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Ministry of Economic Affairs

Sustainable Biomass

Jatropha sustainability assessment

>> Focus on energy and climate change

Colophon

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The Copernicus Institute, part of Utrecht University, aims to support the search for sustainable development and innovation through the development of knowledge, methods and instruments. The Institute has a strong track record in relation to bioenergy research and advice. This report is executed by the Energy & Resources section.

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Executive summary

This report is the result of a jatropha sustainability study that was commissioned by NL Agency as part of its renewable energy support programme titled "Netherlands Programmes for Sustainable Biomass" (NPSB). Staff from three Dutch universities with complementary expertise – UU/Copernicus Institute, WUR-PRI and TU/e - were requested to design a format for data gathering from jatropha projects funded by Dutch programmes - and possibly also by others - that would be comprehensive and yet practically applicable. The aim was to enable a uniform way of data collection about the projects' people-planet-profit sustainability performance and the key barriers experienced by them in achieving their envisaged goals. The designed format contains agronomic, economic, social and some ecological information, thus covering a broad set of sustainability performance dimensions. Separate modules were developed for (large) integrated plantation projects and oil processors on the one hand, and (small-scale) cultivators/outgrowers on the other. A separate module aimed at eliciting in-depth agronomic information about individual cultivation fields was also developed. The format was applied in three countries: Tanzania, Mali and Mozambique. In each country a local organization was subcontracted to execute the actual data collection. The ultimate goal of the exercise is to help increase sustainability and financial feasibility of jatropha projects that are currently being implemented, and at the same time disseminate lessons.

Agronomy
The results of the questionnaires give a good overview of seed yields of jatropha that are achieved in current practise, together with the management practices currently being used. Some bias may occur, however, as the information is based on memory and may be influenced by desired yield levels.

Seed yields were low and generally below 600 kg/ha or 0.7 kg/meter hedge. These low yields were partly because of the young age of trees but also because of limitation of growth by drought and reduction by pests and diseases. The jatropha trees were still quite young, and based on their age some yield increase can be expected in the near future. The amount of yield increase can be estimated from the technical development in Sub Saharan Africa and from comparison with cereals and other perennial crops. It is expected that seed yield for jatropha in Mali, Mozambique and Tanzania can double to 0.65 and 1.3 ton ha^{-1}. Yield may further be improved by genetic improvements, accompanied by good crop management to utilize the yield potential. For the countries in our study, a yield of about 3.5 ton ha^{-1} is to be expected if technology were to be implemented to similar degree as in Europe or North America.

Results of the questionnaires did not allow a quantitative analysis of the effects of specific crop management on seed yield as there were too many factors involved that all have an effect on seed yield. To study best management practices and their effects on seed yield, experiments would have to be carried out in which only one or a few aspects are varied, and where results can be verified objectively.

Economics
Large plantations need a lot of up-front capital to finance land clearing and land preparation. Realistic investment requirements are estimated to be US$ 4.8 and US$ 5 million, possibly more. This leads to extremely high per-ha costs in the initial years of operation (still as high as US$ 3,333 and US$ 5,193 in the two oldest projects that started in 2007). Per-ha costs should decrease to about US$ 1,000 - 1,200 per ha at full operational plantation size. Other factors contributing to an unfavourable cost/revenue situation in the early years include: the slow and unreliable maturation of the crop; oil pressing inefficiencies due to lack of scale economies; inadequate utilization of oil by-products; and competitive prices of the main substitutes for jatropha oil - fossil diesel and palm oil. The financial outlook of large plantations with current plant stock is poor. With an estimated yield of just over 1 t/ha and at the current SVO sales price of around US$1 per ton, the estimated Internal Rate of Return would be in the range of 15-17% and the payback period would be 12-14 years, which is not an attractive business proposition.

Hence, it is not surprising to find that some projects have decided to diversify into food crops; others are waiting for improved jatropha seed varieties to come onto the market. Some have discontinued operations altogether.

Until better plant varieties will become available, the value of jatropha for smallholders is limited to its use in environmentally and economically disadvantaged areas, where people do not have alternative income earning opportunities that are more attractive than jatropha. Even in those circumstances smallholders only value the crop in a hedge set up, because yields are currently too low and unreliable for it to be a viable field crop. The average income received from seed sales by jatropha hedge growers in the survey ranged between US$ 23.00 and US$ 0.48 per 100 metres of hedge.

The “business case” for processors who source from outgrowers also remains largely unproven, as most projects are still in an early stage of establishment and some distance removed from sufficient scale in their operations. At a cost of roughly US$ 1.20 per litre, jatropha oil is still expensive. But the most progressive firms are found to be making progress with efficiency improvements and improved by-product utilisation.

Efforts and ambitions to export to western markets have been abandoned. After 2008, these markets shrank as buyers scaled down their ambitions to source sustainably produced bioenergy. Companies now concentrate on local market development.

Social aspects
The general perception on the food security impacts caused by the jatropha projects is positive on the whole. Competition for land due to conversion for Jatropha cultivation does not emerge as a major concern except on one plantation. However, plantation workers face difficulties in managing increased demands on their labour time and energy arising from the combination of a plantation wage job and cultivation on their own food plot for self-provisioning.

The jatropha projects in our survey had generated in total more than 600 permanent jobs and 1000 temporary jobs. Plantations generate relatively more full-time work, while outgrower-based systems provide more part time seasonal work and incomes. Minimum wage legislation generally appears to have been respected for waged posts. Broader positive effects on rural and social development were also noted in several projects. Income, communal facilities and job creation are all positively influenced by the presence of jatropha projects. Income increased for people working at and with the projects, and regional unemployment rates have reportedly dropped in some cases. However, these effects are sensitive to the financial performance of the operations. Many promises for social development were made during initial land negotiations but in several cases plans have remained unimplemented.

Our survey did not reveal unacceptable working conditions in the projects. However, the poignant work problems lie elsewhere: with the insecurity associated with seasonal employment, and with the threat of projects pulling out without a proper exit strategy for the workforce (as has happened in Tanzania already). This can leave workers worse off than before the introduction of the plantation when they cannot take up their old ways of life again due to permanent loss of key resources such as access to land and water.

The arrival of large plantations clearly has not led to massive forced human displacements, but it has given rise to incidental land rights problems. This has happened even where formal legal procedures appear to have been followed in the land acquisition process. The institutional governance framework in the three countries appears to be too weak to prevent such adverse consequences. The survey also unearthed evidence of inadequate and fuzzy in-kind land compensation arrangements, some of which did not seem to have reached beyond vague verbal promises. Large plantation investors have major responsibilities to behave ethically, and improved oversight is needed. Smallholder-based systems generally do not give rise to land issues, as no land transfers occur.

The jatropha projects in the survey are reporting positive gender effects, and these effects occur in the different business models. Effects are practical benefits, such as improved energy access for cooking and lighting; increased financial independence, more independent decision power and higher social status; attitudinal changes that affect the acceptability of certain roles that women assume, or aspire to, in society.

Environment
Land use changes have occurred with growing jatropha, but in none of the three countries it seemed to have involved much more than a few thousand hectares so far, due to delayed implementation of many projects and outright abandonment of others.

The respondents themselves are positive about the effects of land use change, and hardly see any negative impacts. However, one notable finding is that the converted agricultural land in Mali appears to have been predominantly land under fallow. This is not a positive development, because land use systems that rely predominantly on natural means of soil regeneration - as is the case here - do need to maintain regular fallow in order to avoid structural soil quality decline. The conversion of large swathes of savannah land in Mali could also have ecological consequences. Some conversion of highly bio-diverse forest and woodland also occurred. Projects will not be naturally attracted to the kinds of the harsh, infertile environments that have so widely been touted as the ideal sites for cultivating jatropha.

1 Introduction

A large number of jatropha (*Jatropha curcas* L.) projects have been implemented in various countries to develop a viable bioenergy cropping system, based on the understanding that the tropical woody perennial tree or shrub species may survive in harsh climate and soil conditions. More than 12 jatropha projects are currently being funded under the Netherlands Programmes for Sustainable Biomass (NPSB) coordinated by NL Agency (http://www.agentschapnl.nl/en/programmas-regelingen/sustainable-biomass) and the Daey Ouwens fund (http://www.agentschapnl.nl/en/programmas-regelingen/projects-daey-ouwens-fund). These projects operate on different scales and have varying objectives, and there is insufficient knowledge about some of the agronomic, socio-economic and technical aspects of the jatropha value chain and their implications for the sustainable livelihoods of local communities.

This caused NL Agency to commission a Jatropha Assessment to UU/Copernicus, WUR/PRI and TU/e that was finalized in January 2011, (Van Eijck et al., 2010). That assessment encompassed a review of existing jatropha studies worldwide. In this assessment, which covered several hundreds of publications, three main issues were identified:

- The first problem with jatropha is that no comparable results are obtained from the different projects since there are no standardized methods. This problem concerns cultivation of the crop (density, hedges, rows, mixed systems, impact of inputs on yield), knowledge of environmental factors that influence the growth and production (soil, rainfall, temperature, etc.), and the way in which growth and production is being measured (fresh weight versus dry weight, filtered versus unfiltered oil, and so on).
- A second problem is the lack of knowledge about the business case, what are the key factors that affect the economic feasibility of jatropha production, and which business models are most promising in economic terms.
- And the third problem is the lack of knowledge on major social aspects (working conditions, food security impacts, implications for access to land and complementary resources, gender issues, etc.).

In order to resolve these issues NL Agency requested the three above-mentioned universities to compile a format for data gathering that would be comprehensive and yet still practically applicable, to enable a uniform way of data collection at the jatropha projects that are funded by Dutch programmes, and possibly also by others. This report is the result of the application of that format in three countries: Tanzania, Mali and Mozambique, with the help of local organisations. More than 70 sustainability aspects, linked to agronomic, economic, social and some ecological issues have been covered and analysed, aiming for a better understanding of the projects and enabling the extraction of lessons and dissemination of recommendations.

Chapter 2 contains the methodology that was adopted. In Chapter 3 introductory background information is provided about the projects and countries that were included in this research. Chapters 4-7 contain the analysis of agronomic, economic, social and environmental aspects respectively. Chapter 8 contains the conclusions and recommendations.

2 Methodology

2.1 Format design and test

This analysis started with the compilation of a jatropha data collection format in the form of a set of standardised questionnaires. Two different modules were initially developed: (1) one was directed specifically at jatropha "projects", i.e. managers of integrated plantation companies, and of seed processing activities working with independent outgrower farmers; (2) a second –shorter- module contained a series of questions for (small-scale) cultivators (outgrowers) themselves. The questions in both modules are classified under five main subject headings:

- General
- Agronomy
- Economics
- Social issues
- Environment/ecology

The questions in these two questionnaire modules were reviewed by experts from different disciplines and backgrounds in order to ensure validity and obtain a support base for its application. A discussion meeting was convened where the following experts commented on the draft questionnaires:

- Ab van Peer (jatropha agronomist)
- Wouter Achten (Leuven university)
- Bie Gielen (Leuven university)
- Piet van der Linden (Quinvita)
- Maja Slingerland (Wageningen University)

In addition, Flemming Nielsen (Banana Hill) reviewed the questionnaires by e-mail.

Following this process, a third specialised agronomic module was developed, to be able to obtain more reliable in-depth information about one individual field on each central plantation. This field was chosen according to its broad representativeness for the project's cultivation operations as a whole, by the management. This module was also administered to the managers of seed processors who were sourcing from outgrowers when these firms also had a demonstration plot or some plantation cultivation of their own.

The format was then field tested in detail by means of a three-day personal consultation with the manager and employees of one sizeable project and a handful of its associated outgrowers in Tanzania, by an expert from the TU/e together with staff from the local partner institute. Several changes were made after this, mainly to ensure easier comprehension by respondents and earlier administration by the interviewers.

2.2 Data collection

In all three countries, local partners assisted in the data collection. Furthermore, in Tanzania and Mozambique representatives from Eindhoven University of

Technology and Utrecht University respectively, assisted and coordinated the data collection and trained the interviewers. The three local partner organisations are:

- Tanzania
  - NM-AIST (Nelson Mandela African Institute of Science and Technology)
- Mali
  - ANADEB (National Agency for the Development of biofuels)
- Mozambique
  - IIAM (National Institute of Agronomic Research)

In Tanzania, the project was led by dr. Karoli Njau from NM-AIST. Before embarking on the actual data collection, the NM-AIST staff aided by experts from the TU/e first embarked on an investigation to identify - as much as possible - the currently operating and defunct jatropha projects in the country, as there is no biofuel monitoring agency of any kind in Tanzania. The results of this inventory showed a remarkably high rate of project failure in recent years especially among large plantations, which was informative in itself. Actual data collection from the identified operating projects was handled by two interviewers, who were recruited, trained and appointed especially for this task by NM-AIST. An assistant professor from NMAIST, Francis Moyo, helped to establish contacts with the identified projects and supported the team. Data collection took place during March-August 2012, and involved extensive travel to several different regions. The interviewers were trained and supervised by Sanne Heijnen (TU/e) during the first portion of the fieldwork. She also coordinated the initial field testing. Special attention was paid to reliability of replies and whether information about actual achieved dry seed yield was given.

In Mozambique the data collection relied on a comprehensive project inventory conducted by the coordinator from Utrecht University J.A.J. van Eijck in Mozambique in the year preceding the survey. It was found that jatropha activities in that country are almost completely in the form of large plantations. Data were subsequently collected by a representative of IIAM together with Jouke Rom Colthoff (UU) in April- May 2012. The representative of IIAM focused on the agronomic questions and also translated the responses, whilst Rom Colthoff concentrated on the other aspects. Compiling good data about the "business case" of the large plantations was challenging.

In Mali the data collection was undertaken by a consultant who was hired by ANADEB. The questionnaires were first translated into French, the interviews were then conducted in French, and the results translated back into English afterwards. During the research there was no presence of a Dutch research representative due to the difficult political situation at the time, this impeded the understanding of some of the answers reported by the consultant. The interviews were conducted in September 2012 at different locations in the regions of Kayes, Koulikoro, Sikasso, and Ségou.

The use of standardised questionnaires for data collection had two main advantages: (a) ability to reach a high number of projects and outgrowers with limited time input of researchers, and (b) yielding standardised information on many issues, that could thus be compared across projects and outgrower activities. The amount of data collected and its quality varied to some extent, depending on the willingness of farmers and project managers to spend time to answer all the questions, and on the level of literacy and general understanding of the respondents. The questionnaires were large. This was inevitable, arising from the requirement to get a good grip on a comprehensive range of sustainability issues. Therefore, much attention was paid to training of interviewers to secure a good understanding on their part about the questions, and the reasons why these questions were asked in particular way. They were also coached to stimulate respondents to answer all questions if possible. Consistency in the respondents' answers was checked by comparing their responses to different questions in relation to each other. There were several built-in possibilities for such checks, especially in relation to seed yield. This was done during the fieldwork itself, and again later during the data analysis by comparing the data findings with literature values for plausible ranges.

It has to be said that collection of good-quality quantitative data through structured questionnaires is always methodologically challenging (Iiyama et al. (2012). Therefore it is important to acknowledge some unavoidable errors and possible biases in the data. Respondents may not remember exact amounts of inputs and yields, or may report desired levels instead of realized ones, or they may give answers that they think the interviewer would want to hear. Outgrowers do not keep written scientific records. Even if they would be sufficiently educated to enable them to do so, there is no scientific measuring equipment available in their local environments. Weights and volumes sometimes were also expressed in local measures such as "buckets", which the interviewers then tried to convert into "scientific" equivalents. Not surprisingly, some respondents struggled to answer questions relating to, for instance, the quantity of seeds they had harvested during the past year prior to the survey, or the amount of time they had spent for different activities. Inconsistencies in field size, planting pattern and total number of trees were also revealed during the cross checks, and not all of those could be cleared up.

Still, efforts were made to make the methodology as rigorous as possible within those limitations. The fact that 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 Wahl et al., 2012) ensured that the reliability of the answers could always 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.

2.3 Overview of the analysed projects and outgrowers

Data were collected from 23 jatropha projects in total, see Figure 1. This included 10 projects in Tanzania, 7 projects in Mali and 6 in Mozambique. A total of 35 questionnaires were administered to smallholder cultivators in Tanzania. In Mali the total outgrower interviews was 40, and in Mozambique 5. The low number of smallholder interviews in Mozambique is explained by the fact that there is only one outgrower-based project operating in that country, and very few outgrowers have a long enough history with jatropha to be able to furnish sufficient information for this research. In Mozambique a range of other types of interviews were also held, with local authorities, plantation workers, and communities affected by plantations. Hence, the total number of interviews conducted in Mozambique was 45. However, those interviews were not strictly part of the NL

Agency research project which is subject of discussion in this report. Yet, some of the results of that work are reported in the social issues chapter in view of their high relevance. For further information about those interviews and further analysis see Rom Colthoff (2013).

Figure 1: Countries included in the analysis

In all three countries the number of project respondents is quite high compared to the total number of jatropha projects that are currently active in the country. As far as information was provided, 10 projects were active in Tanzania, 9 in Mali, and 12 in Mozambique. One Japanese project in Tanzania refused collaboration. However, one interview was held with a representative from an already defunct project who was still available on site, so the total number of interviews is still 10.

The following projects have received financial support from NL Agency; these projects collaborated to the survey as part of their on-going relations with NL Agency:

- Diligent Tanzania Ltd
- Max Havelaar / KNCU, Tanzania
- Mali Folkecentre Nyetaa
- Groupe de Recherches et d'Applications Techniques, Farakala, Mali
- Groupe Energies Renouvelables et Solidarites (GERES), Mali
- Sun Biofuels Mozambique

The remaining projects participated on a purely voluntary basis. NL Agency and the research team are grateful for their valuable contribution to his research project.

2.3.1 Tanzania

Tanzanian projects included in the research:

- Diligent Tanz. Ltd
- Tatedo
- Matumaini Mapya
- EWC / Rotiana
- Tanzania Jatropha Ltd (part of Japan Jatropha)
- Max Havelaar, KNCU
- Kilimangu Estate
- Vincentian Sisters
- Kiumma

- Prokon-Ajuaye-Kundi

  Total projects: 10

Smallholders in:

- Leguruki: 6
- Engaruka: 4
- Bukoba: 5
- Terat: 3
- Tunduru: 1
- Mpanda: 6

  Total outgrowers: 35

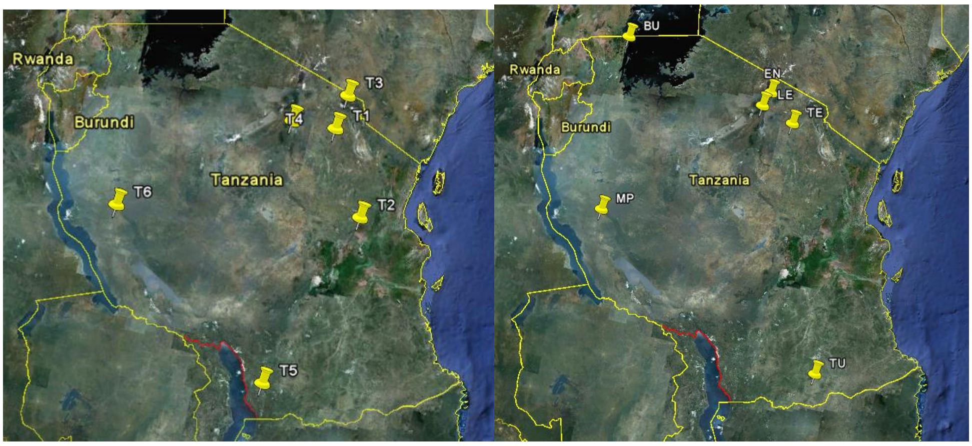


Figure 2: Locations of projects (left) and smallholders (right) in Tanzania.

Diligent Tanzania ltd.
This is the biggest processor in Tanzania by far. It is located in Arusha in the North. In 2011 it sourced from approximately 40,000 small farmers located in several different regions of the country, almost exclusively from old jatropha hedge stock. It had plans to expand to over 100,000 hedge-outgrowers. The average quantity of dry seeds supplied is about 10 kg per farmer.

Tatedo
Tatedo is a local Tanzanian organisation working towards improvement of technologies for disadvantaged groups in society. Its jatropha projects aim at introducing so called Multifunctional Platforms (MFPs) in villages for local energy self-sufficiency in various parts of the country.[1] In 2011, five MFPs were in various stages of establishment and/or refurbishment and 50 more were being planned. The oldest MFPs in Engaruka and Leguruki (both in Northern Tanzania) were supplied by 200 outgrowers each.

