain reliable data from smallholders about their *total* cost and revenue from intercropped lands.) Even though this amount excludes the income from main (food) crops, this should be considered very low. After all, jatropha bushes always take away some space from food crops. The questionnaires in Mali, where many field cultivators are located, registered many complaints about low yields. The conditions in Mali appear to be harsher/dryer than those in the other two countries, and there are severe problems with termite attacks. As many Malian projects promoted

interplanting of jatropha with food crops, smallholders are understandably dissatisfied. This land definitely carries a positive opportunity cost in regions where several farmers indicated to have seasonal food security problems (see social impact section for details). The substitution has reduced the overall income per unit of surface area. These problems are comparatively less severe among jatropha hedge farmers.

Comparing the two smallholder business models, it seems that the way Jatropha was promoted had a large effect on the satisfaction of the farmers precisely because of the differences in opportunity costs experienced by them. The hedge model (promoted by most smallholder projects in Tanzania and some in Mali) raised lower expectations but also carried lower risks compared to the field model (promoted mainly in Mali). It led to correspondingly less disappointments and frustration when things did not quite work out as expected. In Mozambique, the situation was again different. In most cases unused lands were cleared for jatropha, so no prior economic value was lost. However, farmers could have benefited more from planting higher value crops, so there was a lot of wasted effort.

3.3. Processors

The processors form a highly heterogeneous group, in terms of strategic orientation, value proposition, turnover and size of their sourcing areas. We encountered pure non-profit entities aiming primarily for increased social well-being of local farming communities, but also for-profit entities, albeit there was no manager who did not express a broad concern for the wellbeing of local society and an eye for environmental integrity. The for-profits are thus companies that try to practice some form of corporate social responsibility. There are also in-between organizational forms, for instance a project aiming to establish a fair trade export line of jatropha energy products. Others complement a commercially funded, for-profit core operation with various foundation-funded activities that aim at long term development such as increased food security, building of management capabilities, and empowerment of women. We also encountered a few development projects funded by hard commercial investors, who appeared to use these as a bargaining chip to get permission to conduct commercial activities in the countries concerned.

Data limitations do not allow an in-depth assessment of each processor. We draw out some more general patterns and highlight some illustrative examples that are broadly indicative of achievements and bottlenecks experienced.

An overview of key characteristics of the processors is given in Table 5. The earliest processing activities were started in 2005; all of these were located in Tanzania. In 2006, this was followed by the first Mali processor-outgrower arrangement. Several new projects began in the following years, and projects kept being established as recently as 2010 and 2011, at a time when the jatropha hype was already well on the wane. To structure the discussion about the processors, we analyze their physical throughput (measured in tonnes of dry seeds handled), their turnover (gross revenue in US$), the estimated surface area covered by the associated outgrowers and own (trial) fields, and estimated numbers of associated outgrowers. The differences between the schemes in these respects are enormous.

Table 5. Basic characteristics of processors for financial analysis.

Id. Nr	Start of Jatr activ.	Throughput 2011 (Tonnes Seeds)	Turnover 2011 [a] (SVO + Byproduct Sales)	Profit 2011 (Y/N)?	Jatropha Surface 2011	Inter-Planting (Y/N)	Nr of Outgrowers in 2011	Planned Full Size
Ma_Pr1	2007	1 t (1st harvest)	US$ 300	N	2546 ha with outgr.	Y	Appr. 2546 (1 ha p.p.)	1300 ha by 2009, but grew on to 3646 ha by 2012
Ma_Pr2	2007	10 t [g]	US$ 3000	Not given	3300–5400 ha own fields + unspecified surface with outgr.	Y	>4000	25,000 ha fields by 2030
Ma_Pr3	2010	No harvest yet	Negligible	N	50 ha	Y	18	Not given
Ma_Pr4	2009	No harvest yet	Negligible	N	Not given	Y	Not given	Not given
Ma_Pr5	2008 [b]	1.74 t [g]	US$ 522 (est.)	N	3500 ha own fields + 58 ha with outgr.	N	30	50,000 outgr.; 10,000 ha
Ma_Pr6	2006	5 t	US$ 1500 (est.)	Not given	450 ha; 25,000 m hedge	Y	248 (fields) + 90 (hedges)	1000 ha fields with 500 outgr; 50 km. hedge with 99 outgr.
Ma_Pr7	2009	17.8 t	US$ 5340 (est.)	Not given	765 ha	Y	1200	765 ha; 1200 outgr; 344 km. hedge.
Ta_Pr1	2005	400 t (est.)	US$ 180,000 (est.)	N	800,000–1,000,000 m hedge [c]	Some	Appr. 40,000	>100,000 outgr.
Ta_Pr2	2011	No harvest yet	Negligible	N	<1 ha	Y	40 indiv. outgr + 2 schools	Not given
Ta_Pr3	2010	No harvest yet	Negligible	N	2 ha	Y	25	78,000 outgr.
Ta_Pr4	2007	4 t (approx. 1000 L SVO)	$1333 (est.) [h]	N	24 ha (12 ha planted in 2007, 12 ha in 2009)	Starting	0	24 ha own fields
Ta_Pr5	2008	0.5 t (approx. 100 L SVO)	US$ 200	Y:US$ 37	2.4 ha (2 ha fence + 0.4 ha demo plot)	Y	72	200 outgr.