Matumaini Mapya
Matumaini Mapya ("New Hope") is a small project located in Kagera region, which lies to the west of Lake Victoria, primarily famous for banana production. In 2011

1 An MFP consists of a small diesel engine turning one or several types of milling machinery and/or an oil expeller and a generator for production of electricity.

it had established a one acre demo plot and had 72 outgrowers attached to it, who jointly farmed jatropha on 5 acres in hedge format. It had plans to expand to 200 outgrowers eventually.

EWC

EWC stands for Energy & Water Company – part of a larger consortium called OMASI, which encompasses various types of income-generating activities for and with Maasai around Terat, the principal town in Singida region, which lies some distance to the South of Arusha. Within the OMASI consortium, EWC is the part that deals with jatropha, which is primarily used to supply energy to the other companies in the consortium and the local community in Terat. EWC has its own (still incipient) plantation of 300 ha, and also sources from existing hedge stock from an unknown number of outgrowers in Singida. It also processes large quantities of Croton seeds. The operation is already quite large: 147 tons of jatropha were processed in 2011, future expansion is expected to come primarily from higher yields through maturing of the plantation.

Tanzania Jatropha Ltd

Tanzania Jatropha Ltd is a small Japanese–owned socially oriented venture located in Morogoro, not far from Dar es Salaam. It is part of a larger set up called Japan Jatropha which also conducts private agronomic experiments for private commercial purposes. The latter part of Japan Jatropha was not open to interviews. Tanzania Jatropha Ltd started in 2011 and has 40 private outgrowers as well as two institutional ones (schools), who farm jatropha on a total of 2 acres.

Max Havelaar / KNCU

Max Havelaar / KNCU is a collaboraton between the Dutch fair trade organisation Max Havelaar and the Tanzanian Kagera coffee farmers union, operating since 2010. It is an experimental or pilot project that tries to establish whether small farmers could structurally increase their yield from a given amount of land by introducing intercropping of food crops with jatropha while improving agronomic practices and using better quality food crop seeds. In addition to its fields in Kagera, it has sites in Moshi (in the Northeast) and in Mbinga (in the South). For this survey its Moshi operations were covered, which consist of 25 farmers farming 5 acres of jatropha in total. Eventually this ambitious project plans to extend to 78,000 outgrowers.

Kilimangu Estate and the Vincentian Sisters

Kilimangu Estate and the Vincentian Sisters are both local projects aiming at self-sufficiency. Kilimangu Estate is a farm in Singida region run by a private farmer, who has 60 acres under jatropha with no ambitions to expand. The Vincentian Sisters is a religious order in Mbinga (South) with 8 acres of jatropha.

Kiumma and Prokon:

In addition to the eight full interviews conducted with the above organisations, partial interviews were conducted with representatives from Kiumma and Prokon. Kiumma is a religious group similar to the Mbinga project. It is located on the border with Mozambique, where 2 acres of jatropha are cultivated for self-use. Prokon used to be a sizeable German-financed outgrower scheme in Mpanda (West Tanzania), which closed down in early 2012. In the year before closure, its outgrowers covered just 25 acres, whereas its plans (stated in 2008) were 16,800 outgrowers with 9,600 ha jatropha in total (source: Prokon Renewable Energy Ltd, as cited in Loos (2008)).

2.3.2 Mali

Projects covered in the research:

- ULSPP, Koulikoro
- Sud Agro Industrie (SUDAGRI, SARL), Sikasso
- ONG GERES /IRAM /AMEDD, Koutiala
- Mali Folkecenter
- Jatropha Mali Initiative
- GRAT (groupe d'recherchés et applications technique)

Total projects: 6

Outgrowers in:

- Kayes: 14
- Koulikouro: 3
- Segou: 9
- Sikasso: 14

Total outgrowers: 40

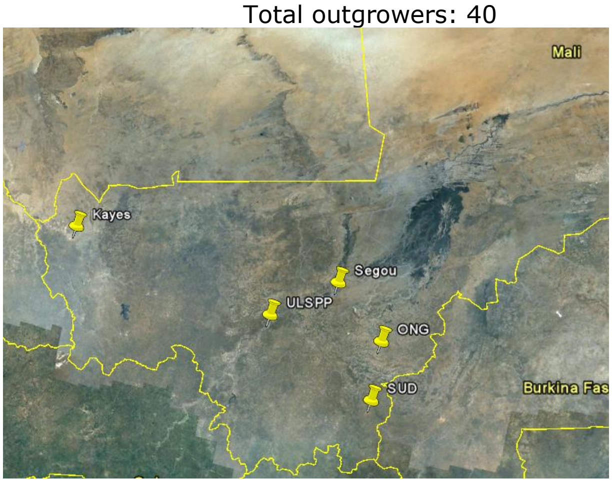


Figure 3: Project locations in Mali

The seven projects in Mali that were covered by the research all work with smallholders/outgrowers. From four of these projects there is information on the number of outgrowers, total number of hectares planted with jatropha and the total quantity of seeds collected in 2011. Together these four projects reported to have 1,480 outgrowers which had planted jatropha on almost 1300 ha, and 370 thousand meters of hedges. In 2011 almost 50 tons of seeds were collected from them.

Table 1: Projects and outgrowers in Mali included in the research

Regions	*Localities*	*Project interviews*	*Nr of smallholder (outgrower) interviews*	*Total nr of questionnaires*
Kayes	Kita	Jatropha Mali Initiative	14	15
Koulikoro	Koulikoro	Union Pourghère de Koulikoro (ULSPP)	3	4
Ségou	Teriya bugu	AEDR	9	10
Sikasso	Sikasso	South Agro Industry (SUDAGRI,SARL)	4	5
	Koutiala	ONG GERES /IRAM /AMEDD	2	3
	Garalo	Mali Folkcenter Nyetaa	6	7
	Farakala	Groupe de Recherche et d'Application Technique (GRAT)	2	3

Jatropha Mali Initiative
This project has been active since 2006, and its goal is to produce jatropha Straight Vegetable Oil for local sale. They have gradually increased their area under jatropha cultivation, in 2012 this was 1100 ha.

ULSPP
The project ULSPP (Union Pourghère de Koulikoro) has been active since 2007, and has in total 2 outgrowers with 20 ha. In 2011 around 25,000 kg of jatropha seeds were collected. Their objective is to collect 100,000 kg of seeds from 100 ha. The union can sell their seeds to Mali Biocarburant, which is a social entrepreneurial for-profit venture involved in jatropha seed processing located in the same area. Mali Biocarburant is of comparable size to Diligent Tanzania ltd, possibly larger.

SOCIMEX – SARL – Bagani
This project has been active since 2006, but only since 2010 on the current location. It is an organisation that produces soap and perfumes and since 2008 also jatropha oil.

SUDAGRI
The project SUDAGRI (Sud Agro Industry) has been active since 2009. It has 30 outgrowers with 58 ha under jatropha in total. In 2011 they collected 1,740 kg jatropha seeds. The goal is to reach 10,000 outgrowers in 2018 from 50,000 ha in total, and to collect a total of 174,000 kg seeds.

GERES
The GERES project (ALTERRE Mali), a not-for-profit NGO has been active since 2007 with a total of 1,200 outgrowers and 765 ha. This size is also their objective. They also have an additional 344,000 meters of live hedge. In 2011 they collected 17,800 kg of jatropha seeds but their goal is to collect 290,000 kg. They aim to utilise jatropha for rural electrification.

Mali Folkecenter
Mali Folkecenter (MFC Nyèta) has been active since 2006. It has 248 outgrowers and 450 ha has been planted with jatropha; in addition around 25,000 meters live fences have been planted. In 2011 5,000 kg of seeds were collected. The goal is to reach 500 outgrowers with 1000 ha in total, so that a total of 15,000 kg seeds can be collected. The project has one site in Garalo, where it has installed a jatropha press, and connected two electricity generators to a small grid in the village. Every day the villagers who are connected receive a few hours electricity against a fee. The generators also work on fossil diesel, but the goal is to use only jatropha oil eventually.

Groupe Recherche et d'Application Technique (GRAT)
This group has been active since 1990 in Bamako, they promote rural socio-economic development in the rural community of Farakala through diversification of sources of income through the production, commercialization and processing of jatropha seeds. 120 ha of jatropha has been planted. The long-term goal is processing of jatropha seeds for making biodiesel.

2.3.3 Mozambique

The projects and outgrowers analysed in Mozambique are:

Projects/plantation fields:

- AVIAM (2 interviews)
- ADPP
- Niqel
- MoçamGALP
- SAB
- Sun Biofuels

Total projects: 6

Smallholders/outgrowers:

- ADPP outgrowers: 5

Total outgrowers: 5

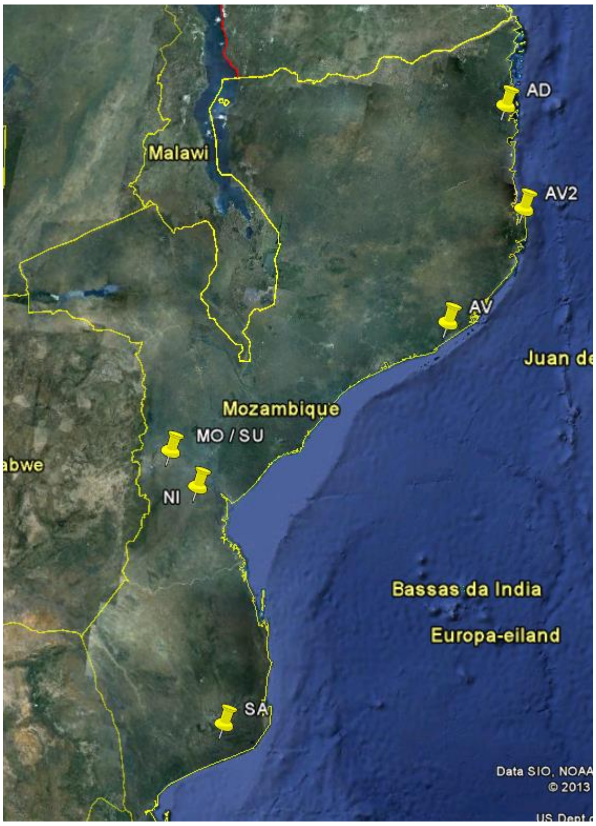


Figure 4: Project and outgrower locations in Mozambique

AVIAM

AVIAM is located near the village of Micolene in Nacala a Velha district. It is an Italian funded project that has started its activities in 2009 and has 250 hectares of jatropha planted so far, and aiming for 10.000 hectares in 2017. At the moment, AVIAM is still in the start-up phase and has not reached its goal, nor has it started operating commercially yet. The aspect on which they focus most is agronomical knowledge: best cultivation practices, yield optimization and planting seed quality. However, management is positive and hopeful for the future. They plan to enter the industrial phase this year, which means they will start planting on a larger scale and start producing oil. They expect to reach the break-even point 8 years from the start of the industrial phase, so in 2020 (AVIAM-Management, 2012).

ADPP

ADPP's main office is located in Bilibiza district. ADPP has been active on this site since 2006 and started with jatropha activities in 2009. ADPP works with outgrowers that are paid for their produced jatropha seeds. They also have their own plantation field, but this is on a very small scale and only meant for trials. At the moment they have a network of 1800 outgrowers and they intend to continue the expansion without a fixed defined goal. ADPP wants to produce and sell oil and also by-products, such as soap. However, at the moment they have not engaged in any commercial activities yet, nothing has been sold but they have a working expeller. They intend to start selling for local use this year (ADPP-Management, 2012).

Niqel

Niqel is located near the village of Grudja in Buzi district. Niqel is a private initiative of Nick Gagiano, who is the general manager, and since recently belongs to the 'Dutch Jatropha Consortium'. Niqel started operations in 2007 and currently has 1.500 hectares of jatropha planted and is aiming for about 5.000 hectares in 2014. Niqel has not produced or sold any oil yet. It has been bulking up all the seeds that were harvested over the last few years and will send all those seeds to the Netherlands for processing soon. The new owners of the Dutch Jatropha Consortium have facilities in the Netherlands to extract and process the oil.

Sun Biofuels

Sun Biofuels, a plantation company, is located near the city of Chimoio in Manica province. Sun Biofuels was previously a UK based company, but changed ownership in august 2011 and was taken over by other investors. The general manager is South African. The Sun Biofuels jatropha plantation, located on the site of a former tobacco plantation, is the biggest in Mozambique with 2500 hectares planted. However, since the ownership changed the project has decided not to focus on jatropha any longer. They will maintain the jatropha that is already there but will not expand. Instead, they will go into food crops. The jatropha that they still have and the oil that might be produced could be used for their own use for their machinery (Sun Biofuels-Management, 2012). A pilot test of the RSB certification scheme was conducted on Sun's operations with funding from NL Agency, with positive results.

MoçamGALP

MoçamGALP is located near the city of Chimoio in Manica province. It is a combined initiative from Petromoc, Ecomoz and GALP Energia. There are multiple locations of this project. There is another location in Buzí, using the name GALPBuzi, and also locations in Inchope and Mocuba. Apparently, Mocuba is supposed to become a large plantation in the future, but there is nothing there yet. The location in Chimoio has about 165 hectares planted. The company is aiming for an area of 15.000 hectares on this location, but it has trouble acquiring more landv(MoçamGALP-Management, 2012). The general manager of Sun Biofuels opined that MocamGALP would soon be the largest jatropha project in Mozambique, with 30.000 hectares planned, but this could not be verified.

SAB

SAB, which stands for SECI API Biofuels is located near the village of Inhassune within Panda district in the province of Inhambane and is an Italian investment. SECI and API are two Italian companies that are backing this project. SAB has acquired a DUAT for 6000 hectares and they have a business plan for 7000 hectares. SAB currently has about 240 hectares planted, but has slowed down its planting progress, preferring to wait until there is a good enough variety available that will give constant quality. So it is working on trials and also cooperating with a university in Israel. When it will have found seeds of high enough quality they will resume planting (SAB-Management, 2012).

3 Agronomic aspects

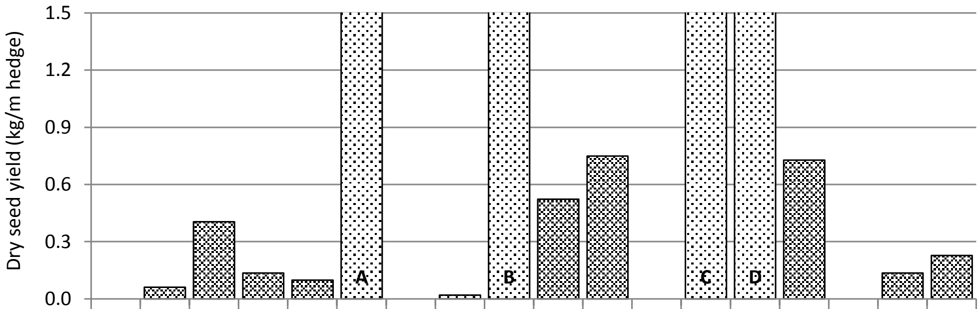
This chapter on agronomy starts with the results on seed yield as this is a major goal of jatropha cultivation for bio-energy production. Results of seed yield will be presented in relationship to a number of aspects that may affect yield: plant age, planting density and the occurrence of intercropping, fertilization and irrigation. In a following paragraph, various agronomic practices will be discussed.

After the yield data as derived from the questionnaires, an overview of the various agronomic practices that are applied will be given. The questionnaires cover a wide range of production circumstances like soil type and climate, differences in age of the jatropha trees and various cropping measures such as soil tillage, fertilization, irrigation and crop protection. This large variation in production circumstances within the data only enables a general picture on yields and the practices that are applied. For deriving best practices these data are not suitable, and for specific recommendations experiments should be carried out.

3.1 Seed yield

Seed yield is a major goal of jatropha cultivation when jatropha is grown for bio-energy production. Farmers, however, may also have other goals with jatropha, next to seed yield. Grown in hedges, jatropha functions as land demarcation or as a fence to prevent animals passing through. Other goals of growing jatropha can be to produce shade or to give support to vanilla plants. These other objectives do not necessarily contribute to seed yield as a goal. Moreover, intercropping of jatropha with other crops may limit yield of jatropha but improve production of the field as a whole, because of a more efficient use of all resources.

Hedges (outgrowers)
Seed yield of hedges is given in Figure 5. Seed yield has a strong relationship with the amount of light that is intercepted by the hedge and that is used for growth and seed production. Bigger plants or more plants per area increase light interception. Therefore, information on year of planting (age of the jatropha trees), plant density and intercropping (competition for light) is given below each bar in Figure 5. In addition, nutrient and water availability increase growth, and information about the occurrence of fertilization and irrigation around planting and at later stages of growth is also given.



fer1	no	no	no	no	yes		no	no	no	no		no	no	?		yes	yes
fer2	no	no	no	no	no		no	no	no	no		?	?	?		no	no
irr1	no	yes	no	no	yes		no	yes	no	no		no	no	no		no	no
irr2	no	yes	no	yes	yes		no	yes	no	no		no	no	yes		no	no
tr/10	31	74	19	17	12		16	102	19	26		20	20	20		7	7
year	'09	'08	'04	'01	'01		'09	'09	'02	'01		'06	'05	'97		'09	'09
spp	no	no	no	no	no		yes	yes	yes	yes		no	no	??		no	no
ID	LE2	EN9	LE6	LE3	EN10	.	LE4	EN7	LE5	LE1		Se24	Se26	Se25		AD1	AD2
	Tanzania										Mali				Mozambique		

Figure 5: Seed yield in 2011 of hedges (kg/m; dry seeds) of outgrowers in Tanzania, Mali and Mozambique. (See table below for explanation of the codes. Data are grouped per country and occurrence of intercropping, and within a group the plant age increases from left to right.)

Table 2: Codes used in Figure 5 to 8

Code	Explanation
fer1	Fertilization of jatropha before or within 4 weeks after planting
fer2	Fertilization of jatropha after 4 weeks after planting
irr1	Irrigation of jatropha within 4 weeks after planting
irr2	Irrigation of jatropha after 4 weeks after planting
tr/10	Number of trees per 10 m of hedge
tr/ha	Number of trees per hectare, as given in questionnaire
tr/ha2	Number of trees per hectare, calculated from planting pattern
year	Year of planting
spp	Occurrence of other tree species in the hedge besides jatropha
int	Application of intercropping between field-grown jatropha (any year; single or multiple years)
ID	Code of the farm. First letters indicate the region

Seed yield varied between a few grams per meter of hedge for young hedges, to yield levels above values that can be expected based on literature. For hedges, a value of 0.8 to 1.0 dry seed per meter of hedge is often found in literature, based on observations in Mali (Henning, 1998, cited by (Jongschaap et al., 2007)). However, a larger range in yield levels can be expected for various growing conditions (Jongschaap et al., 2007). Henning (2003), mentions that in general yield of a hedge in Mali was 0.8 kg/m per year, but that seed yield of old, non-pruned hedges was 2 kg/m per year. The age of these hedges is not given. Iiyama et al. (2012) carried out a large survey among 267 farms in Kenya, and reported low yields for hedges during the first six years (below 0.1 kg/tree) and higher yields afterwards (0.62 kg/tree). Converting these data to yield/meter hedge by using their reported average distance between jatropha trees of 2.28 m gives a yield of 0.27 kg/m for hedges of seven years or older. The amount of jatropha trees/m hedge as reported by Iiyama et al. (2012) is much lower than in our study, and also the derived yield of 0.27 kg/m hedge for hedges of seven years or older is lower than the yields of older hedges as found in the present study (Figure 5).

Actual measured dry seed yield was asked for in the questionnaire, but it cannot be excluded that farmers sometimes responded with expected or desired yields, or that the information on length of the hedges was inaccurate. In addition to the above literature data, yield levels can be judged by comparison with data from outgrower fields and plantations after conversion into a yield per hectare[2]. In Figure 5, the yield scale has been maximized at 1.5 kg/m, and higher values are expected to be unrealistic. A yield of 1.5 kg/m is similar to about 3000 kg/ha, and much higher than yields of a few hundred kilograms that were achieved on fields (see Figure 6 and Figure 7).

In Figure 5 there are four outliers with higher yields than 1.5 kg/m, for which the following comments can be given:

A	Reported total seed yield and length of the hedge gave a yield of 3.2 kg/m. Although this hedge is more than ten years old and well established (see Photo 1), this yield seems unrealistic high for the dry region of Engaruki. The hedge was not irrigated in 2011.
B	Reported total seed yield and length of the hedge gave a yield of 2.1 kg/m. The hedge was a intercropped with other species at a spacing of 0.6 m. This suggests that 2.1 kg/m is an overestimation of seed yield.
C and D	The hedges were 25 and 30 m long, and no inconsistencies were found in the questionnaires. However, the yields of 2.6 and 1.7 kg/m seem too high for the area of Ségou where the highest yield of an outgrower field was 600 kg/ha (Figure 7)

2 Assuming a spacing of 5 m between hedges, one hectare has 20 hedges of 100 m length. A yield of 1.5 kg/m hedge will give a yield of 3000 kg/ha (20 hedges/ha x 100 m x 1.5 kg/m)

Photo 1. Hedge of EN10, planted in 2001 (Engaruka, Tanzania; photo taken 2012)

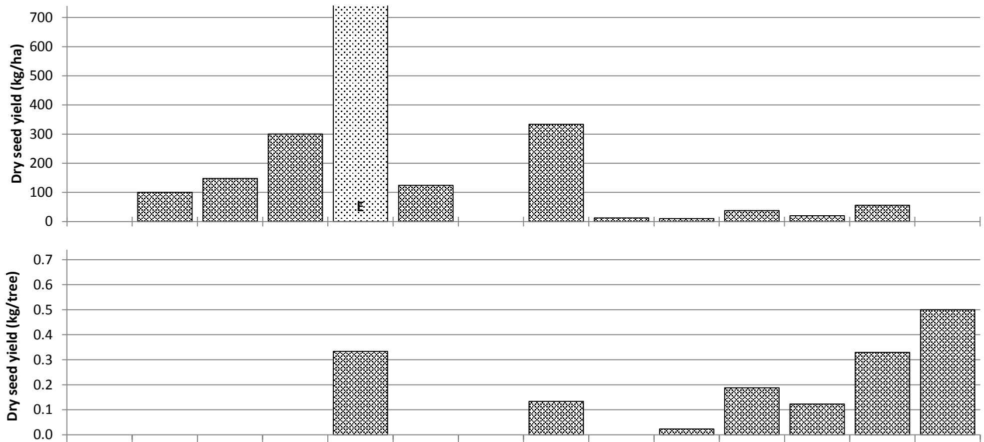
Fields (outgrowers)

Yields of the fields of outgrowers in Tanzania and Mali are shown in Figure 6 and Figure 7, both in kg/ha and in kg/tree. For Mozambique, there were no respondents with yield data of fields (one field was only planted in 2011). Below each bar in Figure 6 and Figure 7, information is given on year of planting (age of the jatropha trees), plant density, intercropping (competition for light) and the occurrence of fertilization and irrigation around planting and at later stages of growth. Sometimes, this information was not given in the questionnaire, which is indicated in Figure 6 and Figure 7 with a question mark or left blank. In the questionnaire, information was asked on area of the field, total number of trees and planting pattern to create options to check the data and increase accuracy. The information givenwas not always complete and not always consistent. Especially for Mali, in about half of the questionnaires total tree number did not agree with the tree number calculated from planting pattern and field size. This indicates that farmers are often not aware of important variables that determine seed yield. In Figure 6 and Figure 7, both plant densities are given, but yield/tree is calculated from the density as calculated from the planting pattern in order to agree with the other half of the questionnaires where total tree number was not provided and only planting pattern and field size were given.

When studying yield, planting density plays a major role in the relationship between yield per hectare and yield per tree. In young plantations, plants are not yet competing for resources such as light, water and nutrients. Then, yield/tree will be similar for situations with high or low planting densities, and yield/ha will be higher at the high planting density. However, when plants grow bigger and compete for resources, the impact of plant density on yield/ha will be limited, but yield/tree will be lower at high planting densities compared to low densities. Therefore, yields observed on specific trees cannot be simply extrapolated to other planting densities, and yield/tree has to be evaluated for the specific planting density where it has been observed.

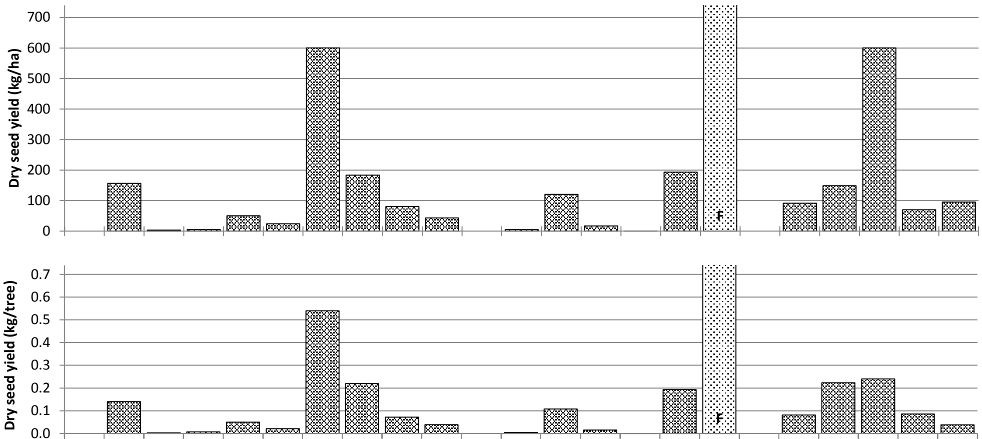
Yield per ha varied between zero for recently planted fields (data not shown) to 600 kg/ha. There were two farms where yield/ha was above expected values. MP25 in Tanzania had 30 trees on 0.01 ha (A in Figure 6. This area seems too small for a reliable calculation of the yield/ha. Ka12 in Mali (B in Figure 7) had a field size of 1 ha and reported a high yield of about 1800 kg/ha, 1.65 kg/tree. These values are much higher than other farmers in the area, without specific differences in crop cultivation, and therefore questioned.

The farmers in Bukoba, Tanzania (Bu11-Bu15) grow jatropha as support for vanilla plants and intercrop with banana trees (Photo 2). The low planting density and competition with the banana trees gives a low jatropha yield/ha. Trees were 4 to 9 years old, and yield/tree varied between 0.02 and 0.50 kg, average 0.23 kg. Yet, this is higher than many other outgrowers have on their fields with, often, younger jatropha trees.



fer1	no	no	no	no	no		yes	no	no	no	yes	no	no
fer2	no	no	no	no	no		no	no	no	no	no	no	no
irr1	no	no	no	no	no		no	no	no	no	no	no	no
irr2	no	no	no	no	no		no	no	no	no	no	no	no
tr/ha2													
tr/ha				3000			2500		425	200	160	170	
year	'09	'08	'08	'08	'05		'10	'08	'07	'04	'02	'02	'02
int	no	no	no	no	no		yes	yes	yes	yes	yes	yes	yes
ID	MP23	MP21	MP24	MP25	MP22	.	TU19	MP20	BU13	BU12	BU11	BU14	BU15

Figure 6: Seed yield (dry and clean) in 2011 of fields of outgrowers in Tanzania. Top in kg/ha; bottom in kg/tree. See Table 2 for explanation of the codes. See text for explanation of calculation of yield per hectare or per tree.

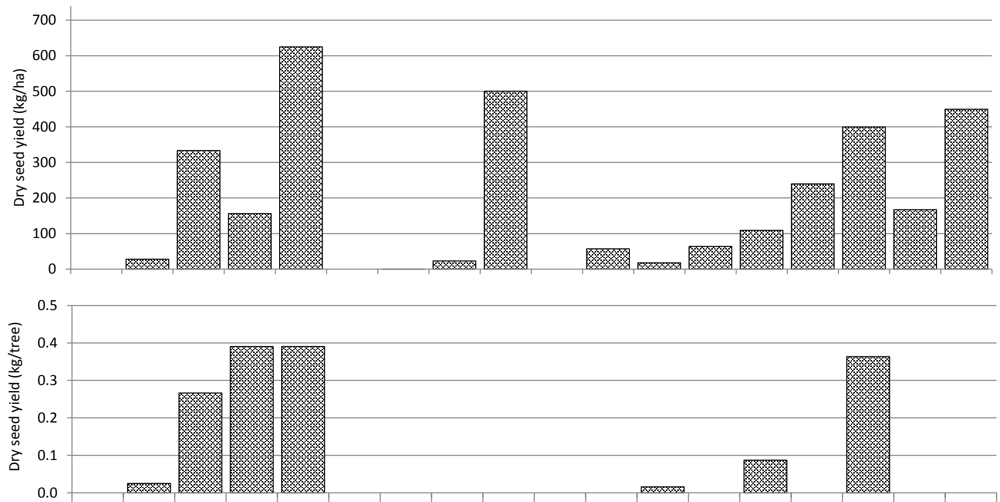


fer1	yes	yes	no	yes	yes	yes	no	no	no		no	no	no	yes	yes	yes	no	yes	no	yes	?	yes
fer2	?	?	?	?	?	?	?	?	?		no	?	?	?	?	?	?	?	?	?	?	?
irr1	no	no	no	yes	no	no	no	no	no		no	no	no	yes	yes	no	no	yes	no	no	no	no
irr2	no	no	no	yes	no	no	no	no	no		no	no	no	yes?	yes	no	no	no	no	no	yes	no
tr/ha2		351	380			2000	317	456			1100			1		1100					648	
tr/ha	1111	1111	667	1000	1111	1111	833	1111	1111		1111	1111	1111	667	1000	1111	1111	1111	667	2500	816	2500
year	'10	'09	'07	'07	'07	'07	'02	'02			'10	'10	'08	'07	'07	'07	'07	'07	'06	'06	?	?
int	no	no	no	?	no	no	no	no	no		yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
ID	Si18	Si21	Ko5	Ko1	Sé27	Si1	Ko4	Se23	Si19	.	Ka15	Sé30	Sé31	Ko3	Ko2	Ka12	Ko41	Si36	Si35	Sé28	Si2	Sé29

Figure 7: Seed yield (dry and clean) in 2011 of fields of outgrowers in Mali. Top in kg/ha; bottom in kg/tree. See Table 2 for explanation of the codes. See text for explanation of calculation of yield per hectare or per tree.

Photo 2. Jatropha supporting vanilla and intercropped with banana, Buboka, Tanzania (photo taken 2012)

Projects and plantation fields
Results for yields of projects and plantation fields are given in Figure 8. Within a project, differences can occur between the answers for the project as a whole or for an individual plantation field. When answers of both questionnaires per project differed, results of both questionnaires are given.
Trees on the plantations are still quite young, and yields are therefore low, but in the same range as yields achieved by outgrowers.



fer1	yes	no	no	yes	no	yes	no		yes		yes		no		
fer2	no	no	no	no	no	no	yes		yes		yes		no		
irr1	no	yes	no	no	no	yes	yes		yes		yes		no		
irr2	no	yes	no	no	no	no	yes		no		no		no		
tr/ha	1111	1250	400	1600					1111		1250		1100		
year	'08	'07	'05	'05	'09	'09	'07	'10	'10	'10	'10	'09	'09	'09	'08
int	no	no	yes	no	no	yes	no	no	no	no	no	yes	no	no	no
								project	field	project	field	project	field	project	project
ID	TaPr10	TaPr4	TaPr7	TaPr8	MaPr5	MaPr7	MaPr2	MoPl6		MOPl5	MOPl3	MOPl1		MOPl2	MOPl3
	Tanzania				Mali			Mozambique							

Figure 8: Seed yield (dry and clean) of projects and project fields in Tanzania, Mali and Mozambique. Top in kg/ha; bottom in kg/tree. See Table 2 for explanation of the codes.

3.2 Agronomic practices

3.2.1 Planting material and planting

Outgrowers
In Tanzania, planting material was provided by a project In Mpanda and Terat. In the other areas it was derived from family, friends or neighbors. The old trees for vanilla support in Bukoba were from cuttings, directly planted. Most hedges were also established by direct planting of cuttings, but for the hedges in Terat transplants grown from seed in containers/polybags were planted. In Mpanda and Tunduru also mainly transplants grown from seed were planted. All plants were planted in a planting hole.

In Mali, planting material in Sikasso was provided by jatropha projects, in the other regions it was both from projects and local sources. According to the questionnaires, on a little more than half of the farms jatropha was directly seeded, either in tilled soil or in a planting hole. The other farms used transplants, mostly grown in a seedbed and transplanted into a planting hole.
In Mozambique, the outgrowers derived their planting material from family, friends or neighbors or from the ADDP project. Two farmers established their hedges by cuttings, two by direct seeding on the spot.

Survival rates of planted jatropha were high in Tanzania, and if plants had died they generally were replaced. A low survival rate was only found in Mpanda because of damage by termites: average survival rate of jatropha plants at six farms was 57% (between 13 and 95%). Only two farms replaced the plants that had died. In Mali, the question on survival rate was missing in the translated questionnaire. However, many farmers mention problems with termites, which will also have had a negative impact survival rate. For Mozambique, survival rate was not given.

Projects
The projects in Tanzania mainly use local seeds, Ta_Pr3 tests also imported seeds on specific plots. Jatropha Tanzania Ltd applies direct seeding in planting holes, all other projects use transplants that were grown from seed in containers/polybags. The survival rate varied between projects. When plants died, this was because of pests and diseases, drought, flooding (water logging), destruction by cows or people. Most often, plants that had died were replaced.
In Mali, planting material is mainly of local origin. In Mozambique, planting material from various locations of the world is used (local, Brazil, Ghana, Malawi, Zimbabwe, Malaysia, Tanzania). Transplants, cuttings and direct seeding is used. The survival rate varied between 80 and 100% (average 94%), and plants died because of pests/diseases, drought or waterlogging. In general, dead plants were replaced.

3.2.2 Fertilization

Outgrowers
In Tanzania, fertilization was only carried out by a few farmers at planting (6 of 25). The farmers in Terat mixed cow manure in the planting holes, one farmer in Engaruka used ashes, one in Bukoba compost and the farmer in Tunduru goat manure. After planting, jatropha was not fertilized.
In Mali, 16 of the 41 farmers fertilized at planting, evenly distributed over the four regions. In most cases, organic manure or cow manure was applied in a planting hole. Whether jatropha was fertilized or not after planting was not clear from the questionnaires, but likely jatropha has not been fertilized after planting. In Mozambique, three out of four growers indicate to fertilize the hedge before planting with manure, about 1 kg/meter.

Projects
In Tanzania, Ta_Pr4 and Ta_Pr7 did not fertilize at planting. The other projects applied cow manure in the planting holes. After planting, jatropha was not fertilized. In Mali, Ma_Pr3 and Ma_Pr6 used cow manure at planting of jatropha, the other projects did not fertilize. In Mozambique, two of the three project fields were fertilized with NPK fertilizer, both before and after planting. Mo_PL6 used 135

g NPK per tree at planting, and after that an annual application of 100 g NPK/tree. They expect to increase the fertilization when the field is producing seeds. Mo_Pl3 applied some NPK fertilizer in the polybag, and applied 60 g LAN/tree in the first year, together with foliar application of magnesiumsulfate and MAP 39, 100 g/tree. In the second year, 100 g NPK 15:5:20 was applied per tree. Mo_Pl3 is satisfied with the current fertilizer applications.

3.2.3 Irrigation

Outgrowers
In Tanzania, plants were irrigated both at planting and at later stages of growth in Engaruka. In Terat, plants were irrigated at planting only. In all other areas of Tanzania, no irrigation was carried out. In Mali, only irrigation at planting was carried out on two farms in Koulikoro. These farms and two additional farms in Koulikoro also irrigated after planting, mainly as protection against termites. This irrigation was done daily, twice a week or once a week. Hedges in Mozambique were not irrigated.

Projects
In Tanzania, Ta_Pr4 irrigated the jatropha from planting until the plants were strong. Ta_Pr3 irrigated during the dry season. Ta_Pr4 use a bowser (tanker), Ta_Pr3 uses furrow irrigation. The other four projects in Tanzania did not apply irrigation. In Mali, MA_PR2 and MA_PR7 irrigate at planting, and MA_PR2 also after planting using a hose. MA_PR3 does not irrigate. Irrigation at the other projects is not known. In Mozambique, the plantation fields of Mo_PL6 and Mo_Pl3 were irrigated at planting. The field of Mo_Pl1 was not irrigated, and survival rate of the plants was only 80% because of drought. More than four weeks after planting, no irrigation was carried out.

3.2.4 Pruning

Outgrowers
In Tanzaniza, hedges in Terat were not yet pruned as plants were still young. In Leguruki, pruning was done 1-3 times per year, in Engaruka this was once a year. Jatropha on fields were pruned annually, in general to about 1.5 m height. Pruned material is sometimes left on the soil, and often used as planting material. In Mali, half of the hedges in Ségou was pruned once a year. Of the fields, a little more than half of the farmers pruned jatropha, in general to increase branching and sometimes to limit the height of the trees. One farmer pruned to make space for the intercrop. First pruning was often one or more years after planting. In Mozambique, two farms with hedges planted in 2009 indicate to prune to increase branching, two other farms with younger hedges had not yet pruned.

Projects
In Tanzania, Ta_Pr7 did not prune and recommend not to prune as when there are too many branches a lot of branches bear no fruits. Jatropha Tanzania Ltd had planted in 2011 and did not prune. Other projects are satisfied with their way of pruning. Ta_Pr10 first pruned one year after planting at 30 cm height, and intend to prune until the trees are 4 years old. Ta_Pr4 first pruned 1.5 year after planting at knee height, and intend annual pruning. Ta_Pr8 first pruned three years after planting at 2.5 m height and look at the plants for further pruning. Ta_Pr3 first

pruned 3 months after planting, and applies pruning at knee height and shoulder height. Aim of pruning is to increase branching.
In Mali, Ma_Pr5 did not yet prune, and Ma_Pr4 did not give information on pruning. Ma_Pr1 has pruned once, two years after planting at 50-60 cm height. MA_PR2 and Ma_Pr6 have pruned for the first time three years after planting, MA_PR2 at 1.5 m height, Ma_Pr6 at 0.5 m height. Ma_PR7 has pruned in the 1st year after planting at 30 cm height, and in the next years based on the branching of the trees. Ma_Pr7 is experimenting to find the best moment for pruning. Ma_Pr1 has left the pruned material on the field, or used it for planting material. The other projects have removed the pruned material from the field, mainly for composting.
In Mozambique, Mo_Pl1 pruned the plants twice: the first time 7 months after planting at 50 cm height, the second time 19 months after planting at 80 cm height. No further pruning has been done, and for the future it is intended to prune only once in the first year. Mo_Pl3 pruned at 50 cm in the nursery, and had a second pruning 4 months after planting. Mo_Pl6 did the first pruning 6 weeks after planting at 80 cm height, and annually in August at increasing height. Mo_Pl1 collected the pruned material for composting, the other two projects left the material in the field.

3.2.5 Weeding

Outgrowers
In Tanzania, both hedges and fields were generally weeded two or three times per season. On some farms, weeding was carried out more frequently. Fields in Mpanda and Tunduru were weeded using a hand hoe; in Bukoba fields were weeded manually without tools and in most cases weeds were removed from the field. Entire fields were weeded, not just only around trees. For weeding of hedges, generally a hand hoe was used, sometimes a knife.
In Mali, 16% of the farms weeded around the trees only, the other farms weeded the entire field. Almost 80% of the farms weeded manually, the other farms used chemicals or mowed the weeds. On two-thirds of the farms the weeds were removed and used as straw, for animal, burnt or thrown away. This means an additional export of nutrients from jatropha fields, next to the export with harvested seeds.

Projects
In Tanzania, all projects use manual weeding and leave the weeds on the field. One project indicates that it prefers manual weeding despite it is time consuming because the chemicals do not kill all the weeds. Another project also prefers manual weeding, but is thinking of chemical options because of lack of labour force. In Mali, weeding is carried out once a year (2 projects), twice (3) or three times a year (1). Weeding is done manually (2 projects), a combination of manual and chemical (1) and by plowing (2 projects).

3.2.6 Pest and diseases

Outgrowers
In Tanzania, few pests occur in the hedges of Leguruki. In Engaruka and Terat, farmers mention that roots and leaves of the plants in their hedges were eaten. Some farmers don’t know the cause, other farmers mention termites. Incidentally, crop protection was carried out. In Bukoba, birds sometimes eat from the seeds.

In Mpanda, major pest was termites, and crop protection was carried out with Deltra, supplied by the project Ta_Pr10.
On almost all farms in Mali (33 of 41), jatropha was attacked by termites in one or more of the previous years. Mainly the roots were attacked, but sometimes also the stems and leaves. Up to 60% of the plants was attacked (average 25%). In many cases (20 farms), no crop sanitation measures were taken. Measures that were taken against termites are irrigation (4, mainly in Koulikoro), neem powder (3), Furadan (carbofuran) (5), Lamdat super (2), Toppel and Decis (3).
In Mozambique, 2 of 4 farmers report some unknown pests without indicating the degree of infection. No crop protection was carried out.