Table 5. *Cont.*

Id. Nr	Start of Jatr activ.	Throughput 2011 (Tonnes Seeds)	Turnover 2011 [a] (SVO + Byproduct Sales)	Profit 2011 (Y/N)?	Jatropha Surface 2011	Inter-Planting (Y/N)	Nr of Outgrowers in 2011	Planned Full Size
Ta_Pr6	2008	unknown	Unknown	N	0.4 ha research plot + unknown amount of hedges	N	400 [d]	5000 outgr and 55 MFPs
Ta_Pr7	2005	0.5 t (<0.06 kg/tree)	Not given [h]	N	3.2 ha	Y	0	3.2 ha own field
Ta_Pr8	2005	0.5 t (0.4 kg/tree)	Not given [h]	N	0.8 ha	N	0	0.8 ha own field
Ta_Pr9	2009	147 t jatr. + 50/60t croton [g]	≥US$ 100,000	N	300 ha plantation + unknown nr of outgr.	Unclear	Not given	400 ha + unknown nr of outgr. by 2017
Ta_Pr10	2006	538 kg (0.07/tree)	Negligible	N	10 ha	N	0 (project closed)	16,800 outgr on 9600 ha [e]
Mo_Pr1	2009	4.8 t (in 2012)	US$ 4800 (est.) [f,h]	N	1800 ha hedge outgr. + 3 ha own trial plot	N	1800	No specific goal

Notes: [a]: All amounts for Mali processors converted from CFA @ US$ 1 = CFA 50. Seed price quoted is always 15 CFA cts per kg; [b]: respondent said 2012, but according to other questionnaire data, jatropha was planted from 2008 onwards; no yield from own fields yet by 2012; [c]: calculated from total throughput and average 0.5–0.4 kg seeds/m. hedge; [d]: 200 in Engaruka (2008) + 200 in Leguruki (2008) + unknown nrs in Selela and Mpanda (2009); [e]: Source: Prokon Renewable Energy Ltd., as cited in Loos (2008). Data based on 2008 situation; [f]: US$ 4800 (192,000 mtc) turnover seems very high, as no VSO was produced in 2011 yet; [g]: from outgrowers only; [h]: for self use only.

3.3.1. Big Processors

The biggest processor by far is a Tanzanian firm established in 2005 (Ta_Pr1) that sourced approximately 400 tonnes of dry seeds from different regions from an estimated 40,000 hedge outgrowers, *i.e.*, an average of 10 kg per outgrower. Many of its farmers are located in environmentally adverse areas where jatropha had already been used as boundary fences decades before the advent of any seed collectors. This has been a key reason why it was possible for the firm to upscale at a fast pace in the years preceding our survey, and why no major acceptance issues were arising from interference with the cultivation of any alternative useful hedge species.

The logistics involved in the collection and transport of such huge quantities of seeds from large numbers of very small-scale suppliers is extremely complex given the poor state of rural road infrastructure in Tanzania. The manager explained that the firm has set up several hundreds of regional collection points which serve as focal centers for seed collection and making cash payments to the farmers. The system does seem to work quite well: in 2012 the firms' throughput went up further to 500 tonnes, sourced from 50,000 farmers with established hedge stock. Its total turnover in 2011 was around US$ 180,000 from the sale of approximately 160,000 L SVO, fuel pellets and briquettes made from seed cake, and raw seedcake used as fertilizer; all destined for the local market. Its earlier exports to a western airline for bio-kerosene did not work out in the longer term, as the buyer decided to pay according to the volatile world market price for palm oil crude, which led to a 60% price reduction within a year. After this experience, the firm decided to solely focus on the local market.

Turnover in 2011 fell still a little short of covering total annual costs, but the firm was expecting to be able to reach its break-even point within 1–2 years from 2012 with an estimated supply base of over 100,000 farmers. Unfortunately, acrimonious relations between the two main investors led the largest one to pull out in the course of 2012, which induced bankruptcy. However, the promise shown by the business model induced the entry of a new sponsor and operations were restarted in early 2013, albeit still with rented equipment and at a somewhat reduced scale of operations.

The firm pursued different ways to improve process efficiency, conversion technologies and utilization of by-products and waste products. While it still remains to be seen whether sufficient investment capital will be forthcoming for full re-capitalization in due course, for the time being this case remains one of the best positive examples of a for-profit and simultaneously socially focused jatropha project in our survey. (Another notable positive example is Mali Biocarburant in Mali, but this firm was not covered in our survey.)

The next-biggest operation in our survey is a non-profit activity for local energy generation, located in an environmentally deprived region of Tanzania (Ta_Pr9). It is funded by a Dutch private foundation. This company is mainly supposed to play a supporting role for other, commercial entities in the same business consortium and for the local community, aiming at the provision of essential energy services for business and household activities. The company is supposed to run on a no-profit, no-loss basis, while the profits are supposed to accumulate within sister businesses that use its services. This firm has more advanced and larger capacity processing machinery than Ta_Pr1, which enables it to process jatropha seeds as well as harder croton seeds. In 2011 it crushed 147 tonnes jatropha and 50–60 tonnes croton. The consortium as a whole has leased a 300 ha plantation which is mainly being planted up with jatropha, but its dominant business model is sourcing from outgrowers. The company

expects to need several more years to reach its break-even point. The consortium as whole has had some serious management problems over the past years. One condition for making ends meet is said to lie in higher-value utilization of by-products. For instance, there were plans to start producing biogas from the seed cake for local electricity generation.

The above two firms are in a league of their own; all other entities listed in Table 5 are (still) very modest in size. There was another substantial outgrower scheme operating in Tanzania in the past (Ta_Pr10), but this firm went bankrupt in early 2012. According to interviews with several of its former outgrowers and former manager, its demise was mainly induced by disappointing and erratic seed yields, combined with an unviable business model centerd around the promotion of intercropping of jatropha on farmers' food crop land.

3.3.2. Mid-Size Processors

The mid-size segment of processors is formed by a group of six projects processing between roughly 1 and 17 tonnes in 2011. Five of those are located in Mali and one in Tanzania. Two of these Malian projects are social development projects aiming at increased income generation for small farmers or fostering rural energy supply (Ma_Pr1 and Ma_Pr6). One of these had actually surpassed its planned full size, working with 2546 outgrowers (1 ha per grower). The other was still expanding. It sourced from 248 field outgrowers with 1–2 ha jatropha each, and 90 growers with 278 m hedge on average, and aimed to broadly double these numbers by 2016. The other four projects in the medium-size segment are (more or less) commercially orientated activities, some of which had substantial ambitions for future expansion (see right hand column in Table 5). For instance, there is a large cooperative that sells seeds to processor Mali Biocarburant from an estimated 3300–5400 ha involving more than 4000 farmer members. Ultimately, this cooperative wants to cover 25,000 ha by 2030, mainly by foresting savannah land with jatropha. The Malian ventures in this segment tend to conduct agronomic research on own fields alongside promoting jatropha and collecting seeds from outgrowers.