Projects
In Tanzania, jatropha on all projects suffered from pests or diseases. Crop protection was carried out on all projects against different pests and diseases such as beetles, termites, golden flies, leaf spot and powdery mildew. One project uses traditional pesticides based on neem, the other projects use chemicals. In Mali, Ma_Pr1 indicates a fungus causing rot of the trunk. Ma_Pr3, Ma_Pr5, Ma_Pr6 and Ma_Pr7 indicate attack by termites each year. Ma_Pr5 also mentions scale insects each year. Crop protection is carried out, but not specified. MA_PR2 indicates no pests occurred; Ma_Pr4 did not give information on occurrence of pests. In Mozambique, Mo_Pl6 reports attack by flee beetle and maggots, both treated with cipemetrion. The degree of attack was not specified. Mo_Pl3 reports bark eaten by termites and rats, leaves eaten by the gold beetle and infected by mildew. About 80% of the plants was affected. Crop protection was carried out with Karate against termites and golden beetle, and with super metrine against mildew. At the field of Mo_Pl1, flee beetle and fusarium occurred. For fusarium, infected plants are removed as soon as possible.

3.2.7 Intercropping

Outgrowers
In Tanzania, other plant species were grown in the hedges of three farms in Leguruki, spaced 1.5-2 m apart. In Engaruka, one hedge was mixed with trees of mijohoro and neem, spaced 0.6 m apart. In Terat, one hedge was mixed with cactus, 2 m apart. Other common species that are used as hedge are amongst others Euphorbia tirucalli and sisal. In Bukoba, jatropha was used as support for vanilla, and intercropped with banana, coffee and vegetables. In Mpanda, one farm intercropped jatropha with sweet potatoes in the second year after planting. In Tunduru, the farm intercropped with cassava in the year of planting, and beans in the second year.
In Mali, the four farms with hedges had no other species in the hedge. Intercropping was applied on 23 of the 37 fields; all farms in Kayes carried out intercropping, and in the other regions about half of the farms. In most cases, intercropping was done in one year only: the year of planting or the year after planting. Five farms have been intercropping for multiple years, at a jatropha plant spacing of 2x2, 3x3, 3x3, 3.5x3.5 and 5x2. Four farms in Kayes have been planted in 2001 at a spacing between rows of jatropha of 8 m and will continue with intercropping. There is a wide range of crops grown as intercrop (number of farms): peanut (11), cowpea (6), sorghum (6), millet (5), cotton (3), corn (3), pepper (2), sesame (2), sunflower (2), okra, rice and soybean. Farmers mention as advantages of intercropping: improvement of soil fertility (21), protection

against erosion (9), facilitate maintenance of jatropha (7), and additional income (6).
In Mozambique, no other species were grown in the jatropha hedges.

Projects
In Tanzania, intercropping was only applied by the Ta_Pr7 in the year of planting (2005). Ta_Pr3 uses a system of permanent intercropping of two rows of jatropha alternated with space for food crops.
In Mali, no intercrop is grown by MA_PR2 and Ma_Pr5. Ma_Pr1 alternates two rows of jatropha with a wide spacing for the intercrop. The other projects alternate one row of jatropha with a few meters for the intercrop, although Ma_Pr7 mentions to shift towards a wider spacing of more than 6 metres between rows of jatropha. Crops grown as intercrop are bean, corn, cotton, cowpea, peanut, pepper, sesame, sunflower and watermelon.
In Mozambique, Mo_Pl1/Quinvita recommends to intercrop in the first two seasons after planting of jatropha. The field of Mo_Pl1 that was used for the questionnaire was not intercropped, nor were the fields of MO_PL6 and Mo_Pl3.

3.2.8 Harvesting

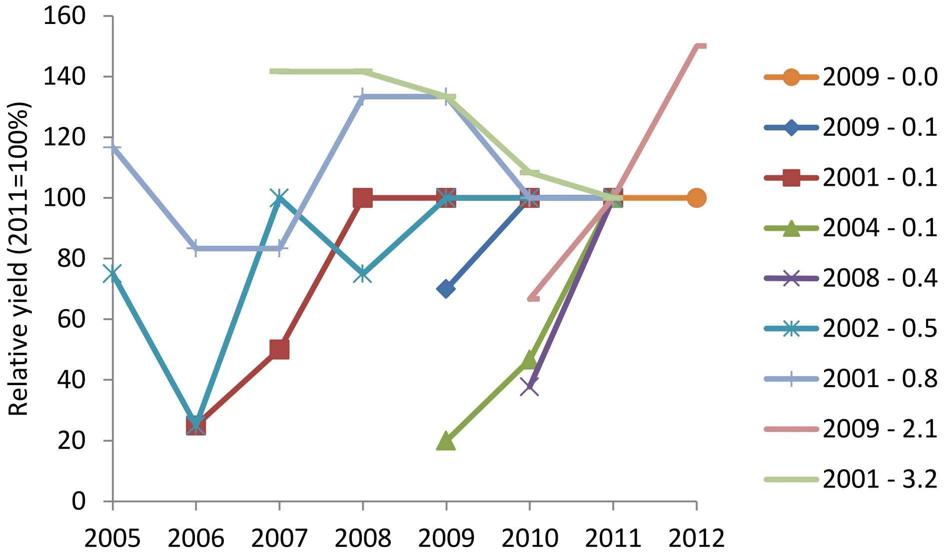
Outgrowers
In Tanzania, harvest was carried out between 1 and 3 times per year, and both yellow and black fruits were harvested. All fruits were opened manually, and seeds were dried in the sun for a few days. In Mali, harvests were carried out 1, 2 or 3 times per year, all options equally often occurring. Yellow, a mixture of yellow and black or only black fruits were harvested, and dried in the sun for 2-4 days. Mostly, fruits were opened manually, but in three cases this was done mechanically. In Mozambique, black fruits were harvested of two hedges only, the others were still too young to bear substantial yields.

Projects
In Tanzania, four of the six projects have harvested and picked the fruits between 1 and 4 times per year, a mixture of yellow and black. Ta_Pr10 has developed a machine for dehulling, the other projects open the fruits manually. Seeds are dried in the sun for a few days.
In Mali, yellow fruits or a mix of yellow and black was harvested. Dehulling was done manually by MA_PR2, Ma_Pr6 and Ma_Pr7, and mechanically by Ma_Pr1 and Ma_Pr3. Ma_Pr5 used both manual and mechanical dehulling. The hulls are composted by most projects for use as fertilizer. Seeds were dried between 4-15 days.
In Mozambique, seeds were harvested when yellow, yellow/black and black. At MO_PL6, seeds were also said to be harvested when the hulls were still green in order to save time. Dehulling was done manual at Mo_Pl1 at Mo_Pl3, and mechanical at MO_PL6. Seeds were dried in the sun for 1-3 days.

3.3 Discussion

3.3.1 Yield and plant age
Seed yields at the fields of projects and farms of outgrowers were not very high. This is partly because of the young age of jatropha in many fields and hedges. However, also trees at the age of five years or more did show low yields.

A yield increase can be expected when the trees grow older. In the questionnaires, information of yield in different years was recorded, and enough data are available for outgrowers in Tanzania and Mali to study and describe relative yield increase over time (Figure 9). For hedges in Tanzania, yield increase was not always apparent, and in some cases yield in 2011 was lower than in previous years, caused by lower rainfall in 2010 and 2011. Strongest relative yield increases are found for the fields in Mali, even more than 300 percent in 2012 compared to 2011. The high increases around 300 percent are mainly possible because of low yields in 2011 of less than 100 kg/ha.



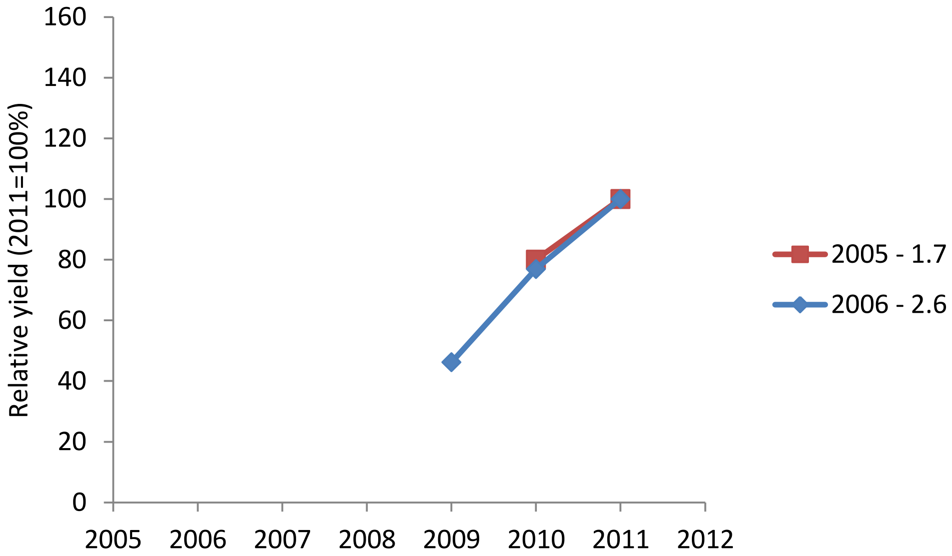
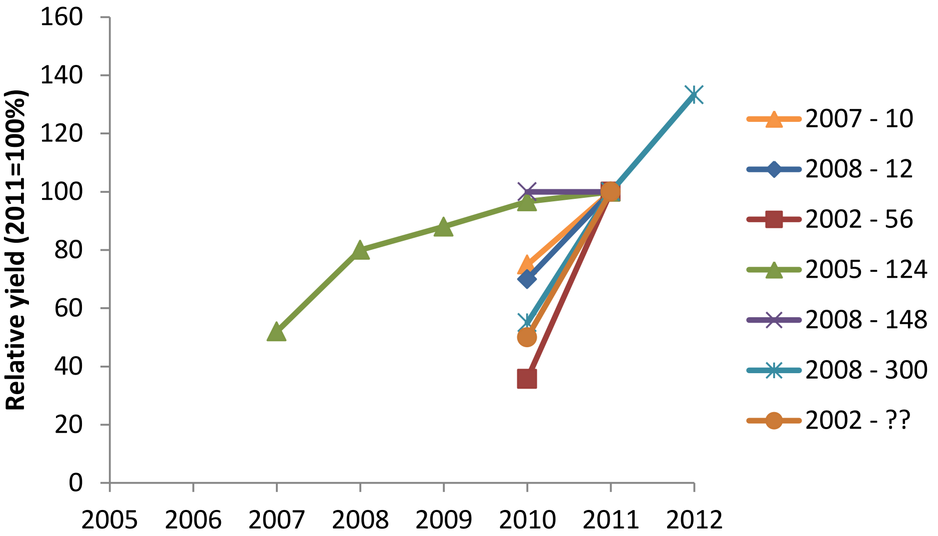


Figure 9: Relative yield development over time for hedges of outgrower farms in Tanzania (top) and Mali (bottom). Yield of 2011 is 100%. The legend indicates year of planting and dry seed yield in 2011 (in kg/m).



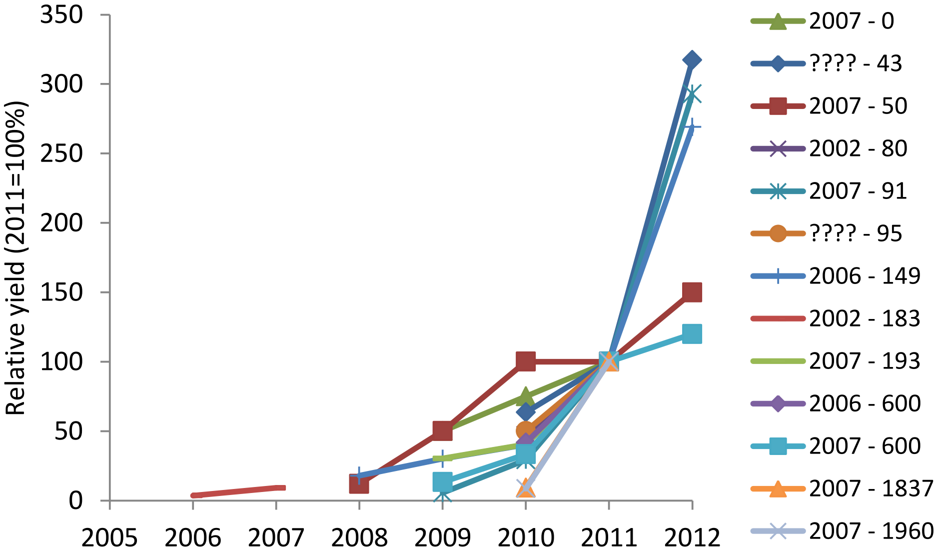


Figure 10: Relative yield development over time for fields of outgrower farms in Tanzania (top) and Mali (bottom). Yield of 2011 is 100%. The legend indicates year of planting and dry seed yield in 2011 (in kg/ha). Note: the vertical axis of the top and bottom figures varies.

When yield per tree is plotted against tree age for yield data of all years that were available in the responses, a trend of increasing yield with increasing plant age can be seen (Figure 11). There is, however, a lot of scatter. Part of this scatter can be explained by combining yields from different locations within the countries and combining yields of fields with and without intercropping. Iiyama et al. (2012) plotted estimated seed yields against different age classes of jatropha trees in Kenya. They did not find a smooth development over time: yields were low for age classes up to six years old: below 0.1 kg/tree. The age class 7+

showed higher yields of 0.8 kg/tree for monoculture, 0.38 kg/tree for intercropping and 0.62 kg/tree for hedges. Compared to Iiyama et al. (2012), yields per tree in the current study are somewhat higher for young trees, and somewhat lower for old trees.

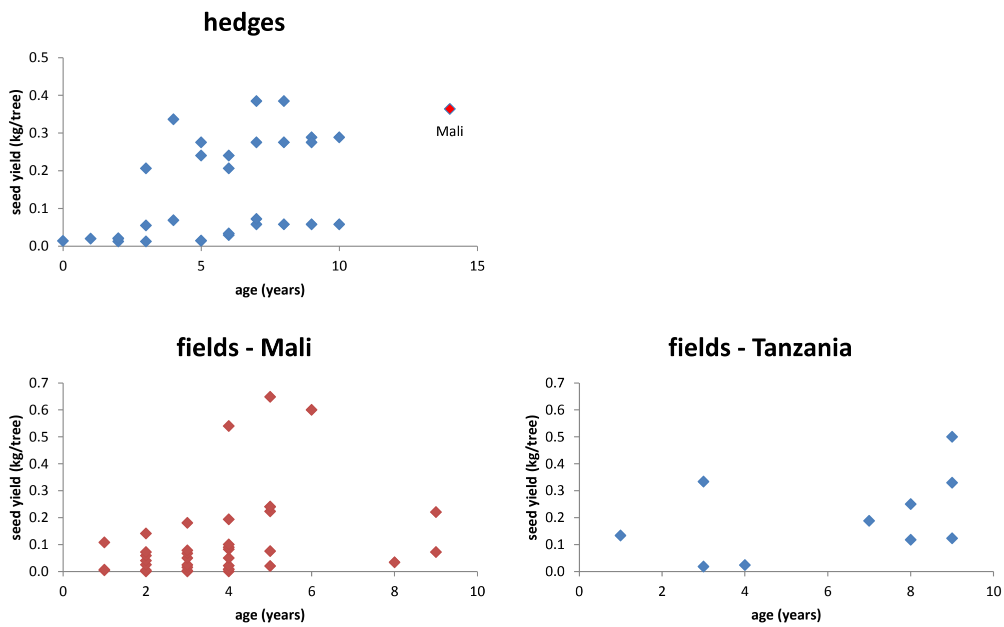


Figure 11: Dry seed yield in 2011 (kg/tree) versus tree age (years) for hedges (Tanzania and one data point in Mali) and fields (Mali and Tanzania).

A team from Leuphana University carried out a survey in 2011 on jatropha and other oil-bearing tree species (Wahl et al. (2012)). For Africa, they reported results of 11 projects with a median yield of 900 kg/ha and yields ranging between 20 and 6000 kg/ha, indicating that the outlier of 6000 kg/ha was probably an expected yield as it is exceptionally high for a two or three year old plantation. The median yield of 900 kg/ha is higher than the values we found in our survey (see Figure 6 to Figure 8). This may be caused by inclusion of more expected yield data, as in the questionnaire 'measured or expected' yield was asked for. In our study we aimed at retrieving actual, experienced yields by careful instruction of the interviewers and face-to-face interviews. Trees were maximum four years old in the study of Wahl et al. (2012). Wahl et al. (2012) found higher yields in Asia (median yield 3350 kg/ha) compared to Africa (median yield 900 kg/ha). Many aspects may cause this difference, such as the trees being on average one year older in Asia compared to Afrcica (Wahl et al., 2012). Other aspects can be differences in production potentials between the sites in Asia compared to Africa (Jongschaap et al., 2007) or cultural differences in replying to questionnaires. These effects have not been studied.

3.3.2 Genetic improvements

Most jatropha is grown with local plant material and breeding for improved varieties is still in its infancy. Genetic improvements are expected to result in higher yields, and currently experiments are running on several locations in the world. Breeding of improved varieties is an important slow process and depends on investments. Improved varieties from private companies will be under Plant Breeders Rights to recover the costs of breeding and in turn re-invest in future variety development. Results of publicly funded projects will become available (e.g. www.jatropt.eu). In India, experiments are carried out with jatropha plants that have been multiplied in vitro from high yielding plants. In these experiments, 1.5 years after planting dry seed yields were achieved between 500 and 2200 kg/ha, depending on the plant spacing (pers. comm. Jongschaap, Plant Research International). These crops were well managed and not representative for the circumstances in Africa, but it may indicate that there are perspectives for yield increases by genetic improvements.

3.3.3 Crop management

Plant spacing has an impact on yield, especially at the early stages of growth. When plants are small, competition for light, water and nutrients is limited and higher plant spacing will give higher yields (Horschutz et al., 2012; Srinophakun et al., 2011). However, for jatropha to flower requires sufficient light, and competition for light within or between jatropha trees negatively affects flowering and seed production. This means that the statement 'the more branches, the higher seed yield' is not always valid, and there is an optimum in the number of branches on a tree and/or per m^2 soil surface. Indications for such a competition effect are found with Reddy et al. (2012), Sharma (2012) and with preliminary results of an experiment in India on the effects of four plant spacings (30, 60, 100 and 200 cm) within rows that were 4 m apart (pers. comm. R. Jongschaap, Plant Research International). Within the dataset of the current study, effects of plant spacing on seed yield could not be studied as many other aspects varied as well. To study best management practices and their effects on seed yield, experiments have to be carried out in which only one or a few aspects are varied.

3.3.4 Outlook on future yields

As described in the previous sections, jatropha yield may increase with increasing plant age, improved genetics and better crop management. Current farming practice (this study) in Africa achieves yields far below potential yield levels. As a first estimate for seed yield expectations, the gap between actual and potential yield can be used and compared with other crops.

For cereals (maize and wheat) and some perennial species (eucalyptus, poplar and willow), biophysical productivity potentials were calculated for various regions in the world and compared with actual yields as recorded by FAO (SWAFEA, 2011). Europe and North America achieve about 80 percent of the yield potential, whereas Sub-Saharan Africa remains on 15 to 30 percent. Theoretical yield potential of jatropha was explored by Jongschaap et al. (2007). Net primary production was calculated from intercepted radiation, and distribution of dry matter between various plant parts based on literature data. Annual potential seed production for a mature jatropha stand then varied between 1.5-7.8 t ha^{-1}. For the three countries in our study, net primary production is 50-60 percent of the highest value used by Jongschaap et al. (2007), corresponding to a potential yield level of about 4.3 t ha^{-1}. Assuming for jatropha in Africa the same technical development and the same fraction of potential yield as for cereals and perennial crops (SWAFEA, 2011), a jatropha seed yield of 0.65 to 1.3 t ha^{-1} is to be expected. This range is higher than the range of 0 – 0.65 t ha^{-1} as found in our study.

The above yield range of 0.65-1.3 ton ha^{-1} describes the effect of ageing of the trees and improved technical development to current levels in Africa. In addition to this, genetic improvement may increase allocation of dry matter to the seeds and increase yield potential. What the actual yield increase can be is difficult to quantify and depends on implementation of technology. When this is done to levels equal to Europe or North America, a yield of about 3.5 ton ha^{-1} can be expected for the countries in our study, with some variation caused by local differences in growing conditions.

3.4 Conclusions

- Yields of jatropha were low, partly because of the young age of trees, which do not efficiently use the available resources (radiation, water, fertility). However, yields were also limited by drought and reduced by pests and diseases.
- Ageing of jatropha stands will increase yields, and doubling yields to 0.65 – 1.3 t ha^{-1} can be expected based on the technical development in Africa and comparison with cereals and other perennial crops.
- Genetic improvements may further increase yields, and should be combined with good crop management to utilize the potential. Maximum yield at a high level of implementation of technology is estimated at about 3.5 ton ha^{-1} for the countries in our study.
- The results of the questionnaires give a good overview of yields that are achieved in current practise, together with the management practices currently being used. However, it cannot be excluded that some data are uncertain because they are based on memory or are influenced by desired yield levels.
- Results of the questionnaires do not allow a quantitative analysis of the effects of specific crop management on seed yield as there are too many factors involved that all have an effect on seed yield.
- To study best management practices and their effects on seed yield, experiments have to be carried out in which only one or a few aspects are varied, and where results can be verified objectively.

4 Economic analysis

This chapter addresses the key question of how the projects have been faring in financial terms. To the extent possible it tries to find explanations for the financial performance patterns seen in the data, with reference to key agronomic issues signalled earlier. Based on this analysis, the financial future outlook for jatropha projects will be addressed.

At the outset it should be stated that the quality of the data received from the field posed problems for this analysis. Many crucial figures were missing, while many mutual inconsistences were also discovered between the data that were reported. In many cases it seemed as if respondents themselves did not have a good grasp of the financial situation of their own ventures. The effects of these problems for analysis were compounded by the fact that the project samples from the three countries were highly heterogeneous in terms of project size, activities undertaken, and period of involvement with jatropha.

This does not imply that we cannot draw conclusions from the data, but it poses some restrictions on the analysis that is possible to undertake. Paired with the relatively small numbers of observations that we have, the situation does not permit a detailed statistical analysis of the projects' financial situation. Instead, we opt for a more qualitative, interpretative text-based assessment supported by key tables.

The analysis is structured as follows:

1. Large plantations: primarily based on mono-cropping, involving large-scale land lease transactions.
2. Outgrowers: farmers cultivating jatropha according to some kind of verbal or written contractual arrangement for a seed processor.
3. Processors: these companies/projects specialize mainly in oil extraction and associated activities - such as producing cooking briquettes and pellets from residual seedcake – from seeds that are supplied externally, although some processors may also have their own (trial) field or small plantation.

The first two categories were already encountered in the agronomic part, while the third category covers projects that were not part of the agronomic analysis.

4.1 Large plantations

In our survey, large plantations were only encountered in Mozambique, where they constitute the dominant business model of jatropha cultivation. Although Tanzania until recently had several large jatropha plantations as well (BioShape and Sun Biofuels Tanzania being the most well-known cases; see amongst others (Gordon-Maclean et al., 2008; Habib-Mintz, 2010; Sulle and Nelson, 2009; van Eijck et al., submitted), our survey in Tanzania in 2012 was unable to locate any operational large plantations. It must be concluded that all Tanzania's large plantations folded in the period 2008-12. The only remaining large scheme in Tanzania which is still lingering 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 Jatropa, so all activities have been put on hold. The situation in Mali was always different: in that country there were never any large mono-plantation schemes. Its jatropha activities are centred around smallholder production and small farmer cooperatives. Five large plantations operating in Mozambique were covered by the survey. The earliest two started their activities in 2007, and the two most recent ones in or around 2010. The two oldest projects are of special interest here, because of having accumulated some lessons.

4.1.1 Size and investment requirements

The projected full size of the plantations is indeed very large, ranging between 5,000 ha and 50,000 ha, although the largest one has developed a business plan for only 7,000 ha so far. In comparison, the areas that have been planted up with jatropha at the time of our survey in 2012 were still small. The two oldest projects had 2,311 and 1,500 ha under jatropha, respectively. The area planted up in the three more recent projects ranged from just 165 to 250 ha. Not surprisingly, the break-even points were projected quite far into the future. The smallest project of 5,000 ha expects to need seven years to break even, whereas the others expect to need a full ten years or even more.

We should also realize that these projections constitute the managers' own estimations. In reality, the outcomes might yet be more unfavourable, given the many agronomic problems, such as pests, diseases, and unreliable yields that are still being experienced with the crop, as documented in our agronomy chapter. We also see from Table 3 that two respondents now express more caution in their upscaling ambitions than at the start of their activities: MO_Pl4 initially aimed for 10,000 ha under jatropha, but has since decided to diversify into food production, only maintaining the area of 2,311 ha that has already been planted up with jatropha so far. MO_PL6's initial ambition to cover 50,000 ha should also be seen as a distant and uncertain scenario, as they have decided to put planting on hold and wait for better commercial seed varieties before resuming.

Large plantations invariably need a lot of up-front capital to finance equipment needed for land clearing and land preparation, so that the planting of jatropha can proceed reasonably fast. Delays in planting up are costly, especially in view of the fact that jatropha begins to yield commercially interesting quantities of seeds only after 5-6 years. The investment data given by four projects (Table 4) indicate that the smallest investment outlay so far is in the region of US$ 2 million, but it should be noted that the respondent of this project indicated that the pace of clearing and land preparation will speed up in the coming years, for which additional equipment has been ordered. More realistic investment requirements - from the point of satisfactory pacing of land preparation and planting - are probably the figures US$ 4.8 and US$ 5 million quoted by two other projects. MO_Pl4 even quotes a figure of US$ 12 million.

Although adequate equipment investment will pay off in the longer term by speeding up plantation development, it does lead to extremely high per-ha costs in the initial years of operation. This is illustrated by the column labelled "Investment costs per planted up ha, by 2011" in Table 4. Even in the two oldest projects, the amounts are still a formidable US$ 3,333 and US$ 5,193, respectively. The respondents indicate that these costs should decrease to around

US$ 1,000 and US$ 1,200 per ha at full size. In the projects that started only very recently, the investment is still as high as US$ 10,000 and US$ 20,000 per ha. This, then, also contributes to very high initial *total* production costs per ha, which could be quite a burden in the initial years of operations.

4.1.2 *The problem of low initial seed yield*

The other main problem contributing to major cash flow issues in the initial years are low seed yields per ha (see agronomy chapter and Table 3). In the two oldest projects, the yield figures quoted were 450 kg and 500 kg dry seeds per ha. We should note that these quotes pertain only to the sections of the plantations that were actually yielding by 2011, which are generally still well below 100 ha. 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 a mere 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 project 1-2 tonnes, 3 tonnes, and 1500 L SVO respectively; 1500L SVO translates back into at least 6 tonnes of seeds, which seems rather unrealistic. But with good agronomical practices and professional management, ultimately 2-3 tonnes per ha may be achievable.

4.1.3 *Current cost/revenue situation*

Other elements contributing to an unfavourable cost/revenue situation include low oil content of the seeds, oil pressing inefficiencies and inadequate utilization of oil by-products. Regarding the seed oil content (Table 4), there seems to be a problem with one project whose respondent quotes a figure of 18%, which is well below generally quoted figures (see (FACT Foundation, 2010)). The respondent of this company explained that harvesting of ripe as well as raw seeds is practiced because it is bothersome and costly for labour to harvest the ripe seeds only, since jatropha seeds ripen unevenly in time. Hopefully the company will be able to abandon this practice in favour of a harvesting regime in which only ripe seeds are harvested. The other four plantations, which do practice this selective regime, report seed yields ranging from 30% to 42%, depending on batch & area.

Costs per L SVO of course also depend quite crucially on oil pressing efficiency and productive utilization of by-products, but none of the projects reported any data about this. The main reason is that none of the projects expect Mo_Pl4 has actually been pressing any seeds so far, and even its limited quantities most likely do not provide any reliable indicators of structural processing performance. It was also only Mo_Pl4 that has been the only project so far to realize any commercial turnover (US$ 18,000) from domestic sales of SVO. No export of jatropha oil had taken place at all at the time of our interviews in 2012.

The data given by the respondents about their total production costs so far (Table 4) are highly variable between projects, and hard to compare. Unlike the data discussed above, which show at least some degree of logical consistency, 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 tons SVO is much smaller: US$ 690 and US$ 417, respectively. *If* the data are correct, this suggests that these firms have substantial differences in their cost structures which are hidden from our view. The firm that started in 2009 predictably reports a higher figure of US$ 1,000-1,500 per ha/year (or US$ 2,041/ton 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.

4.1.4 Competitive outlook in relation to fossil diesel and palm oil

Finally, the three oldest projects gave their views on their prospective competitive position in the bio-oil market (Table 4), by comparing their product to two commodities – palm oil crude and fossil crude oil. These are the two closest substitutes for jatropha oil, and hence their prices constitute the lead sales prices for jatropha SVO. Their unpredictability is thus also a big unknown – perhaps the single biggest unknown – for the future economic feasibility of the plantation projects. All three respondents ultimately expect to be able to sell below the local fossil diesel price of Mtc 35-38. Their intended local SVO selling price ranges from Mtc 18,75/L to Mtc 35,80/L. Ironically, the respondents quoting the lowest and highest price in this range both claim that their price is in line with "the going price of palm oil crude on world markets". However, they seem to have a widely diverging view about what that price actually is: one refers to US$ 600-650 per ton oil, while the other talks about US$ 1,193 per ton. As Figure 12 makes clear, the two respondents refer to the price of palm crude at different points in time, as palm crude has experienced enormous price swings since 2008, just like crude petroleum.

So, which of the two managers quotes the more realistic price? We can say something about this when we consider the longer term palm price dynamics shown in Figure 12. The respondent who quoted US$600-650 per ton has quoted a rather conservative, realistic price, which seems a safe bet. Given the fast structural economic growth in Asian countries, it should be considered highly unlikely that the world price of palm oil crude will sink below US$ 600 per ton for prolonged periods of time within the coming decades, even in spite of the recessionary conditions in Europe that show no signs of abating. In contrast, the price of US$ 1193 quoted by the other respondent seems too optimistic when viewed against the palm oil price behaviour shown in Figure 12. During the past few years, the palm oil price attained this level only during two rather brief periods of peak oil prices. 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, which is still well below the price used by the respondent.[3]

3 Own calculations from data provided on: http://www.indexmundi.com/commodities/?commodity=palm-oil&months=300 (consulted 28-04-2013).

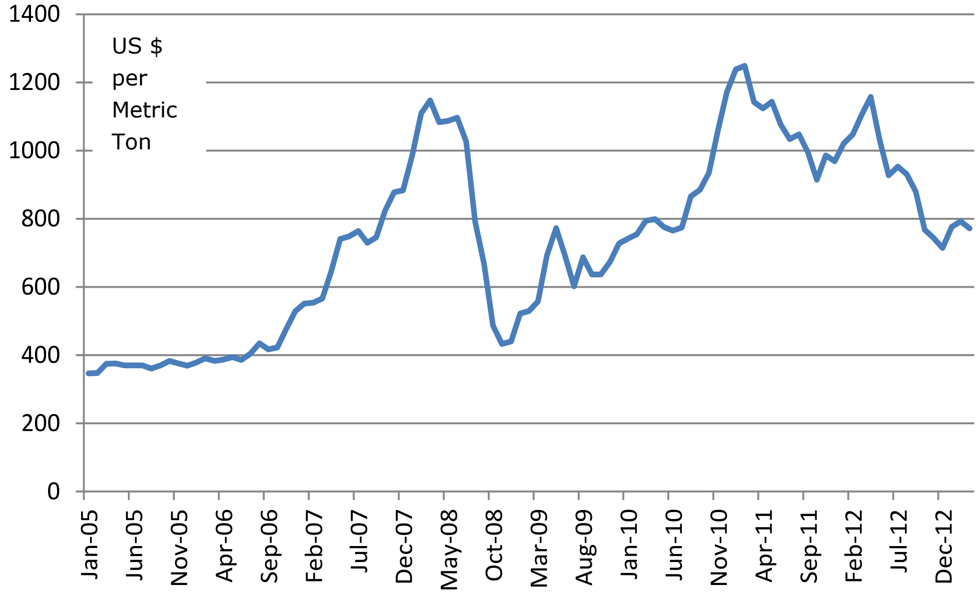


Figure 12: Palm oil monthly price: Jan 2005 - March 2013

Source: http://www.indexmundi.com/commodities/?commodity=palm-oil&months=300 (consulted 28-04-2013)

In van Eijck et al. (submitted), implications for profitability were estimated for the case of a large Tanzanian plantation which is based on similar yield, cost and revenue parameters as the Mozambican plantation projects discussed in this report. Using an average dry seed yield of 1.1 ton/ha, an SVO sales price of US$1 per litre (= the actual SVO price level in Eastern Africa in 2011-13) and a 20 year horizon, the cost-benefit calculations reveal very marginal profitability: the payback period would lie in the region of 12-13 years and the (real) Internal Rate of Return (IRR) would be approximately 17%, quite close to the real discount rate of 8.2%; and this still includes income from carbon credits at US$ 5 per ton. Without the carbon credit revenue, the estimated IRR comes down to a mere 15%, and the payback period lengthens to 14 years. This is not at all an attractive scenario, as it leaves hardly any leeway for unexpected setbacks. In sub-Saharan Africa in particular, project risks and delays are generally substantial. Higher oil prices and/or higher yields are clearly necessary to make large plantation projects viable, preferably a combination of the two. For example, if a seed yield of 2 t/ha could be obtained (without cost increase), the estimated IRR would increase to 22%; and if an SVO price of US$2 could be obtained (still with the original yield of 1.1 t/ha), the IRR would rise to 26%.

4.1.5 Conclusions

- The evidence taken together points to big economic difficulties for the large jatropha plantation model. In the initial decade, cash flows problems are likely to be substantial due to the slow yield curve of the crop, as well as yield uncertainties and risks still associated with its undomesticated status. This is paired with the need for big up-front fixed investment requirements and the inevitable difficulties associated with doing business in an environment with poor physical infrastructure and weakly developed policy institutions. In such environments, projects run the risk of experiencing unexpected changes in economic policy of host countries, which may impact on financial feasibility.[4]

- There are big pressures on the companies by various stakeholders to perform in accordance with "societally responsible innovation" ethics, which is good but also costly. This kind of business model can and should only be undertaken with investors with very deep pockets, a lot of patience, and a strong mission to improve local social conditions so that social benefits are considered as integral parts of the rewards, which make it worthwhile to persevere. The enduring economic recession in Europe, which has made commercial borrowing by western investors substantially more difficult and costly, has undoubtedly contributed to an unfavourable financial climate for this ambitious and risk-prone business model after 2008 as well.

- From the perspective of the conditions on the international fossil and palm oil markets it seems possible for large jatropha plantations to break even within about one decade from start of operations, but high profits should not be counted on. African countries should not count on seeing substantial profitable jatropha plantation ventures arising on their soil for quite some years. The initial idea of many African governments, that jatropha could help realize substantial savings in their energy imports, or generate foreign exchange from SVO exports, has turned out to be a mirage. Therefore, it is not wise to develop biofuel policies that stimulate large jatropha plantations, especially with the current status of western financial markets and because more reliable seed varieties are not yet available.

- In view of the manifold problems, risks and uncertainties it seems best to refrain from commenting on the Internal Rate of Return and Net Present Value estimates given by some respondents in the interviews.

4 For instance, one of the project managers reported that an export tax of Mtc 10/L has been levied by the Mozambican government recently. In the respondent's view this presents a danger to the industry, and it may affect its own future operations.

Table 3: Data for financial analysis of large plantations (part I)

Company id. nr	*Starting year of Jatr act*	*Turnover 2011 (US$ 000)*	*Area planted up by 2011 (ha)*	*Projected full size (ha)*	*Projected break even year*	*Expected NPV*	*Expected IRR*	*Actual seed yield 2011 (t/ha/y)*	*Projected mature yield (ha/y)*
Mo_Pl1	2009	0	200	10,000 (by 2017)	2020	Net CF: €8m/y or $600/t oil, without by-products or carbon credits	50%	0.24/ha (from 1st productive 25 ha)	1,500 L. VSO
Mo_Pl2	2007	0	1,500	5,000 (by 2014)	2015	N.A.	26%	0.45/ha (from 1st productive 60 ha)	3 t seeds
Mo_Pl3	2007	18	2,311	2,311 (down from original 10,000)	2014	$15.9m (40 y. horizon, r = 5%)	7% (by 2016)	0.50/ha	N.A.
Mo_Pl4	2010	0	165	~15,000	2020	N.A.	N.A.	0.06/ha (from 1st productive 78 ha)	N.A.
Mo_Pl5	~2010	0	240	50,000 (but awaiting better varieties)	2020	N.A.	N.A.	0.06/ha	Originally 5t seeds, later reduced to 1-2t

Table 4: Data for financial analysis of large plantations (part II)

Company id. nr	*Total investment costs so far (US$ m)*	*Investment costs for planted-up area by 2011 (US$/ha)*	*Projected total investment costs at full size (US$/ha)*	*Total production costs so far (US$/ha/y)*	*Estim. oil content of seeds*	*Intended selling price (US$/t SVO)*	*Intended selling price (Mtc/L oil)*	*Local fossil diesel price (L)*
Mo_Pl1	2m	10,000	N.A.	$1,000-1,500/ha/y (= $2,041/t SVO). Should ultimately decrease to $500-750 ha/y.	35%	US$ 600-650 (= est. price of palm oil)	Mtc 18.75	Mtc 38
Mo_Pl2	5m	3,333	1,000	$667/ha/y (= $690/t SVO)	31%-42%	US$ 850	Mtc 25.50	Mtc 35
Mo_Pl3	12m	5,193	1,200 (according to original plan)	$176/ha/y (= $417/t SVO)	30%	US$ 1,193 (= world market price of palm oil crude)	Mtc 35.79	Mtc 38
Mo_Pl4	N.A.	N.A.	N.A.	No production yet	18%	N.A.	N.A.	Mtc 38
Mo_Pl5	4.8m	20,000	N.A.	Currently €400 ha/y, should decrease to €200 -220 ha/y	40%	Not yet determined (no sales yet)	Not yet determined (no sales yet)	Mtc 40

4.2 Outgrowers

Outgrowers are present in all three countries, although in Mozambique the processor-outgrower model is limited to just one project in the North. This project started only three to four years previous to the time of our survey. Due to the limited experience that could be accumulated during such a short time, only a few outgrower interviews were conducted in that country. In Tanzania and Mali, on the other hand, the processor-outgrower model is the dominant jatropha business system. In Mali, the seed trade and/or processing are often conducted on a cooperative basis by organized groups of outgrowers. Some of these projects also claim to cultivate fields that belong to their cooperative. There are 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 are present in Tanzania. In both countries we also find one or two larger, more commercially-oriented outgrower-processor arrangements in which the processors are owned by western foundations and/or private investors.
As discussed in the agronomy chapter, outgrowers cultivate jatropha in two basic arrangements: fields and hedges. Within each of these arrangements we can make a further distinction between those who intercrop with other types of plants, and those who don't.

4.2.1 Revenues from seed sales

Table 5 and Table 6 give annual (2011) seed yield and gross revenue from seed sales for outgrowers cultivating jatropha older than two years in hedges and on fields, respectively. Only those respondents who provided estimations about both seed yield and sales value were listed in these tables. A large number of Malian outgrowers did not, or could not, provide any revenue information; hence they had to be excluded from this business case analysis. Therefore this analysis covers only 13 hedge cases and also 13 field cases, a substantially lower number than in the agronomy chapter. Note that the observation numbers in the tables also do not correspond to the numbers used in the agronomic analysis.

Essentially the revenue data given in Table 5 and Table 6 can be interpreted as gross value added (net profit + labour costs). Given the impossibility for many respondents to estimate the labour requirements of their jatropha, let alone to put a value on the hours they spent, we cannot reliably estimate these costs and deduct these from the gross sales figures. Other costs, mainly expenses for some hand tools, are so low that we considered them to be of negligible influence for this analysis.

The tables show a large variability in terms of lengths of hedges and sizes of fields. The shortest hedge is 30 metres, whereas the longest one is 1,200 metres. The size of fields varies between 0.01 ha (basically just a few jatropha trees) and 12.06 ha. In the agronomy chapter we have already seen that intercropping arrangements are also extremely diverse, both in terms of combinations of plant species used as well as plant spacing, weeding, and nutrient & pest management regime. Given this extreme variability and the relatively limited number of observations in different ecosystems, it was concluded in that chapter that a formal quantitative investigation of determinants of seed yield is impossible to conduct. By implication, we also cannot carry out a similar analysis for the revenue from seed sales, which is influenced by even more variables than seed yield (such as: costs incurred, distance to collection point, regional and temporal market conditions, and prices of close substitute products). Instead we make more basic observations around the data given in two tables.

First, we normalized the revenues per 100 metre hedge and per ha, respectively. At this point we still neglect the presence or absence of intercropping, which will be considered further below. Three very small field cases (Ta_O19, Ta_O23 and Ta_O25) were normalized to a 1-ha equivalent by assuming 3 metres spacing between rows of jatropha (as indicated by all respondents who were cultivating in the same village for the same processor). A 100m hedge case is of course not readily comparable to a 1ha field case. We can only use the normalized figures to make the cases *within* the same main categories (hedge or field) somewhat more comparable.