Some of the plans outlined by these firms seem a tall order, although the initial investment requirements of this business model are generally lower than those of centralized plantations. However, in this business model too, the economic feasibility depends on fast upscaling. In the outgrower model, upscaling crucially depends on the extent to which *existing* jatropha stock can be utilized. Winning over thousands of small farmers to engage in planting the crop, and then waiting for results to come, takes a huge amount of time and effort. Fast upscaling with existing hedge stock has proven possible in some regions of Tanzania but our survey in Mali did not shed clear light on the extent of existence of mature jatropha in that country, although older studies—for example Henning [17]—already referred to widespread use of the shrub as an effective windbreak. At the same time, our survey results indicate that the projects in Mali have also involved a lot of new jatropha planting.

3.3.3. Small-Scale Processors

The smallest scale segment of outgrower projects is made up of activities that are either still in an early phase of establishment but with strong growth ambitions, or ventures that were conceived to remain small local projects. Among the former are two young Malian companies and the single

Mozambican outgrower project. In addition, in this league is an experimental project financed by the Dutch Fair Trade movement (Ta_Pr3) which started with limited initial agronomic experiments.

Examples of the second category are two religious communities in Tanzania that cultivated a few ha jatropha for own use. These projects have performed poorly, mainly because of unsuitable climatic conditions. One of them (Ta_Pr7) in fact ceased soon after our survey. The other is still continuing, mainly because it is a useful part of the curriculum of a local vocational school. Another Tanzanian project in this category was designed as a small-scale income-earning activity for women (Ta_Pr5). This activity is in fact the only project in our survey that had made any profit. It made medicinal soap from SVO from manually pressed jatropha seeds. The process is labor intensive, but labor is cheap in rural Tanzania. This model is not amenable to upscaling due to the limited local market for relatively expensive jatropha soap and the arduous nature of manual pressing. There may be some room for similar localized projects in different areas but they are likely to remain small.

Even the biggest and most advanced processors are still quite some distance away from "good practice". The oil conversion efficiency percentages quoted by respondents are illustrative of their problems. Some quoted percentages of 27% and 33%, but there is no doubt that these figures come from unreliable (mostly) Indian websites, not from their own experience. The valid answers appear to be around 20%–25% (depending on the efficiency of press technology, and whether or not SVO filtering is taken into account). The 24% reported by the largest Tanzanian processor should be considered as a good benchmark for mechanically pressed SVO filtered to 1 micron. This statistic is based on regular measurements. Only a few companies in our survey had set up performance monitoring and feedback systems that could give them key insights into the important factors underlying their performance.

4. Social Analysis

In the format for project managers, several questions were asked that concern social issues on five topics; food security, local prosperity, working and labor conditions, land rights and gender. In Tanzania, seven project managers provided relevant information, of which five in detail (Ta_Pr4 and Ta_Pr6 which did not provide much information either had no employees or were still too small). In both Mali and Mozambique five project managers provided detailed information on social aspects, and in Mozambique several workers were interviewed on this topic as well.

4.1. Food Security

4.1.1. Tanzania

Among the five project managers who provided details on social issues, the general feeling was that the projects contributed to increased food security in the region. One manager (Ta_Pr1) could not furnish proof of effect, but stated that the amount of land for food crops was not diminished because its outgrowers cultivated jatropha solely in hedges. Nor was there any known effect on food prices. The income earned from the seed sales by its outgrowers was sometimes used for household expenses, including food items, and for school fees.

One project was specifically designed to increase food crop yields along with the introduction of jatropha (Ta_Pr3) through an integrated approach. By intercropping food crops with leguminous plants, more nutrients (especially nitrogen) were added to the soil. Furthermore, better agricultural practices for food crop production were introduced (including provision of better planting material), and seedcake from jatropha was used as fertilizer. In this way the food crop yield per ha was increased, even though jatropha was added as an extra crop—leading to a diminished amount of land for food production. (Information obtained from A. van Peer, agronomic advisor to the project.)

The other three project managers also mentioned the additional income that was generated by selling jatropha and used for food purchases, or subsidies that were provided to farmers for their agricultural activities. None of the Tanzanian managers mentioned having noticed any deterioration in food security. Most likely this is related to the dominance of jatropha hedge arrangements in that country.

4.1.2. Mali

Four project managers provided information about food security. Two of them indicated that their project had made positive contributions to the food security situation in the country by providing agricultural inputs and diversifying revenues for farmers. Three out of four pointed to an increase in yield of food crops due to increased use of fertilizers.

However, there is reason to believe that food security impacts from Malian jatropha projects have not been universally positive. Food insecurity is an important issue in Mali. Seven outgrowers in our survey indicated they did not have enough food to provide for themselves for several months in the year. In addition, others indicated they had did not produce enough food themselves but had to buy food several months in the year. Furthermore, nine respondents indicated they didn't have enough variety in their diet. This is indicative of the generally precarious local food security situation. Coupling these observations with the previously mentioned prevalence of jatropha yield complaints among the Malian smallholders, it can be concluded that the widespread promotion of jatropha on food crop lands in that country has entailed real food security risks. The same cannot be said for Tanzania and Mozambique.