Table 5: Revenue data for jatropha hedge growers, 2011, all countries, n=13

Outgrower Id. Nr	*mono or mixed cropping*	*total length*	*Total gross sales revenue in 2011 (US$)*	*age of jatropha (y)*	*Revenue per 100m hedge equiv. (US$)*
Ma_O1	hedge, wide spacing, mono	1,200 m	5.80	4	0.48
Ma_O26	hedge, mono	30 m	6.80	6	23.00
Ta_O1	hedge, mixed	80 m	9.40	11	11.75
Ta_O2	hedge, mono	163 m	1.62	3	0.99
Ta_O3	hedge, mono	203 m	3.13	11	1.54
Ta_O4	mainly hedge, mixed	80 m	9.40	11	11.75
Ta_O5	hedge, mixed	153 m	12.52	10	8.18
Ta_O6	hedge, mono	110 m	2.34	8	2.13
Ta_O7	hedge, mixed	140.5 m	70.31	4	50.04
Ta_O9	hedge, mono	111 m	7.03	4	5.00
Ta_O10	hedge, mono	261 m	135.00	12	51.72
Mo_O2	hedge, mono	600 m	25	3	4.17
Mo_O3	hedge, mono	600 m	28	3	4.67

When we examine the total gross revenue and the normalized values presented in Tables 5 and 6, we can say the following:

As far as the 13 hedge cases are concerned, the average actual revenue obtained in 2011 was a little over US$ 24, but with a very large standard deviation of US$ 38. The reported maximum was US$ 135.00 but this case was considered a possible outlier in the agronomic analysis, along with the highest-but-one performer, who got US$ 70.31. If we would exclude these two cases, the maximum total revenue was just US$ 12.52, and the minimum was a mere US$ 1.62.

Table 6: Revenue data for jatropha field growers, 2011, all countries, n=13

Outgr Id. nr	*mono or mixed cropping*	*total size*	*Total gross sales revenue in 2011 (US$)*	*age of jatropha (y)*	*Revenue per ha equiv. (US$)*
Ma_O5	field - intercrop	0.25 ha	7.30	4	29.2
Ma_O7	field - no intercrop	4.00 ha	10.90	11	2.73
Ma_O20	field - no intercrop	12.06 ha	7.30	3	0.61
Ta_O11	field - intercrop	0.81 ha	3.00	10	3.7
Ta_O12	field - intercrop	0.40 ha	2.81	8	7.03
Ta_O13	field - intercrop	0.20 ha	0.38	5	1.9
Ta_O19	field - intercrop	0.03 ha	1.88	2	15.67
Ta_O20	field - no intercrop	0.81 ha	1.88	3	2.32
Ta_O21	field - no intercrop	0.61 ha	16.88	4	27.67
Ta_O22	field - no intercrop	1.21 ha	28.13	7	23.25
Ta_O23	field - no intercrop	0.03 ha	1.88	3	15.67
Ta_O24	field - no intercrop	0.20 ha	11.25	4	56.25
Ta_O25	field - no intercrop	0.01 ha	1.88	4	46.89

The normalized revenue figures also still display high variability, due to the highly variable seed yields per unit of surface area. There is also some effect from differences in seed prices received by the outgrowers, but this is a very minor influencing factor in comparison. The average receipts per 100 metre hedge in 2011 were US$ 13.49, with a standard deviation of US$ 17.69. However, the two possible outliers above, again show remarkably higher normalized values than the others. If we would exclude these cases again, the normalized average comes down to US$ 6.72 per 100 metre hedge, the maximum reduces to US$ 23.00, and the minimum is just US$ 0.48.

4.2.2 *Opportunity costs*

By all accounts, these amounts are extremely modest, especially given the fact that these revenues should also compensate for labour time spent. 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 metres at the most, with a correspondingly low total income earning potential. In Mali, average farm sizes are much bigger, as large extended families tend to jointly cultivate 20-30 ha[5], but here we have to consider the large total family sizes in relation to the jatropha hedge earning potential. It is therefore not surprising that our survey registered many complaints from farmers about low revenues, which they associate primarily with agronomic conditions such as poor soils and insect attacks, rather than low market prices. It is also not surprising to find that in areas where more productive opportunities for labour and the land exist, farmers show little interest in cultivating jatropha. As pointed out by the general manager of a Tanzanian processor whose firm covers different regions of the country, labour power rather than land is often the dominant constraint on family farm earnings.[6]

Still, land can also have a positive opportunity cost, even hedge/boundary land. This was found to be especially the case in areas whose 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 fixation on nitrogen in the soil. Subsequent personal observations in Arumeru and Kilimanjaro regions in Tanzania during spring 2013 also attest to the fact that hedges predominantly consist of mixed plantings of various shrubs, and may even include a variety of trees. A representative sample of species include those listed in Appendix table A, along with their known values for humans, animals and the environment, even though these values cannot be readily expressed in monetary terms. The main point emerging from this exposition is that in more fertile areas with adequate rainfall, it should not be assumed – as has often been done among jatropha researchers, consultants and project managers up to now – that jatropha would always be the best use of boundary land of small farmers because “nothing else productive could be done with it anyway”.

The situation in dryer, less fertile, eroded and geographically remote conditions can be quite different. In such situations, there are fewer alternative hedge crops for jatropha that can thrive, even though it is also very difficult to get a decent seed yield from jatropha in these circumstances. The same jatropha processor quoted earlier pointed out that there is great interest among the small farm populations to collect and sell jatropha seeds to his company in environmentally hostile areas such as Singida, even though the farmers earn much less from the shrub per unit of surface area than in the more climate-friendly and prosperous areas of Northern Tanzania. Whatever little cash the seed sales generate is still appreciated by them, in view of the severely limited alternatives open to them.

The revenue patterns shown by the 13 field cultivation cases also show substantial variability. The average total revenue obtained in 2011 was US$ 7.34, with a standard deviation of US$ 7.94. The maximum was US$ 28.13 and the minimum was a mere US$ 0.38. Averaging the per-ha normalized values results in US$ 17.91, with a still very large standard deviation of US$ 18.07. The maximum was US$ 56.25 per ha, and the minimum was just US$ 0.61. This should be considered a very low revenue per unit of surface area. The questionnaires in Mali in particular registered many complaints from farmers about low yields/revenues. The conditions in Mali appear to be harsher/dryer than those in the other two countries, and there are severe problems with termite attacks (see the discussion in the agronomy part). As many Malian farmers planted jatropha on former food

5 Information obtained from the Managing Director of Mali Biocarburant SA., 2012.
6 Information obtained from the General Manager of the former Diligent Tanzania Ltd in a personal conversation, Arusha, April 2013.

crop land, they are understandably dissatisfied, as this land definitely carries a positive opportunity cost.

We might get some more insights from the data by relating the revenues from jatropha per 100m hedge and per ha, respectively, to the age of the crop. One might expect jatropha to generate more cash as the shrubs mature. Seed yields generally begin at age 2 or 3, but plants only mature fully at 6 to 7 years. Scatterplots relating the age of the jatropha plants (in years) to normalized revenue are contained in Figure 13 and Figure 14 for hedges and fields, respectively. However, an upward pattern in the scatters cannot be detected. If we disregard the two likely outliers, the hedge scatterplot displays no systematic pattern whatsoever. The practice of intercropping with other species in the hedges also does not seem to have any effect on revenue. The field scatterplot likewise does not indicate any relationship between jatropha age and revenue per ha. The only noteworthy point to note is that, with one exception of observation Ma_O5, practicing monocropping seems to be associated with somewhat higher revenues from jatropha per ha than mixed cropping, which is entirely logical. Unfortunately, due to lack of revenue data for the other crops, we cannot establish how the total revenue per ha from those practicing intercropping compares to total revenues from monocropping of jatropha.

We can conclude that good insights into revenues from jatropha can only be obtained from much larger surveys, to be able to deal with “noise” in the data from problems like, limits on what respondents can remember, and what information they want to share.

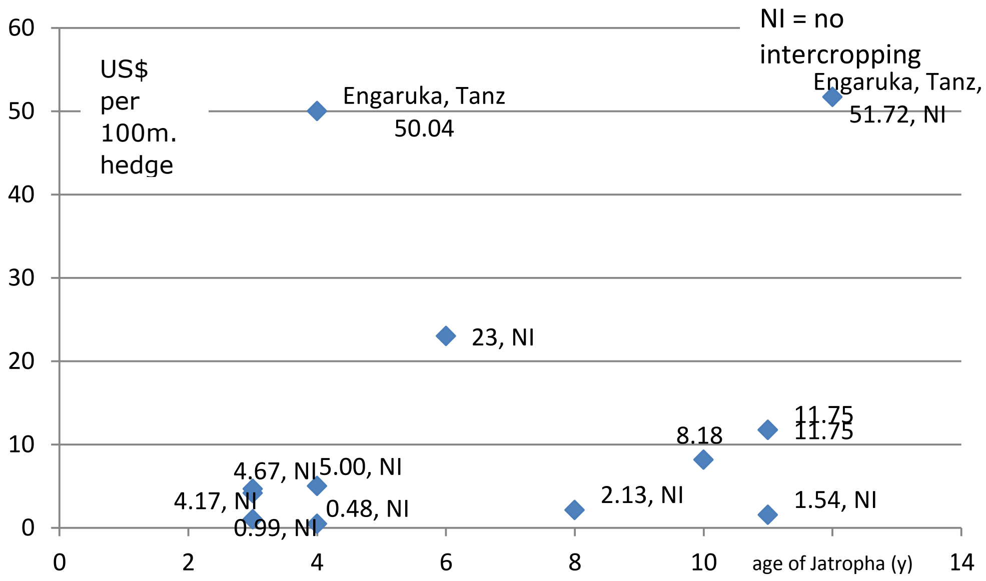


Figure 13: Gross annual revenue from jatropha seed sales for hedge growers in 2011, per 100 m. hedge (n=13)

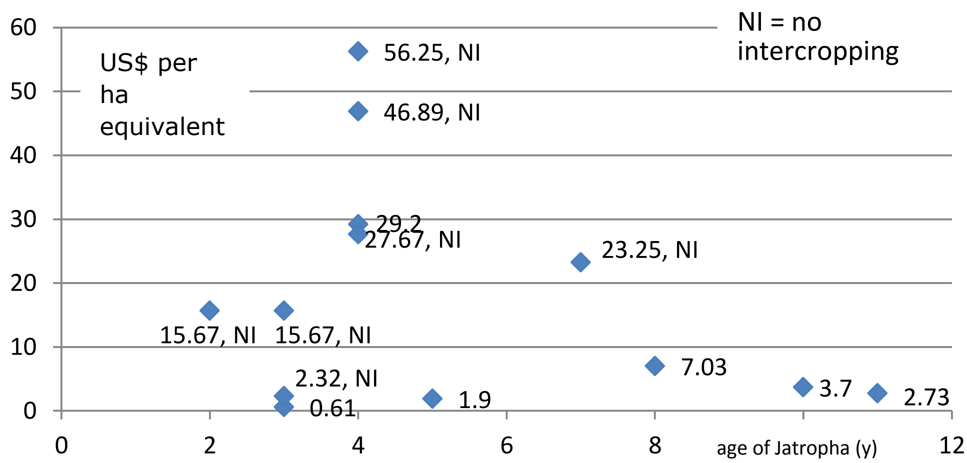


Figure 14: Gross annual revenue from jatropha seed sales per ha for field growers in 2011 (n=13)

4.2.3 Conclusions

- Because of low and unreliable yields, and importance of land and labour for other types of cultivation, jatropha is in economic terms an unviable crop for smallholders, except in environmentally and economic disadvantaged areas where people do not have attractive alternative income earning opportunities. In those circumstances smallholders do value the plant. There is little point in promoting it in relatively more prosperous rural areas.
- In general, the experiences with jatropha as a field crop have been so disappointing that it seems quite unwise to continue to promote it as such, even in intercropping arrangements. Jatropha hedges – possibly intercropped with other useful hedge species - are generally speaking the only feasible and desirable option for small-scale jatropha outgrowers, but even then it always remains crucial to first assess the details of the local situation (mindful of the first conclusion) before taking a decision to promote it among the farming population.

4.3 Processors

Of all three types of jatropha activities encountered in our surveys, the processors are the hardest to analyse, as they are a very mixed bag both in terms of size (turnover, size of sourcing area covered) as well as strategic orientation & value proposition. We encountered pure non-profit entities aiming primarily for increased well-being of local farming communities in non-financial terms, but also commercial for-profit entities, albeit there was none without a broad concern for the wellbeing of local society and an eye for maintaining the integrity of the environment. The for-profits in our sample are thus interesting companies which try to practice some form of societally responsible entrepreneurship. 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 that were entirely funded by Japanese commercial investors, who appeared to use this construction as a bargaining chip to also gain entry for the conduct of commercial activities in the countries concerned.

Given this variety it is almost impossible, nor fair, to compare the entities in our survey in order to determine how well or poorly they are achieving their aims and targets. In principle, each of them deserves to be considered as an individual case in its own right, and assessed against its own objectives and how these match with the local society and milieu. However, data limitations do not allow an in-depth assessment of each of them. We will take recourse to drawing out some more general patterns and mentioning some worthwhile illustrative examples that are broadly indicative of achievements and bottlenecks experienced.

Table 7: Basic characteristics of processors for financial analysis

Id. Nr	start of Jatr activ.	Throughput 2011 (tons seeds)	Turnover 2011	Profit 2011 (Y/N)?	Jatropha surface 2011	Inter-planting (Y/N)	Nr of outgrowers in 2011	Planned full size (year)
Ma_Pr1	2007	1t (1st harvest)	US$300 (15 CFA cts*1,000)	N	2,546 ha	y	approx 2,546 (1 ha p.p.)	initially 1,300 ha (by 2009) but already reached 3,646 ha in 2012
Ma_Pr2	2007	10t (from outgrowers only)	US$ 3,000 (15 CFA cts * 10,000)	n.a.	between 3,300-5,400 ha own plantations/fields + outgrowers	y	4,000+ members	25,000 ha in fields (by 2030)
Ma_Pr3	2010	no harvest yet	none yet	N	50 ha	y	18	not given
Ma_Pr4	2009	Still negligible	negligible (price per kg will be 15 CFA cts)	N	not given	y	not given	not given (2012)
Ma_Pr5	2008 (a)	1.74t (from outgrowers only)	Estimation: US$ 522 (15 cfa cts * 1740)	N	3,500 ha (no yield yet)	n	30 (on 58 ha total)	50,000 outgr; 10,000 ha
Ma_Pr6	2006	5t	Estimation: US$ 1,500 (15 cfa cts * 5,000)	n.a.	450 ha; 25,000m hedge	y	248 (fields) and 90 (hedges)	1,000 ha with 500 outgr; 50,000 m hedge with 99 outgr
Ma_Pr7	2009	17.8t	Estimation: US$ 5,340 (15 cfa cts *17,800)	Unclear	765 ha	y	1,200	765 ha; 1,200 outgr; 344,000 m hedges;

Ta_Pr1	2005	approx.400t	Roughly US$ 180,000	N	800,000-1,000,000 m hedge, calculated from total throughput and average 0.5-0.4 kg seeds/m. hedge	some	approx 40,000	>100,000 outgr
Ta_Pr2	2011	no harvest yet	none yet	N	2 acres	y	40 individual outgr + 2 schools	not given
Ta_Pr3	2010	no harvest yet	none yet	N	5 acres	y	25	78,000 outgr
Ta_Pr4	2007	4t (approx. 1000 L SVO)	self use only; approx. $1,333 if valued at local SVO price	N	60 acres (30 planted in 2007, 30 in 2009)	not so far, but starting	none	60 acres, own fields
Ta_Pr5	2008	0.5t (approx.100 L SVO)	US$ 200	Y (US$37 in total)	6 acres (5 as fence + 1 as demo plot)	y	72	200 outgr
Ta_Pr6	2008	unknown	unknown	N (c)	1 acre (Research Plot in Goba) + unknown amount of hedges	n	200 in Engaruka ('08) + 200 in Leguruki ('08) + unknown nrs in Selela ('09) and Mpanda	5,000 outgr and 55 MFPs
Ta_Pr7	2005	0.5t (this is 62.5 kg/ha, or <0.06 kg/tree)	self use only	N	8 acres (interplanted)	y	none	8 acres own field
Ta_Pr8	2005	0.5t (0.4 kg/tree)	self use only	N	2 acres	n	none	2 acres own field

Ta_Pr9	2009	147 t jatropha seeds + approx. 50/60t Croton seeds (from outgrowers only)	US$ 68,600 from Jatr, probably around US$100,000+ in total	N	300 ha plantation + unknown nr of outgrowers	?	Not given	400 ha + unknown nr of outgr (by 2017)
Ta_Pr10	2006	21.5 kg/acre*25 acres (or 0.07/tree)	negligible	N	25 acres	n	Estimation: 16,800 outgrowers with 12,432ha jatropha (2008) (b)	16,800 outgr with 9,600 ha J.; approx 40 t seeds or 10-15,000 L SVO after end of 2008 (b)
Mo_Pr1	2009	0.5t from 3 ha (trial field only) in 2011; 4.8t in 2012	US$ 4,800 for self use in vehicles, generators, soap production (d)	N	1,800 ha hedge outgrowers + 3 ha own trial plot	N	1,800	no specific goal

Notes:
(a) Respondent said 2012, but according to other data from the questionnaire jatropha was already planted from 2008 onwards.
(b) Source: Prokon Renewable Energy Ltd, as cited in Loos (2008).
(c) The production costs of $1.67 per litre SVO were higher than the local fossil diesel price of $1.33 per litre.
(d) US$ 4,800 (192,000 mtc) turnover seems to be a gross overestimate, as no VSO was produced in 2011 yet.

An overview with basic characteristics of the processors is given in Table 7. Mozambique features only peripherally with just one processor-outgrower scheme. In contrast, there are many such arrangements in Mali and Tanzania. The earliest processing activities were started in 2005; all of these were located in Tanzania. In 2006 this is followed by the first Mali processor-outgrower arrangement. These early cases are obviously of special interest in view of their longer experience. These early initiatives were followed by several new projects 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. In that sense, the picture is similar to what we found for the Mozambican large plantations.

To structure the discussion about the processors, we turn to the physical throughput (measured in tons of dry seeds handled) in 2011, turnover (gross revenue) in US$ in 2011, the estimated surface area covered by the associated outgrowers and own (trial) fields in 2011, and estimated numbers of associated outgrowers in the same year. The differences between the schemes in these respects are enormous.

4.3.1 Big processors

The biggest one by far is a Tanzanian processor established in 2005 (Ta_Pr1), who sourced approximately 400 tons dry seeds from different regions from an estimated 40,000 hedge outgrowers, i.e. just 10 kg per outgrower on average. Many of its farmers are located in environmentally adverse areas, where they had already been using jatropha as boundary fences for decades; indeed, they had been using the plant for this purpose long before the advent of 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 there were no major acceptance issues 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 such large numbers of very small-scale suppliers is mind-bogglingly complex given the poor state of rural road infrastructure in Tanzania. The manager of the company explained that the firm has set up several hundreds of regional collection points which serve as focal centres 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 tons, sourced from 50,000 farmers with established hedge stock. Its total turnover in 2011 was around US$ 180,000 from sale of approximately 160,000L SVO, a lot of fuel pellets and briquettes made from seed cake, and raw seedcake as fertiliser; all destined for the local/national 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 focus on the local market for the time being.

The turnover level 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 of the firm by the end that year. However, in view of the promise shown by its business model by then, the manager has since been able to locate a new sponsor which has enabled the company to restart operations in early 2013, albeit still with rented equipment and at a somewhat reduced scale of operations. Meanwhile it is vigorously researching different ways in which increased process efficiency and better utilisation of by-products and waste products could be achieved in the future, if it gets an opportunity to establish a full own production line again. Different ways of producing biodiesel are also part of this investigation. 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 responsible jatropha project in the three countries covered by our survey.[7]

The next-biggest operation (and competitor of the above firm) is a non-profit activity for local energy generation, also located in an environmentally deprived region of Tanzania (Ta_Pr9). It is funded by a Dutch private foundation. This company is however, not a self-standing entity and cannot be assessed as such; rather, it 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 set its prices in a way that enables it to run on a no-profit, no-loss basis, while the profits are supposed to accumulate within the downstream businesses. 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 tons of jatropha in seven months, and another 50-60 tons or so of Croton in the jatropha off-season. The consortium as a whole has leased a 300 ha plantation which is mainly being planted up with jatropha, but this is not yet yielding substantially. Its dominant business model is therefore sourcing from independent outgrower farmers in the region. In any case, the 300 ha is too small to ever be able to fully substitute for the external sourcing. The company has not reached its break-even point by far and expects to need several more years. 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 are plans to start producing biogas from the seed cake for local electricity generation.

These two firms (as well as Mali Biocarburant, not covered by our survey) are in a league of their own. All other entities listed in Table 7 are (still) very modest in size. There was also 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 centred around the promotion of intercropping of jatropha on farmers' food crop land, instead of concentration on hedge cultivation.

4.3.2 Mid-size processors

7 Another notable positive example is Mali Biocarburant in Mali, but this firm was not covered in our survey.

The mid-size segment of processors is formed by a group of six projects processing between roughly 1 and 17 tons in 2011. Five of those are located in Mali and one in Tanzania. Two of these Mali projects are development projects with social objectives such as increasing income generation for small farmers, and/or fostering rural energy supply (Ma_Pr1 and Ma_Pr6). The first of these has already reached, and even superseded, its intended full size by 2011. In that year it worked with 2,546 outgrowers on an equal number of ha (1 ha per outgrower) . The other development project is still expanding. It sourced from 450 ha field jatropha and 25,000m hedge jatropha in 2011, and broadly wants to double this to 1,000 ha fields and 50,000m hedges by 2016. Its current numbers of outgrowers are 248 (with fields) and 90 (with hedges), and this should grow to 500 (with fields) and 99 (with hedges).

The other four projects in the medium-size segment are (more or less) commercially orientated activities, some of which have substantial ambitions for future expansion. For instance, there is a large cooperative that sells seeds to processor Mali Biocarburant from an estimated 3,300-5,400 ha involving 4,000+ farmer members. Ultimately, this cooperative wants to cover an area of 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; one of them even describes itself as an open ended "Action Research" project which, by the nature of action research, does not have a well-specified end goal. Another one of these Malian projects has its own plantation of 3,500 ha which is however not yet yielding. It also has 30 outgrowers on 58 ha own fields. Its output so far has only come from this outgrower jatropha, dating back to before the firm's establishment. Upscaling to the intended ultimate size of 50,000 ha plantations and 10,000 outgrowers will still take a number of years. Another Malian project had 1,200 outgrowers cultivating jatropha on 765 ha. This firm wants to expand substantially into hedge jatropha.

Some of the plans outlined by these firms seem a tall order, although the initial investment requirements of this business model are much lower than those of the centralized plantations discussed earlier. But 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 different regions of that country, although older studies - for example the work by Henning referred to in the agronomic part - already referred to widespread use of the shrub as an effective windbreak in the country. At the same time, our survey results from processors and outgrowers in Mali appear to indicate that the projects in that country have involved themselves in a lot of new jatropha planting as well.

The one Tanzanian outfit in the mid-size processor segment is actually a mini plantation. It is managed by an individual farmer who cultivates 60 acres with jatropha and who processes his own seeds for self-use in vehicles and generators. It is an "outlier" case, which does not fit well into any of the three main business categories distinguished in this report; it was considered to be too small and too different in orientation to be grouped with the large Mozambican plantations. This project has no expansion plans; in fact the experiences with the crop since 2007 suggest disappointing performance, according to the respondent. This is the reason why the farmer/entrepreneur has decided to introduce intercropping with flowers on the area. If this still does not work out satisfactorily, his jatropha cultivation is likely to be discontinued altogether.

4.3.3 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 as small local projects without desire for substantial upscaling or replication in due course. Examples of the former are two young Malian companies and the single Mozambican outgrower project. Another example is an experimental project financed by the Dutch Fair Trade movement (Ta_Pr3) which started with agronomic experiments involving a limited number of farmers in the first instance.

Examples of the second category are only found in Tanzania, in the form of two religious communities who decided to cultivate a few ha with jatropha for own use since 2005. These projects have not performed well, mainly because of climatic conditions unsuited for jatropha. One of these projects (Ta_Pr7) in fact stopped its jatropha activities soon after our survey was conducted. The other is still continuing despite very poor yields, mainly because it is a useful part of the education 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). It can be seen from Table 7 that this activity is in fact the only jatropha processor project in our survey that had made a profit in 2011, namely US$ 37 on a total turnover of US$ 200 (18.5%). The money is earned by making medicinal soap from SVO resulting from manually pressed jatropha seeds. Despite the inefficiency of the primitive press, it is possible for this project to turn a profit because the equipment costs are very low, and the soap commands a good price. The process is labour intensive, but rural labour is very cheap in Tanzania. This model is, however, not amenable to upscaling due to the limited local market for relatively expensive jatropha soap, as well as the arduous nature of the oil pressing. There may be some room for similar localized projects in different areas of Tanzania and in the other two countries, but they are bound to remain small localized activities.

One small Tanzanian development project (Ta_Pr6) does not fit either of the two types of small projects described above, in the sense that it was indeed established with upscaling ambitions, which did however not (yet) materialize. This was a programme established as a development model for village-level energy provision by means of Multifunctional Platforms (MFPs). However, the initial business model involving cooperative management did not perform well. The local seed procurement price was uncompetitive in comparison with prices paid by the big sourcing companies, so that farmers preferred to sell their seeds to these firms instead. This project had significant replication ambitions with plans speaking of 50 additional MFPs to be established in as many villages. These plans initially could not be realized and output volumes have remained minimal. The programme management has recently rethought the concept in favour of promotion of individual entrepreneurship and management of the MFPs, and will still try to realize its initial aims of providing electricity to at least 50 unelectrified villages.

4.3.4 *Discussion and conclusions*

It is hard to draw out clear financial performance patterns from so much variety; moreover, data for investment costs and production costs are mostly missing. Still, we can make some broad observations about key good and bad principles, based on the data in Table 7 and supplementary information provided by some of the respondents:

- Mainly, the "business case" for processors is still largely unproven. Most projects are still in an early stage of establishment and are still far removed from sufficient scale in their operations. In many case the road to their break even points is likely to be almost as long and winding as that of the large mono plantations discussed earlier, although the respondents themselves still appear to be rather optimistic in this respect, judging by their view about the time needed to reach the break-even point or full size (summarised in Table 8).
- A few relatively more mature cases do show some signs of promise. These companies are managed well, and have adopted a business model that is suitable for their particular circumstances. These characteristics have enabled them to start reaping economies of scale in processing. They have understood that making money from a very low value crop like Jatropha implies the need to pursue economies of scale relentlessly; unless one aims to exploit the high value properties of the oil for specialized non-energy products commanding small niche markets, as the soap making project is doing.
- Making money from low value Jatropha as an energy crop also means that reaching high efficiency in all key stages of operations is vitally important, and that by-products should be utilized to the full. It is evident that the firms in our survey generally still have some way to go to achieve full mastery over their production processes, even the relatively simple processing operations as they exist now (Box 1).

Box 1: Scope for improvement in production processes

The conversion efficiency percentages returned by the respondents in Table 8 are illustrative of some of the problems still being faced in his domain. The majority of respondents did not give any answer to the oil efficiency question at all, although some of them were pressing seeds by 2011. Others returned percentages of 27% and 33%, which should be rejected as unrealistic. The valid answers appear to be in the region of 20% to 25% (depending on the efficiency of press technology, and whether or not SVO filtering is taken into account). The 22% reported by the largest Tanzanian processor should be considered as a good benchmark for mechanically pressed SVO that is filtered to 1 micron. This statistic is based on regular measurements. Until now, only a few companies in our survey seem to have set up internal performance monitoring and feedback systems that can give them key insights into the important factors underlying their financial performance.

- At the same time, we can perceive many signs that process improvement efforts and activities to improve by-product valorization are indeed underway in the more forward looking firms (box 2). However, the costs of such innovations are high and the pay-off tends to be very slow. Not all the ideas will succeed; some will turn out to be over-complex, others simply impossible from a logistical point of view. Being in an African environment with poor innovation support structures (such as the absence of reliable laboratory facilities) does not help either. Active, engaged support and collaborations with overseas non-commercial actors as well as funding at concessionary conditions will remain crucial in order to sustain such difficult processes over a period of years.

Box 2: Innovation ideas being pursued by processors

Recent innovations include generating biogas for electricity generation from seedcake, and using the slurry as a highly effective fertilizer for Jatropha or food crops. Other ideas have included gasification of fruit hulls to drive a gas engine to supply one's own electricity, and applying the biochar to fields of outgrower farmers at cheap rates. One firm is exploring possibilities for extraction of seed cake ingredients for higher value products made by the chemical industry. Another is planning to utilize the filtering sediment for all-purpose soap which could potentially make an excellent substitute for Unilever's Sunlight bars.

Table 8: Further engineering-economic indicators for processors

	Throughput in 2011 (seeds)	*Conversion efficiency*	*Oil content of seeds*	*Estim. BEP year, or year full size to be attained*	*Costs of operations 2011*	*Total inv. costs*
Ma_Pr1	1t (1st harvest)	n.a.	n.a.	initially 2009, but growing on		
Ma_Pr2	10t (from outgrowers only)	n.a.	33%	2030		
Ma_Pr3	no harvest yet	n.a.	30-34%	n.a.		
Ma_Pr4	Still negligible	n.a.	n.a.	2012		
Ma_Pr5	1.74t (from outgrowers only)	n.a.	n.a.	2018		
Ma_Pr6	5t	n.a.	35%	2016		
Ma_Pr7	17.8t	n.a.	24%	2014		
Ta_Pr1	~400t	22%	32%	2012/3	approx US$ 220,000 total	
Ta_Pr2	no harvest yet	n.a.	n.a.	2016+		
Ta_Pr3	no harvest yet	33% (expected, not realised)	n.a.	2020		
Ta_Pr4	4t (approx 1,000 L SVO)	25% (to increase to 28.5%)	25%	unclear		US$ 6,700-8,000 (SVO unit)
Ta_Pr5	0.5t (~100 L SVO)	20%	n.a.	2014	Avg conversion costs: US$ 0.33/L SVO	US$ 433 (SVO unit)

Ta_Pr6	unknown	20-25%	n.a.	2013	n.a.	n.a.
	Throughput in 2011 (seeds)	*Conversion efficiency*	*Oil content of seeds*	*Estim. BEP year, or year full size to be attained*	*Costs of operations 2011*	*Total inv. costs*
Ta_Pr7	0.5t (this is 62.5 kg/ha, or <0.06 kg/tree)	n.a.	n.a.	indefinite	n.a.	n.a.
Ta_Pr8	0.5t (0.4 kg/tree)	n.a.	n.a.	n.a., unclear	n.a.	n.a.
Ta_Pr9	147 t jatropha seeds + approx. 50/60t Croton seeds, from outgrowers only	27%	26-27%	2012/3 (*if* biogas can be produced)	Avg total prod. costs: US$ 1.20/L SVO	n.a.
Ta_Pr10	21.5 kg/acre *25 acres (or 0.07/tree)	n.a.	n.a.	end 2008 (end of 1st phase)	n.a.	n.a.
MoPr1	0.5t from 3 ha (trial field only) in 2011; 4.8t in 2012	n.a.	20%	2013 (BEP)	US$ 6,400 total; US$ 1,167/t SVO; avg conv. costs: US$ 0.50/L VSO	n.a.

5 Social analysis

In the format for project managers, several questions were asked that concern social issues. In Tanzania a total of seven projects provided relevant information, of which five in detail (the two projects that did not provide a great deal of information (Ta_Pr4 and Ta_Pr6) either have no employees or are still too small). In Mali and Mozambique also five projects provided detailed information. In the format for outgrowers, questions were included about their current food security and the impact on food security by the jatropha projects.

5.1 Food security

5.1.1 Tanzania

Among the five projects that provided detailed information the general feeling by the management is that the projects contributed to increased food security in the region. One project (sourcing solely from hedge outgrowers Ta_Pr1) could not furnish proof of effect, but stated that the amount of land for food crops was not diminished, nor was there any effect on food prices, whereas the income earned from the seed sales by its outgrowers is sometimes used for household expenses, including food items.

One project was even 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) are added to the soil. Furthermore better agricultural practices for food crop production are introduced (including provision of better planting material), and seedcake from jatropha is used as fertiliser. In this way the food crop yield per ha is increased, even though jatropha is added as an extra crop, leading to a diminished amount of land for the latter.[8]

The other three projects also mentioned the additional income that is generated by selling jatropha and used for food purchases, or subsidies that are provided to farmers for their agricultural activities. None of the projects mentioned having noticed any deterioration in food security.

5.1.2 Mali

Four projects provided information about food security. Two of them indicated that they had found that their project contributes positively 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.

Food security is an important issue in Mali; this is evident from the fact that 12 outgrowers in our survey also voiced an opinion on the subject. Seven among

8 Information obtained from A. van Peer, agronomic advisor to the project.

these indicated that they do not have enough food to provide for themselves for several months in the year. The twelve householders on average rely on their own food production for 9 months of the year, and have to buy food during 3 months. Nine among them indicated that they find that they not have enough variety in their diet.

5.1.3 *Mozambique*

In Table 9 the results are shown for the five Mozambique projects whose management provided information on food security. Data for Mozambique are more detailed than for Mali and Tanzania, because Rom Colthoff (2013) probed this issue in more detail with extra questions, and he also obtained additional information by administering separate questionnaires to five plantation workers in each company. Although this work strictly speaking was not part of the survey with the jatropha format, its highlights are reported here in view of their high relevance.

Table 9 reports some of the responses by the plantation workers to a question in which they were asked to compare the share of household food expenditures before and after the start of the plantation. A lower % share percentage in the "after" situation compared to the "before" situation means that people either make more money or that the absolute amount they spend on food is reduced, e.g. as a result of lower food prices. An increase in the % share indicates the opposite situation.

Table 9: Difference in average share of food expenditures before and after the start of jatropha projects

Project	*Ave. household exp. before start (Mtc)*	*Ave. food exp. before start (Mtc)*	*Ave. share food exp. before start (%)*	*Ave. household exp. after start (Mtc)*	*Ave. food exp. after start (Mtc)*	*Ave. share food exp. after start(%)*
Mo_Pl 1	2500	1225	50,0	1500	1000	33,3
Mo_Pl 2	3480	933	52,9	2739	1440	55,5
Mo_Pl 3	2150	1438	71,7	5400	2563	45,7
Mo_Pl 4	2667	2313	78,1	6175	4138	66,4
Mo_Pl 6	2500	1500	60,0	3150	2075	70,1

Source: Survey among plantation workers (Rom Colthoff, 2013).

The results show that the change in the share of food expenditures varies among the projects: in three projects the share had reduced significantly. This could be a positive sign. In one project the share had remained more or less the same, whereas it had increased significantly in the one remaining project (Mo_Pl6).
An increased need to buy food from external sources rather than self-production *can* be indicative of food security problems. But this is not necessarily the case, as the share can also be affected by a reduced time available for own food production due to finding employment on a plantation (see Table 10). However, this could be compensated by a new earned wage income, which allows increased food purchases.

Table 10: Difference in average time spent on food production before and after the start of jatropha projects.

Project	***Ave. time spent on food prod. before start (h/week)***	***Ave. time spent on food prod. after start(h/week)***
Mo_Pl 1	33,3	33,3
Mo_Pl 2	23,4	3,9
Mo_Pl 3	24,8	9,00
Mo_Pl 4	24,0	13,8
Mo_Pl 6	19,3	3,8

Source: Survey among plantation workers (Rom Colthoff, 2013).

The results in Table 10 show that the average time spent on food production has indeed dropped significantly for employees of most projects. There could be however different reasons why the amount of time spent on food production is reduced; perhaps the employees can now afford to buy food, or they now have enough money to pay other people to work on the land for them. The respondents were therefore also asked about their own perception about a link between the start of the jatropha project and impact on food security (Figure 15 and Figure 16).

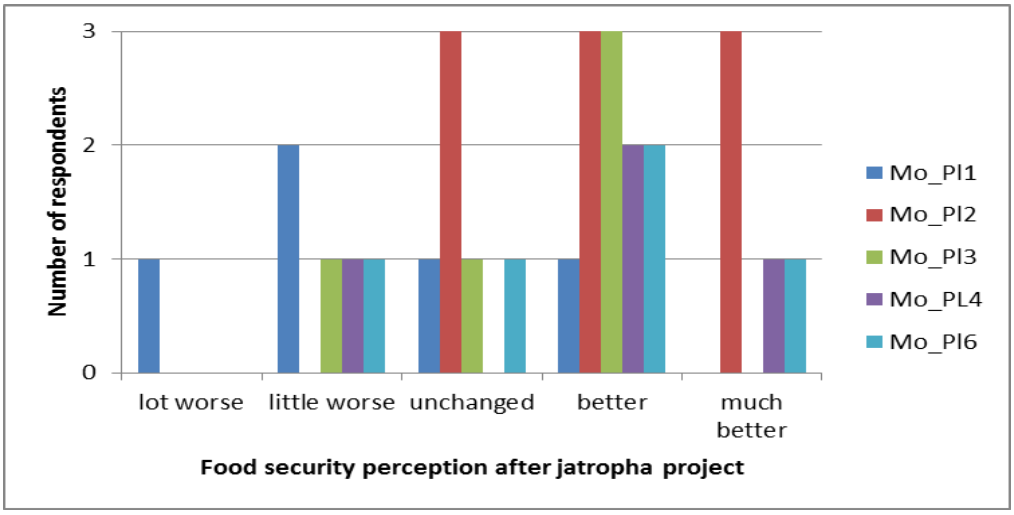


Figure 15: General perception of food security after the arrival of jatropha project for each project individual: Survey among plantation workers (Rom Colthoff, 2013)

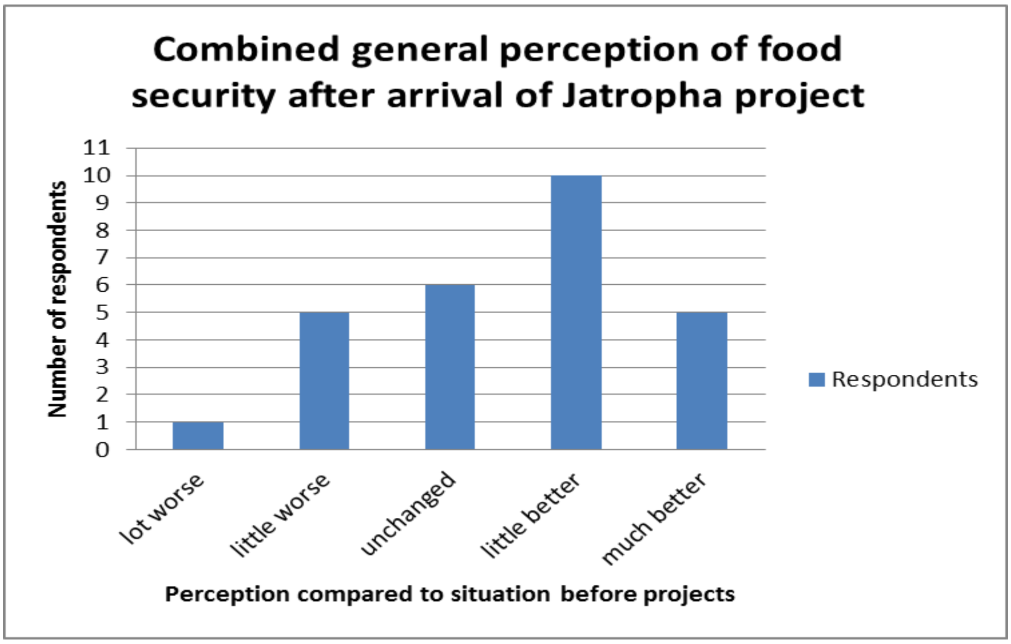


Figure 16: Combined general perception of food security after the arrival of jatropha project. Source: Survey among plantation workers (Rom Colthoff, 2013).

The results vary across the projects, as can be seen in Figure 15. The results for Mo_Pl6 that was flagged as potentially problematic indicate divided opinions, but point towards improvement on average. Meanwhile, the project which has had the most negative effects in the perception of the respondents is Mo_Pl1. This was one of the projects in which the share of income spent on food production had *decreased* a lot (Table 9). This may point towards complexities in the relationship that we are not quite able to understand with the information that we have. But on the whole, the impression that surfaces from aggregating the responses from the five projects (in Figure 16) is that the workers perceive a somewhat positive trend in their food security situation.

In Table 11 some additional information from the plantation worker survey are given, which shed further light on the reasons behind this finding. First, on all plantations except Mo_Pl1, the workers do indicate problems with competition for their labour since they started work on the plantation. They obviously experience difficulties to combine their waged work with their traditional self-provisioning activities which they still want to carry on. But this tension is related to the more general level of poverty, and cannot be solely attributed to the arrival of the plantations as such. It is vital to note in this connection that the reduced time spent on food production by project workers noticeable at all except one projects was in almost all cases compensated by their salary, which was then used to pay others to work on their land for them. Second, reduced land availability as such does not emerge as a constraint except for the workers in Mo_Pl4.

Table 11: Project-specific sustainability regarding food security, separate for each indicator and an overall combined score.