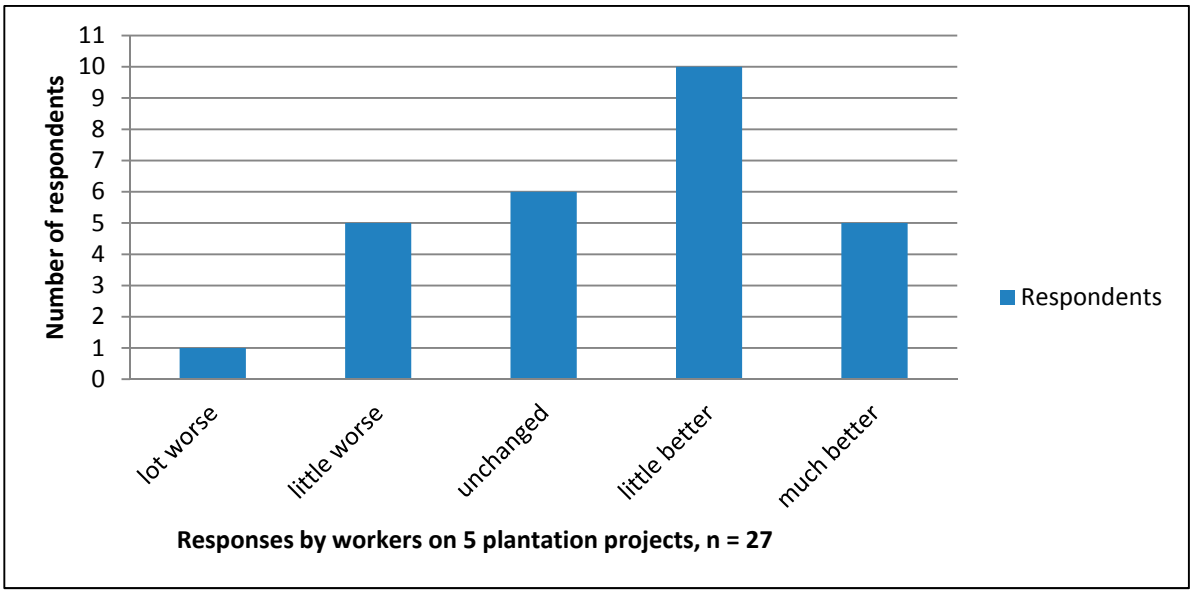
4.1.3. Mozambique

Five Mozambique project managers provided information on food security, and additional information was obtained from 27 plantation workers working at the five different projects. All project managers except one indicated that they have a positively impact on food security. This is done either by providing salaries so that the employees can hire people to work on their farms, by installing water wells, by preparing (ploughing and clearing) land for communities, by intercropping with food crops or by providing training.

The plantation workers were asked to compare the share of food expenditure in the household before and after the start of the plantation. The results show varied responses: in three projects the share spent on food had apparently reduced significantly (from 50%–70% to 30%–45%). In one project the share had remained more or less the same, whereas it had increased in the one remaining project (from 60% to 70%). An increased need to buy food from external sources rather than through self-production *can* be indicative of food security problems, but this is not necessarily the

case. It can also signal a reduction in time available for own food production due to finding paid employment on a plantation. In such cases, higher cash income can enable relatively more food to be procured from the market, or it may allow the plantation employee to hire someone else to cultivate his/her food plot. Indeed, the plantation workers indicated that the average amount of time devoted to own food production had dropped significantly after they started to work on the plantation, from 20–25 h/week to 4–14 h/week (in only one project the amount of time stayed the same at 33 h/week). The question is whether the higher cash income would on balance lead to higher or lower food security. The respondents were therefore also asked directly about their own perception about a link between the start of the jatropha project and impact on food security (Figure 2).

Figure 2. Perception of plantation workers about food security after arrival of jatropha project.



The aggregated responses from the workers on the five projects (see Figure 2) signal that they perceived a somewhat positive trend in their food security situation in average. However, these results hide variations across the projects. The results for Mo_Pl6 indicate divided opinions, and the perceptions about Mo_Pl1 were overall negative.

On all plantations except Mo_Pl1, the workers indicated problems with competition for their labor time and energy since they started work on the plantation. Even though they indicated that the reduced time spent on own food production was in almost all cases compensated by their salary, which was then used to pay others to work on their land for them, this did not seem to be the desired option. Workers evidently preferred to carry on with self-provisioning alongside their wage job, even to the point where, according to their own statements, they experienced difficulties in combining the two. This problem seems related to the general poverty level (*i.e.*, people wanting to use their cash income to buy goods and services other than foodstuffs). It cannot be solely attributed to the arrival of the plantations as such. Despite the large sizes of the plantations, reduced land availability for local food cultivation did not emerge as constraints except for the workers in Mo_Pl4.

4.2. Local Prosperity

The jatropha projects in our survey had generated more than 600 permanent-contract jobs and 1000 temporary jobs in total (Table 6).

Table 6. Employment created by the jatropha projects (excluding employment of outgrowers).

No	Project	Permanent Jobs	Temporary Jobs
1	Ta_Pr1	20	300
2	Ta_Pr3	1	20
3	Ta_Pr9	10	200
4	Ta_Pr2	4	0
5	Ta_Pr6	x	x
6	Ta_Pr5	2	2
7	Ta_Pr4	n/a	n/a
8	Ta_Pr7	n/a	n/a
9	Ta_Pr10	2 (30 [a])	0
10	Ta_Pr8	0	7
	Tanzania TOTAL	**37**	**537**
1	Ma_Pr1	32	200
2	MA_Pr2	33	15
3	MA_Pr3	x	x
4	MA_Pr5	40	0
5	MA_Pr4	x	x
6	Ma_Pr6	x	x
7	Ma_Pr7	x	x
	Mali TOTAL	**105**	**215**
1	Mo_Pl 1	55	150
2	Mo_Pl 2	12	0
3	Mo_Pl 3	230	50
4	Mo_Pl 4	80	0
5	Mo_Pl 5	45	33
6	Mo_Pl 6	120	50
	Mozambique TOTAL	**509**	**283**
	OVERALL TOTAL	**684**	**1029**

[a]: 30 permanent jobs before project closure, reduced to 2 after closure. x: no data provided in the questionnaire, n/a: not applicable, the two outgrowers only have jatropha as additional crop and did not employ any additional people.

Most of the permanent-contract jobs had been created in Mozambique (>500), while most of the temporary jobs had been created in Tanzania (537). This might be due to the dominance of salaried wage work on large plantations which were the dominant business model in Mozambique, while the smallholder-based models in Tanzania provide more seasonal work especially during the harvest period. The lowest number of jobs had been created in Mali. Only smallholder-based models were practiced there. In Tanzania, there were a few small-scale plantation projects in addition to outgrower projects (such as Ta_Pr4), which however did not generate much employment. Temporary jobs were typically for 6 months, during harvest (Ta_Pr1 and Ta_Pr9 in Tanzania).

4.2.1. Mozambique

In Mozambique we were able to obtain more detailed information on the skill level of the jobs generated in the plantations, and the numbers of jobs created in relation to the surface area that the companies operated at the time of survey. We can also get insight into the total investment requirements per job created in four out of five plantation projects (Table 7).

Table 7. Employment intensity of the Mozambican plantation projects per unit of surface area and total investment, and total jobs created by skill level.

Project	Starting Year	Jobs	Ha	Jobs/ha	Total Investment Costs (US$) [a]	Inv Costs/Worker (US$)	Skilled	Unskilled
Mo_Pl 1	2009	205	200	1.03	$2,000,000	$976	1	204
Mo_Pl2	2007	280	1500	0.19	$5,000,000	$17,857	10	270
Mo_Pl3	2007	80	2311	0.03	$12,000,000	$150,000	11	69
Mo_Pl4	2010	45	165	0.27	Not given	Not given	12	33
Mo_Pl5	~2010	170	240	0.71	$4,800,000	$28,235	80	90

[a]: data from Table 2.

The jobs created per hectare vary widely, ranging from 0.03 up to 1.03. In general one would expect older projects to employ more workers in total than more recent ones, but this is only true for Mo_Pl2. The plantations also differ remarkably in terms of their capital intensity. Mo_Pl1 employed far more workers per US$ investment than the other projects. With an amount of US$ 150,000 investment per worker, Mo_Pl3 is by far the most capital-intensive plantation project in our survey. It is more than 5 times more capital intensive than MoPl5, more than 8 times more than MoPl2, and 154 times more than Mo_Pl1. Mo_Pl3 also employs the fewest workers per unit of plantation area. This firm seems to have adopted a singularly capital intensive production model for a country with abundant labor in need of jobs. Thus, while one can say that the plantation projects are generally capital- and land-intensive, this observation does not hold to the same extent for all.

The data about skilled *versus* unskilled jobs created show that the majority of the jobs at jatropha projects are unskilled. However, the companies do differ in terms of the shares of permanent and temporary jobs created (Table 6). For example, the most labor-intensive plantation Mo_PL1 employed relatively more temporary workers, while the highly capital intensive Mo_Pl3 employed relatively more permanent workers. While creation of work on permanent contracts is preferable over temporary work from a social security point of view, there is also much to be said in favor of a more labor-intensive business model that involves a lot of temporary job creation in a country with extensive rural poverty. However, the managers indicate that labor costs and management of a large labor force are important issues for the projects.

According to the managers, all monthly wages at the projects in Mozambique were equal to or higher than the legal minimum wage in the agricultural sector, which is around 65 US$/month. With 130 US$/month, the single outgrower project in Mozambique stands out from the plantations in this respect, as it mostly employed extension workers with skilled higher paid jobs, but the downside of this project is that the total number of jobs created is only 12. The differences among the other projects

(ranging from 65–80 US$/month, according to the managers) are likely to stem from regional differences in income levels, comparable to local minimum agricultural sector wages.

To assess remuneration, the managers say that project contributions to education, health care and infrastructure are also significant. This can only be expressed in material contributions, the precise value of which could not be determined. In addition, it was impossible to assess accurately how much the projects contribute towards education, health and infrastructure in relation to the total of such investments made in their region, e.g., by government. Still, some qualitative information given by the Mozambican project managers and other local project stakeholders is informative (Table 8).

Table 8. Managers' claims and local stakeholders views on project contributions to education, health care and infrastructure.

Project	Contribution towards Education, Health and Infrastructure
Mo_Pl1	Plans to build a new hospital/maternity center, new school and football field; although none realized according to community leader.
Mo_Pl2	Constructed over 70 km of roads and bridges, renovated a hospital and created a football team. Plans to build a school, police station, medical clinic and new houses; not (yet) realized according to the community.
Mo_Pl3	Restored a police station, fixed a medical clinic and built a community office and a school, also provided water through piping. Plans to build a church, not (yet) realized.
Mo_Pl4	Purchased 20 computers for a local school.
Mo_Pl5	Built a hospital and a water pump to provide the community with water, sprayed the village against mosquitoes and created a football team. Uncertain plans to build a school.
Mo_O1	Helped build a bathroom in a local school, educated teachers who can teach at local schools. the company extension workers trained outgrowers on the cultivation of jatropha and food crops. The provision of supplies for jatropha cultivation had not been followed up on in every case.

Most project managers claimed that their project contributed to social causes and physical infrastructure in various ways, but Table 8 also shows that other local stakeholders indicated many instances where plans had ended up being postponed, or not executed at all. This could be related to the severe difficulties that were being experienced in getting the "business case" of the projects on track.

4.2.2. Tanzania and Mali

The wage employment in the projects in Tanzania and Mali is significantly more modest than in the Mozambican plantations. The workforce in the largest Tanzanian company consists of 20 persons, and the more substantial effects from its operations lie in creating income for tens of thousands of smallholders on a seasonal basis. The money earned by them is reportedly used mainly for paying school fees and household expenses. No significant information was generated through the survey about wages and secondary benefits by the projects in Mali. The projects tend to be small, and revolve around outgrowers or cooperative members without any hired workforce.

4.3. Working Conditions

The project managers provided information about the normal number of hours worked per day (between 5–10 h) and the maximum (up to 13 h), the average number of days worked per year (140–300 h), and the total number of leave days per year (12–30 days). The reported hours are rather similar in the various projects and countries. In Mozambique, the maximum number of hours reported was somewhat lower than for the other countries. In Tanzania, there is one outlier (Ta_Pr3); however, this respondent referred to his own working hours as an owner/manager, rather than the hours of a hired employee (see Supplementary II for details).

4.3.1. Secondary Benefits

According to the project managers, quite a number of their employees were offered secondary benefits such as on-the-job training, education for staff or their children, meals, health care, contribution to social services such as to a national pension fund, transport and safety gear. There is a difference, however, between permanent staff and temporary staff, the latter being provided with less benefits.

4.3.2. Other Important Aspects

According to the interviewed plantation managers in Mozambique there had been no incidences of forced labor, child labor or discrimination. They claimed that all work was done according to Mozambican law and workers were content with their job at jatropha projects that offers them financial security and an occupation. No accidents were reported and membership of a labor union was permitted in all cases (one case had no union available).

In sum, according to the managers the working conditions at the Mozambican projects are good, but it has to be said that we were not able to verify the conditions independently from the side of employees in the absence of their managers.

4.4. Land Ownership and Land Rights

Arrangements for land rights transfers and land access are often problematic in Africa [1,14]. Vulnerable groups such as women and elderly and secondary land users can experience reduced land access due to increased claims on land due to biofuel projects and other types of large land-using activities. This has happened for example in Mali [18] and Tanzania [19].

4.4.1. Mozambique

The Mozambican project managers claimed that the land acquisition for plantations had gone according to the Mozambican legal procedures to obtain a DUAT. This had happened in consultation with the local authorities and communities to come to an agreement. The respondents did not indicate major difficulties with land rights acquisition in Mozambique (see Supplementary III for details). There was, however, a minor conflict with the relocation of four families and the payment thereof. In another case, the local community said to be disadvantaged by the arrival and subsequent

departure of a jatropha project owing to the loss of their land as well as their jobs/wages after project discontinuation.

The managers' responses about changes in land access do not suggest big changes to secondary land users either (see Supplementary IV). From the perspective of our respondents it appeared as if this was not a key issue of the land acquisition process. This may explain the cursory responses we obtained, but this could also be an indication of issues which they did not wish to discuss. For most projects, land access for secondary land users was said to have remained unchanged, but these answers could not be confirmed from secondary land users themselves and cannot be taken at face value. There are many reports of ever more land enclosures in various African countries for purposes of tourism (national park creation), large scale cash crop production by big investors, and biofuels cultivation, that are indeed leading to the disruption of traditional trekking routes of itinerant people and animals, upsetting the nomadic way of life and migrations of wild animals.

The survey results about land compensation show there is a broad array of things that project managers consider under the rubric of compensation, ranging from financial payment to material and physical compensation; and sometimes community development activities and even job creation by a project. Evidently, this state of affairs and the lack of rules or their enforcement leaves a lot of room to make "convenient" arrangements from the perspective of investors. In only one case, the project management took a more astute view: there had been no land compensation—services to the community and job creation could not be considered as such (see Supplementary V).

4.4.2. Tanzania

The dominant business model of Tanzanian projects at the time of the survey was based on outgrower-processor combinations. Ta_Pr1, Ta_Pr3, Ta_Pr5 and Ta_Pr6 all worked exclusively with smallholder-outgrowers which did not involve any transfer of land rights or changes in land access, according to the interviews with both parties. Ta_Pr1 estimated that it sourced more than 95% of seeds from decades' old hedge stock. The tiny demonstration plot of Ta_Pr2 was only rented for five years. Ta_Pr9 (300 ha) and Ta_Pr4 (24 ha) held private title deeds that were unchallenged based on the information we obtained. These lands had been under private ownership and were not publicly accessible even before the advent of jatropha cultivation. The 3 ha jatropha plot of Ta_Pr7 belonged to a long-settled religious order and was most likely also privately owned. Disruption of land access to smallholders and secondary land users from the Tanzanian projects in our survey can be assumed to be incidental at most.

However, there have been severe long-term land access consequences from Tanzanian large plantation projects that had failed and closed down before our survey took place, similar to the project closure case reported above in Mozambique. The projects' discontinuation has given rise to big social issues because land rights that were transferred when the projects began were not remitted to villagers [1]. In the case of Sun Biofuels, the workers from the local communities were almost all laid off without compensation, and the company has been in limbo (although not officially bankrupt) ever since. The workers have regained only partial access to ancient gravesites and water points, and this happened only after major protests, press coverage and NGO pressure. These are sites from which they had been cut off when the plantation was in development (see [20], for a detailed account).

4.4.3. Mali

In Mali, all business models are based on outgrowers which did not involve any land rights transfers, according to the interviews with both project staff and outgrowers. In the case of Ma_Pr1; the farmers are owners of the land on which they operate. A precondition for becoming an outgrower for Ma_Pr5 is even that land has to belong to the farmer who will produce. According to Ma_Pr4, the project was still at the beginning so they could not make statements about land rights transactions, but there were no land access problems encountered within the project zone. In Ma_Pr2, no land rights were transferred either. However, the Ma_Pr6 respondent expressed worries about potential conflicts with pastoral land users. Most likely this comment refers to the conversion of savannah land into jatropha fields by the members of one project.

4.5. Gender

The project managers provided information on the number of women they employed in high-skilled jobs such as managerial, marketing, accounting, agronomic or technical posts (Table 9). While a more complete picture would be provided if the women themselves had been interviewed, the managers' responses provide a glimpse of some of the ways the projects interacted with gender relations.

In total, 51 women were reportedly employed in highly skilled positions, but the percentage-wise female–male distribution of high skilled jobs could not be established. In Mozambique the total number of female employees in high skilled jobs seemed relatively low, although there are too little data to draw firm conclusions. In Tanzania the percentage of women in high skilled jobs is comparatively high. Almost none of the projects provided special services to women employees, only Mo_Pl2 in Mozambique provided hospital transport during birth. On the other hand, almost all project respondents opined that their project did not have any negative gender impacts either. In the questionnaires there was also room to elaborate in a qualitative manner on gender impacts by the projects; the responses are described per country below.

4.5.1. Tanzania

Three projects in Tanzania provided some information on effects which they considered to be beneficial for women specifically. One project (Ta_Pr1) helped women to obtain access to a good energy source for cooking through the sale of jatropha seedcake pellets and cooking stoves and also through the sales of (unpelletized) seedcake. At another project (Ta_Pr3) it was observed that in the Kilimanjaro region traditionally men tend to have more power in decision making but things seem to change now that people have seen women work in the project. A similar positive impact was observed by the manager of Ta_Pr9, where it was even stated positively that "gender issues have changed due to the project". "Initially women did not touch machines because they perceived it as men's work, but now women do everything and thus there is more equality between men and women". It was also noted that in company meetings nowadays things are discussed together, whereas before women would stay aside.

Table 9. Number of women employed in high skill jobs.

Project	Number of Women in High Skilled Jobs	Total Number of High Skilled Jobs	Remarks
Ta_Pr1	2	4	
Ta_Pr3	0	1	Currently 1 job only, women will be considered if there are job opportunities
TA_Pr9	1	No data provided	
Ta_Pr2	1	1	
Ta_Pr5	2	2	
Tanzania Total	**6**	**8**	
Ma_Pr1	3	No data provided	
Ma_Pr5	0	No data provided	
Ma_Pr4	10	No data provided	
Ma_Pr2	30	No data provided	
Ma_Pr6	0	No data provided	Project employs women but not in high skilled positions
Mali Total	**43**	No data provided	
Mo_Pl1	0	1	Project employs women but not in high skilled positions
Mo_Pl3	2	10	At nursery and HR
Mozambique Total	**2**	**11**	
OVERALL Total	**51**	**Insufficient data**	

The same changes were noted in the Ta_Pr9 "borehole and milk project" in relation to water: boreholes operated by Ta_Pr9 had become accessible to everyone rather than solely to men. Women formerly had to ask for permission to fetch water; now they no longer depended on men for their water supply. Before, men had been owners of cows and women the owners of the milk, and milk did not have much of an economic value. However, as a result of the project, women could now sell their milk commercially and earn income, which made men and women more equal. In addition, as women had money, they also gained decision power over it. On a negative note, men sometimes felt that women wanted to overpower them. Especially in Maasai culture, women are not allowed to come into close contact with men, or to compete with them.

Positive effects had been observed at Ta_Pr5 as well. It was said that more women had become empowered and were now aware of their rights, e.g., regarding land ownership and inheritance issues. Women were reported to earn more income nowadays and to have become more independent. An increased participation of women in decision making was also observed, again through the power of earning income.

In Ta_Pr2 gender issues were currently not considered separately, but in the future the project indicated it might work with micro financing and other options. Through training, an increased participation in decision making in the family had emerged. A negative observation was that generally, once women earned money from jatropha cultivation, they were obliged to pass the earnings to the men. The two remaining projects Ta_Pr6 and Ta_Pr4 did not provide relevant information.

4.5.2. Mali

In Mali similar observations were noted, although the changes observed are less profound. Ma_Pr4 for example, is still in its first year. According to the respondent, the women were slowly becoming more empowered through economic advancement which the project promotes, but it seemed too early for definite statements. In addition, the manager of Ma_Pr2 observed a positive influence on women's empowerment and reports to facilitate this process with its project activities. Ma_Pr1 increased local energy access by making jatropha oil available. The respondent in Ma_Pr6 acknowledged the financial empowerment of women but questioned the strategic importance of their own project contributions, recognizing that other development activities would also contribute. This respondent also made more critical observations. Potential conflicts with pastoral land use and the management of income were seen as challenging. Men had also entered a traditional women's activity, the collecting of jatropha seeds for soap making. At Ma_Pr5, no change in gender issues was observed.

4.5.3. Mozambique

In Mozambique a major difference was observed in the management of two projects, because before the advent of the projects women were not even allowed to work for an employer (it was considered very uncommon/unusual). Both these projects (Mo_Pl1 and Mo_Pl2) now do employ women. The Mo_Pl1 manager stressed that the project wants women to work and to have a voice, since women only worked on their own plots before. Mo_Pl2 also noted the positive impact of employing women. The project also employed women in high skilled jobs: one woman was second in charge at the nursery under the nursery foreman, and there was one woman in Human Resources. This project also provided hospital transport when women were due to give birth. However, the management of the three other plantation projects indicated that they felt their project did not influence gender issues. Although the sample is small, the impression conveyed is that attitudes of management matters for gender management and gender impact achievement.

5. Discussion

The research set out with expectations that an extensive survey of jatropha activities in three different African countries, using clearly structured, standardized questionnaires would yield a wealth of information that would lend itself to some degree of quantitative cross-project analysis. This expectation could be materialized only in part, due to a variety of reasons. The information needed for this kind of analysis is inevitably detailed, and it proved hard for many respondents to supply all that was asked for. In this respect, there were evident trade-offs between data quality and quantity, which imposed some limitations on the extent of information that could be gathered in the end. For instance, in a situation in which the majority of smallholder respondents were found to struggle hard to come up with reasonable estimates of the yields of their jatropha trees, it proved sheer impossible to obtain additional information from them about other crops that the jatropha might be intercropped with. Other practical problems encountered included miscommunications between interviewers and respondents and between questionnaire designers and interviewers due to barriers of language and differences in professional background, despite great care and efforts to avoid and overcome these problems through

iterative questionnaire design and extensive interviewer training. Inevitably, there were also trust issues among respondents, especially when financial details were requested. The survey instrument also could not facilitate an objective assessment of the social and environmental impact assessment of the large plantations, whereas a more rigorous assessment of these aspects involving extensive fieldwork among other actors (such as local leaders, community members, family members of workers, farmers who don't grow jatropha *etc.*) was beyond the resources and the main purpose of the research project, *i.e.*, to carry out a performance and impact "quick scan" of projects funded by Dutch governmental biofuel programs, within a limited time span. It did not help that the company surveys proved to be much more time- and resource intensive than initially expected. In particular, drawing up sampling frames for the projects proved to be a daunting task in the absence of up to date company data bases. Verifying the existence of certain companies required veritable detective work, or personal visits to remote locations. Thus, the research was methodologically challenging in many respects. Hence, the results reported in the preceding sections should be taken as being broadly indicative of conditions and trends on the ground, not as precise estimations.

Efforts were made to make the data collection methodology as rigorous as possible within the limitations imposed by the conditions discussed above, following guidelines in [21,22]. The interviews were held face-to-face on the project locations and on the outgrower sites in all instances (in contrast to some other recent jatropha surveys such as [23]) with the intent to try to ensure that the reliability of the answers could be verified against the physical attributes of the local context, and that respondents' answers could be probed when they did not make sense to the interviewers. Several control questions were also inserted into the questionnaires as checks. Contradictory information received in different questions could not always be resolved; however, as in many cases it appeared as if the respondents themselves had an incomplete grip on their jatropha operations. This was especially notable with regard to financial issues, even in the case of the large plantations. The effects of the financial data collection problems for analysis were compounded by the fact that the sample projects from the three countries were highly heterogeneous in terms of project size, activities undertaken, and period of involvement with jatropha. This inhibited detailed statistical analysis of the projects' and outgrowers' financial situation.

Another area in which the survey results remain uncertain concerns the working conditions on the plantations. On the basis of the self-evaluation of the company managers and interviews with a limited number of employees in Mozambique, no unacceptable working conditions were reported. Possibly, legal and social sensitivity concerning labor conditions may have led to a bias towards socially more acceptable answers, but the survey could not analyze such bias. To confirm the quality of the labor conditions, an independent evaluation of the working conditions should be carried out, for example by interviewing employees in a safe and anonymous setting, but such an independent evaluation was beyond the resources and purpose of the study. Similar remarks can be made in connection with possible impacts on land access for local people caused by the plantations.

Finally, it is important to note that many of the jatropha projects had only been in operation for a limited time, and many had not even been fully implemented yet. This affects the extent of jobs created, seed yield, as well as the realizable oil sales and technical efficiency and valorization of by-products. Our questionnaires could only document actual impacts experienced up to early 2012.

On the whole, these do not look favorable, but the performance of all these parameters may improve if the projects would get a chance to reach full-scale implementation.

6. Conclusions and Recommendations

6.1. Economics

- The economic benefits of jatropha cultivation for biofuel purposes have remained disappointing for all parties involved, owing mainly to low and unreliable seed yields from a plant that has not yet been systematically and professionally bred, in combination with a sharp decline in international reference prices for fossil and palm oil since mid-2008. This has also driven down domestic fossil prices in the jatropha-producing countries, making jatropha uncompetitive as an alternative fuel.
- For smallholders, jatropha is by and large an unviable crop, except as a hedge plant in environmentally and economic disadvantaged areas where people do not have attractive alternative income earning opportunities for their land and labor. For the time being, jatropha hedges—possibly intercropped with other useful hedge species—are generally the only feasible and desirable option for small-scale jatropha outgrowers. Promotion of jatropha intercropping arrangements on cropland is generally not wise, except in specific instances where symbiotic relations can be obtained, as with vanilla [5]. This may change in the future when more reliable and better yielding varieties become available, or when fossil oil prices rise again. Given current plant breeding efforts, agronomic advances could come in a matter of years rather than decades, see e.g., [24,25], but it still remains an open question under what conditions smallholder farmers would be able to gain access to these (presumably patented) improved varieties, and whether resource-poor smallholders could furnish the kind of cultivation regime that these varieties would demand in order to flourish.
- For plantations, the current financial outlook is also poor: upfront investments are very high while returns are uncertain and slow to arrive. Large plantation establishments should not be encouraged until varieties with better yields and more reliability become available. When these conditions do improve, governments could guide investors so as to avoid overly capital-intensive operations, and maximize their employment creating potential. The fact that some companies in this research employed many more workers per unit of invested capital than others suggests that firms can indeed make choices in this respect.
- Regarding oil processors, the best performing ones had yet to reach their breakeven point. However, these firms were apparently vigorously pursuing economies of scale through increased sourcing volumes and they seemed to be making efforts to optimize their process efficiency and improve the valorization of by-products and waste products.
- These efforts are probably worth supporting for some years as they may lead to viable processor-outgrower business models in the longer run with benefits for many rural people. In this connection it is a pity that many western support organizations are now phasing out their support for jatropha in the belief that there is no scope for viable projects at all. That conclusion might be somewhat premature.

6.2. Social Aspects

- The interviews yielded insights into many social aspects from the perspective of jatropha project managers, but their answers on their own cannot be used for drawing definite conclusions. Additional information from a complementary survey among plantation workers therefore proved valuable. Insights from this survey showed that the food security dynamics in relation to large plantations were highly complex, almost warranting a separate survey on its own.
- Most plantation projects and some outgrower-processor projects did start out with plans to provide education, employment, training, and sometimes improved energy access and contributions to women's empowerment that would have had positive socio-economic impacts for employees and the local community if they would have been implemented. Many plans however had not (yet) materialized at the time of the survey. This appears to be related to the problematic financial situation of the projects.
- The worst social impacts are associated with projects that have discontinued: communities had been left worse off than before the projects arrived due to the permanent loss of land-based resources as well as their income from plantation employment. Such impacts appear irreversible.
- Due to the relatively limited area planted up so far, other socio-economic impacts have remained rather modest. Even so, more than 1700 (permanent and temporary) jobs had been created by the projects included in the survey, which is a very positive effect since most projects were located in poor rural areas with low opportunities for employment. The survey did not uncover evidence of projects paid below legal minimum wages or unacceptable working conditions. On the whole, there also seem to have been positive or neutral impacts on food security, although a more comprehensive study is required on this topic to reach more definite conclusions.
- Gender effects were generally positive and varied from practical benefits, such as improved energy access for cooking and lighting and some increased financial independence, more independent decision power and higher social status, to attitudinal changes that affect the acceptability of certain roles that women assume, or aspire to, in society. Special attention for, and sensitivity to women's needs, problems, capacities and aspirations in company strategy can make a difference.

6.3. Policy Recommendations

- Competition for labor resources in plantations settings appears to be a key issue. This may be an issue that requires attention mostly from plantation management, e.g., through introducing flexible working hours that permit workers to carry on self-provisioning work during daylight hours.
- The land problems encountered indicate the need for better oversight. Realistic, legally binding exit strategies should be made mandatory for large plantation projects as part of their official business plans. Effective governance in the actual implementation of these agreements is equally called for. The responsibility of monitoring of these arrangements should not be put solely on the shoulders of governments in sub-Saharan Africa, or local land rights NGOs. The responsibilities should be shared more widely, by local and western stakeholders alike. For instance, financial investors can demand CSR conditions from projects. A case can also be

made for supporting capacity building among local organizations so that they can take on part of this monitoring role.

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Author Contributions

Janske van Eijck was responsible for the overall coordination of the project, and designed the initial format for data collection. She managed the data collection by the local partner institutes in Mozambique and Mali, whereas Henny Romijn and Sanne Heijnen coordinated the data collection by the Tanzanian partner institute. Sanne Heijnen managed the field test, finalized the data collection format, and executed the data collection in Tanzania in collaboration with the local partner institute. Jouke Rom Colthoff executed the data collection in Mozambique in collaboration with the local partner institute, and analysed part of the data. Data analysis and manuscript drafting was performed by Henny Romijn (economic aspects, overall) and Janske van Eijck (social aspects), and Boris de Jong edited the manuscript.

Supplementary Materials

Supplementary materials can be accessed at: http://www.mdpi.com/2071-1050/6/9/6203/s1.

Conflicts of Interest

The authors declare no conflict of interest.

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