Project	*Land conversion from food crops to jatropha*	*Change in share food expenditures*	*Labour competition*	*General perception*
Mo_Pl 1	+	0	0	-
Mo_Pl 2	+	0	-	+
Mo_Pl 3	+	0	-	+
Mo_Pl 4	-	0	-	+
Mo_Pl 6	+	0	-	+

'+' meaning no issues or a positive influence, '0' meaning no noticeable influence, '-' meaning the occurrence of issues or a negative influence.
Source: Survey among plantation workers (Rom Colthoff, 2013).

5.1.4 *Conclusions:*

- The general perception of the respondents of their own food security impact by the jatropha projects is positive, although there are some differences between plantations and even between individual workers on the same plantation depending on the specifics of their personal situation. This signals the need for management to be alert to the occurrence of problematic cases, and for policy makers to monitor different (ideally all) big projects on their food security impacts.
- As far as increased competition for local resources is concerned, competition for land due to conversion for jatropha cultivation was not mentioned as a major concern in the responses except on one plantation.

- Competition for labour resources appears to be a key issue. This may need to be addressed by plantation management through e.g. introducing flexible working hours that permit workers to carry on self-provisioning work during daylight hours.

5.2 Local prosperity

The JATROPHA projects in our survey have generated in total more than 600 permanent jobs and 1000 temporary jobs, see Table 12.

Most of the permanent jobs have been created in Mozambique (+500), while most of the temporary jobs have been created in Tanzania (537). This might be due to the fact that in Mozambique there are almost exclusively larger scale plantations who tend to create more employment, while in Tanzania the smallholder-based models provide more seasonal employment, especially during the harvest period. In Mali, where the lowest number of jobs have been created, only smallholder-based models are practiced. In Tanzania besides smallholder projects, there are a few small-scale plantation projects such as Ta_Pr4 which do not generate much employment. Temporary jobs are typically for 6 months, during harvest (Ta_Pr1 and Ta_Pr9 in Tanzania).

Table 12: Employment generation at the jatropha projects (excluding outgrowers' income-generation activities)

no	*Project*	*Permanent jobs*	*Temporary jobs*
	Tanzania	(37)	(537)
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*)	0
10	Ta_Pr8	0	7
	Mali	(105)	(215)
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
	Mozambique	(509)	(283)
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
	OVERALL TOTAL	**684**	**1029**

*Before the investor declared closure there were 30 permanent jobs, however currently only 2 remain.

5.2.1 *Mozambique*

In Mozambique we were able to obtain more detailed information on the skill level of the jobs generated, and the numbers of jobs created in relation to the amount of ha the company operated at the time of survey (only plantation model), see Table 13.

Table 13: Jobs created per ha, and total skilled and unskilled jobs created

Project	*Jobs*	*Ha*	*Jobs/ha*	*Skilled*	*Unskilled*
Mo_Pl 1	205	200	1.03	1	204
Mo_Pl 2	12	-	-	12	0
Mo_Pl 3	280	1500	0.19	10	270
Mo_Pl 4	80	2311	0.03	11	69
Mo_Pl 5	45	165	0.27	12	33
Mo_Pl 6	170	240	0.71	80	90

Table 13 shows that the results for jobs/hectare vary widely, ranging from 0.03 up to 1.03 jobs per hectare. The data about skilled versus unskilled jobs created show that the majority of the jobs at jatropha projects are unskilled, with an exception for MO_PL2, which does not cultivate jatropha itself but only employs extension workers.

The companies also differ in terms of the shares of permanent and temporary jobs created. For example, MO_PL1 employs more temporary workers, while Mo_Pl3 employs more permanent workers. Permanent work is preferred from a social sustainability point of view, because it entails more security for the workers. However, for the projects labour costs are an important factor, and some of the work is seasonal.

Table 14: Overview of the average wages paid at the jatropha projects based on both statements from project management (survey with format) and project worker respondents (Rom Colthoff, 2013).

Project	*Average wage (Mtc/month)*
Mozambique Mo_Pl 1	€ 50

Mo_Pl 2	€ 99
Mo_Pl 3	€ 57
Mo_Pl 4	€ 62
Mo_Pl 5	€ 50
Mo_Pl 6	€ 65

(exchange rate 40.49 Mtc=1 €)

The monthly wage earned by an average worker at each of the projects is given in table 14 above. All wages are equal to or higher than the legal minimum wage in the agricultural sector, which is 50€/month. Only Mo_Pl2 stands out, because they mostly employ extension workers, which occupy skilled jobs and get paid more. The wages could only be compared to the minimum wage in the agricultural sector, because no secondary data were available that would enable us to make other comparisons. The differences among projects Pl1 and Pl3-6 are likely to be associated mainly by regional differences in income levels.

For assessing remuneration, project contributions to education, health care and infrastructure is also significant. This can only be expressed in material contributions. The precise value of these investments could not be determined. Also, 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 from the Mozambican projects is informative:

- Mo_Pl1 has plans to build a new hospital/maternity center, but there has been no progress yet. The same goes for a new school and a football field. These have been promised according to the community leader, but nothing has happened yet and the community leader doubts whether this will still happen.
- Mo_Pl2 helped build a bathroom in a local school. Also, they educate teachers, who can teach at local schools. They works with outgrowers, and the extension workers that work for the company train the outgrowers how to cultivate jatropha and also how to cultivate food crops. The respondent also said to provide the outgrowers with supplies needed for the cultivation of jatropha, but this has not been followed up on in every case.
- Mo_Pl3 constructed over 70km of roads and bridges. They stated they also have plans to build a school, a police station, a medical clinic and new houses. The community confirms this, but also says none of these plans have been executed yet. However, renovations on a hospital have been done and also a football team was created. Furthermore, the company has created more jobs in the region; unemployment in continuously decreasing.
- Mo-Pl4 Biofuels restored a police station, fixed a medical clinic and built a community office. Also, they provide water through piping and built a school. Furthermore a church was promised, but that plan did not go through.
- Mo_Pl5 purchased 20 computers for a local school..
- Mo_Pl6 built a hospital and a water pump to provide the community with water. Furthermore, they sprayed the village against mosquitoes and they created a football team. They also said to have plans to build a school, but it is unsure whether this will go through.

So most projects did contribute in various ways, but there are many instances where plans have ended up being postponed, or not executed at all. This could be related to the severe difficulties that are being experienced in getting the "business case" of the projects on track.

5.2.2 *Tanzania*

In Tanzania only one project provided information on average wages, see Table 15.

Table 15: Average wages for four different work categories in Tanzania, based on one project

Tanzania	*Wage*
general manager	€ 1.196
supervisional manager	€ 644
supervisors	€ 368
shop floor employees	€ 138

Worker wages at this project are substantially higher than in Mozambique, but since the data came only from one project, no firm conclusions can be drawn. It has to be said however that these data are from a project based in an urban area in a relatively more wealthy part of Tanzania (North), where wage and price levels tend to be higher than in outlying rural areas. The plantations in Mozambique are located in more remote rural areas.

The workforce in the Tanzanian company is not large, 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.

5.2.3 *Mali*

No significant information was generated by the survey about wages and secondary benefits by the projects in Mali. They tend to be small, as they all revolve around outgrowers who are not hired employees.

5.2.4 *Conclusions:*

- Taken together, the jatropha projects in the three countries have generated substantial employment, both permanent and temporary. Plantations generate relatively more full-time work, while outgrower-based systems provide more part time seasonal work and income. Minimum wage legislation generally appears to have been respected for waged posts.
- For those projects that we were able to get more detailed information on, i.e. five large plantations in Mozambique and two outgrower-based projects, resp. in Mozambique and Tanzania, broader positive effects on rural and social development were noted. Income, communal facilities and job creation are all positively influenced by the presence of these jatropha

projects without exception. Income increased for people working at and with the projects, and regional unemployment rates have reportedly dropped in some cases.

- However, these effects are sensitive to the success and/or failure of the jatropha operations. A project where progress in production slowed down due to disappointing results induced a decrease in the number of jobs created and a decrease in income earning opportunities.
- Communal facilities are funded by the projects to gain goodwill during the land consultations and to support communities on social development, but promises are not always honoured.

5.3 Working conditions

5.3.1 Working hours

The projects provided information about the number of hours worked per day, normally and at maximum; the average number of days worked per year; and the total number of leave days per year, see Table 16.

Table 16: Working hours and leave days per project

	name of the project	*hours worked per day*	*maximum nr of hours worked/day*	*hours worked per week (or days)*	*average days worked per year*	*leave days/year*
	Tanzania					
1	Ta_Pr1	8	12			28
2	Ta_Pr3	10	13		300 (364)	28
3	Ta-Pr2	8	8			28
4	Ta_Pr5	9		45	265	28
5	Ta_Pr9	8	8		270	28
	Mali					
1	Ma_Pr1	8	x		226	
2	Ma_Pr2	8	8		253	
3	Ma_Pr3	x	x		x	
4	Ma_Pr5	8	9.5		x	
5	Ma_Pr4	8	12		140	
6	Ma_Pr6	n/a	n/a		n/a	
7	Ma_Pr7	x	x		x	
	Mozambique					
1	Mo_Pl1	8	8		26 days/month	26

2	Mo_Pl2	8		(6)		30
3	Mo_Pl3	9	[a]		240	30
4	Mo_Pl5	5	6			
5	Mo_Pl6	8	8	44(5.5)		1st year 12, 2nd year 24 etc.

[a] 20 h/month overtime max

Note: Ta_Pr6, Ta_Pr4, Ta_Pr10, Mo_Pl4 are not included in the table because no information on working conditions was provided/not applicable.

There is no great variability in the working conditions between the various projects and countries. In Mozambique the maximum number of hours is somewhat lower than for the other countries. In Tanzania there is one outlier, the Ta_Pr3 project, however, the respondent was a manager and referred to his own hours and not to hours of e.g. a factory employee.

5.3.2 *Secondary benefits*

Looking at the secondary benefits employees are offered, there are quite a number of them that are offered benefits such as, training on the job, education for staff or children of the staff, meals, health care, contribution to social services such as a national pension fund, transport and safety gear. There is a difference however between permanent staff en temporary staff, the latter being provided less benefits.

5.3.3 *Other important aspects*

In Mozambique we were able to obtain the most detailed information. See Table 17 where five aspects are included.

Table 17: Project specific performance regarding labour and working conditions for the projects in Mozambique

Project	***Forced labour***	***Child labour***	***Discrimination***	***Union***	***Accidents***
Mo_Pl 1	+	+	+	+	0
Mo_Pl 2	+	+	+	+	0
Mo_Pl 3	+	+	+	+	0
Mo_Pl 4	+	+	+	+	0
Mo_Pl 5	+	+	+	0	0
Mo_Pl 6	+	+	+	+	0

+ : no irregularities / positive influence
0 : no noticable influence
- : problems occured

According to the interviewed project managers, there have been no incidences of forced labour, child labour or discrimination whatsoever. All work is according to Mozambican law and workers are content with their job at jatropha projects that offers them financial security and an occupation. So, if we can rely on the responses by the management, working conditions at the Mozambican projects seem to be good, although we were not able to verify this from the employees.

5.3.4 Conclusions

- Our survey did not reveal unacceptable working conditions in the projects, but our research method does have some limitations, as this is a sensitive area. A more detailed investigation among the workers without the presence of management would be needed to get more reliable data on these aspects.
- It is quite possible that the more poignant problems with working conditions lie in spheres which are not usually labeled under that term, for instance with the insecurity associated with seasonal employment, or with the threat of projects pulling out without a proper exit strategy for the workforce (as has happened in Tanzania already). This can leave workers worse off than before the advent of the plantation when they cannot take up their old ways of life again due to loss of key resources such as land and water point access (see section 5.4).

5.4 Land ownership and land rights

5.4.1 Tanzania

Almost all business models of the respondents to the project managers format in Tanzania, rely on outgrowers. Ta_Pr1, Ta_Pr3, Ta_Pr5 and Ta_Pr6 all work exclusively with outgrowers and have therefore no effect on land rights. The demonstration plot of the Ta_Pr2 project is rented for five years, so land rights are not transferred. TA_PR9 has its own plantation of 300 ha, this land has been privately owned since a long time. The royal Dutch family originally owned the land and sold it to the foundation who owns the project. The land is now privately owned by ROTIANA with a title deed. Ta_Pr4 is a privately owned farm for which the owner has a title deed. The estate was previously owned by the government, after that privately owned by someone else, thereafter the rights were transferred to the current owner. No problems surrounding these transfers were indicated. The land of the Ta_Pr7 is probably privately owned as well, however, no information was provided.

However, there have been several cases of failed jatropha projects that have discontinued, including large plantations such as BioShape (81,000 ha) and Sun Biofuels Tanzania (8,000 ha). Although these cases are outside the scope of this survey, which only covered ongoing entities, a few observations need to be made, as the discontinuation of both projects has given rise to big social issues. In both cases it has remained unclear what will happen with the land rights that were transferred as part of these project deals, first from the villagers to the government, and then onwards from the government to these projects in 99 year lease constructions (Sulle and Nelson, 2009).

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) for quite some time. The workers have since regained only partial access to ancient gravesites and water points, and this happened only after major protests. These are sites from which they had been cut off when the plantation was in development (see Bergius, 2012, for a detailed account based on ethnographic fieldwork among the local communities). In the case of Bioshape, 35,000 ha village land was transferred against a low compensation, and leased. When the firm went bankrupt, this land was not re-transferred to the villages as there is no legal procedure for doing so. A Tanzanian land rights NGO staffed by lawyers, HakiArdhi, is pursuing the case and has also filed a lawsuit in Dar es Salaam High Court on behalf of the almost 100 contract workers who have remained unpaid during the last 6 months of their employment contract until now. The hundreds of temporary (predominantly female) workers lost their jobs and incomes from one day to the next without prior notice (for more details see van Eijck et al. (submitted)). Most likely, the government will look for another investor to develop the land in the future, but the outcome of this is unclear and the local communities have no say.

5.4.2 Mali

In Mali all business models are based on outgrowers so there have been no issues with land rights transfers. In Ma_Pr1; the farmers are owners of the land on which they operate. A precondition to become an outgrower for MA_PR5 is that land has to belong to the farmer who will produce. According to MA_PR4, the project is still at the beginning so they cannot make statements about land rights transactions, but there are no land access problems encountered within the project zone. In Ma_Pr2; no land rights were transferred either.

5.4.3 Mozambique

Generally, 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 Appendix Table B for details). There was however, a minor conflict with the relocation of four families and the payment thereof. In one 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 wages after project discontinuation. This experience is similar to the two Tanzanian cases discussed above.

The survey results about land compensation show there is a broad array in the nature of compensation, ranging from financial compensation to material and physical compensation; also community development and job creation was in some cases considered as compensation. In one case there was no land compensation according to project management, not taking into account other services to the community and also job creation (see Table C in the Appendix).

The responses about change in land access do not suggest big changes in land access to secondary land users either (see Appendix Table D). Table DFrom the perspective of our respondents it appeared that this was not a key issue of the land acquisition process, which explains the cursory responses we obtained. For most projects, land access for secondary land users was said to have remained unchanged. These answers could not be confirmed from the secondary landusers themselves, however.

5.4.4 *Conclusions*

- The evidence from the survey suggests that the arrival of large plantations has not led to massive forced human displacements, but it has given rise to incidental land rights problems.
- Land rights problems happened even where formal legal procedures appear to have been followed in the land acquisition process. The institutional governance framework in the three countries appears to be too weak as to prevent adverse consequences for local people in case firms want to (mis)use their unequal bargaining position or are simply acting naively, lack sufficient knowledge about the local situation, or do not take enough care. In practice, a positive outcome that all can agree on is therefore very much contingent on the goodwill, knowledge and skill of the investors to negotiate in a fair, capable and transparent manner. Thus, large plantation investors have major social responsibilities in this respect.
- The survey also unearthed evidence of inadequate and extremely fuzzy in-kind land compensation arrangements, some of which did not seem to have reached beyond verbal promises.
- Smallholder-based systems generally do not give rise to land issues, as no land transfers occur in this business model.
- Evidence from one case where a plantation folded, corroborates findings from several other studies that communities can suffer permanent loss of rights of access to key land-based resources when projects withdraw, which leaves them worse off than before the project arrived.
- From the perspective of the management of the projects covered by the survey, negative land access effects on secondary land users (such as trekking herders with their cattle) did not occur; but research among these communities themselves is needed to confirm that this is really so.

5.5 ***Gender***

The projects provided information on the number of women they employed in high-skilled jobs such as managerial, marketing, accounting, agronomic or technical posts, see Table 18.

In total 51 women are employed in highly skilled positions, but for some projects it is not known out of how many high skilled jobs in total. In Mozambique the total number of female employees in high skilled jobs seems relatively low, although there is too little data to draw conclusions. In Tanzania the percentage of women in high skilled jobs is high. Almost none of the projects provide special services to women employees, only Mo_Pl3 in Mozambique provides hospital transport during birth. On the other hand, almost all project respondents indicated that they felt their project did not have any negative impact on gender issues as such. In the questionnaires there was also room to elaborate on a more general impact on gender issues by the projects, the responses are described per country below.

5.5.1 *Tanzania*

Three projects in Tanzania provided some information on effects which they considered to be beneficial for women specifically. One projects (*Ta_Pr1)* has helped women to obtain access to a good energy source for cooking through the sale of jatropha seedcake pellets and cooking stoves and also due to the sales of (unpelletised) 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 at *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 also in company meetings nowadays things are discussed together, whereas before women would stay aside.

Table 18: 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	?	
Ta_Pr2	1	1	
Ta_Pr5	2	2	
Total Tanz	**6**	**8**	
Ma_Pr1	3	?	
Ma_Pr5	0	?	
Ma_PR4	10	?	
Ma_Pr2	30	?	
Ma_Pr6	0	?	they do employ women but not in high skilled jobs
Total Mali	**43**	**?**	
Mo_Pl1	0	1	they employ women but not in high skilled jobs
Mo_Pl3	2	10	at nursery and HR
Total Moz	**2**	**11**	

The same changes have been noted in the Ta_Pr9 borehole and milk project in relation to water: nowadays the boreholes operated by Ta_Pr9 are accessible to everyone and not owned by men as was the case before. Women formerly had to ask for permission to fetch water but now they no longer depend on men for their water supply. Before, men were owners of cows and women the owners of the milk, and milk did not have much of an economic value. But as a result of the project, women can now sell their milk commercially and earn some money, which makes men and women more equal. And as women have money, they have also the decision power over it. On a negative note, men can sometimes feel that women want to overpower them. Especially in Maasai culture, women are not allowed to come into close contact with men, or to compete with them.

Also at *Ta_Pr5* similar positive effects had been observed. More women have been empowered and are now aware of their rights e.g. land ownership rights and inheritance issues. Women are reported to earn more income nowadays and more independent compared to the past. An increased participation of women in decision making was also observed. This is because they now earn an income, hence they have a voice and decision rights within their families.

In *Ta_Pr2* gender issues are currently not considered separately but in the future the project might work with micro financing etc. Through trainings there is an increased participation of decision making in the family. A negative observation is that generally once women get money from jatropha cultivation, men demand the money. The two remaining projects Ta_Pr6 and Ta_Pr4 did not provide relevant information.

5.5.2 Mali

In Mali similar observations were noted, although the changes observed are less profound. The project (Ma_Pr4) for example, is still in its first year. The women are slowly becoming more empowered through economic advancement which the project promotes, but it is still early days. Also the project 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. Ma_Pr6 acknowledged the financial empowerment of women but they questioned the strategic importance of their own project contributions, recognising that other development activities would also contribute. Potential conflicts with pastoral land use and the management of income were seen as challenging. Initially, collecting jatropha seeds for soap making was a women's task, but this has changed now. At one project Ma_Pr5, no change in gender issues was observed.

5.5.3 Mozambique

In Mozambique a major difference was observed by 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_Pl3) now do employ women. Mo_Pl1 even adds that they want women to work and have a voice, since women only worked on their own plots before. Mo_Pl3 also noted the positive impact of employing women. The project employs women also in high skilled jobs: one women is 2nd in charge at the nursery under the nursery foreman, and there is one women at HR. This project also provides hospital transport when they are due to give birth. But there were also three projects whose management indicated that they felt their project did not influence gender issues: Mo_Pl5, Mo_PL6 and Mo_PL2.

5.5.4 Conclusions

- The survey uncovered a lot of evidence, albeit inevitably subjective, that jatropha projects are having positive gender effects. Positive effects seem to occur in the different business models.
- The effects vary from practical benefits such as improved energy access for cooking and lighting; to 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.
- In some cases the projects actually have women's empowerment as a major aim itself, and jatropha is just a means to that end. In other projects, gender impacts seem to derive more from personal priorities and visions by the management. Their experiences seem to suggest that special attention for, and sensitivity to women's needs, problems, capacities and aspirations in company strategy can make a difference.

6 Environmental issues

6.1 Previous land use

Significant land conversion due to the arrival of jatropha projects has occurred (or is in the process of occurring) in Mali and Mozambique (detailed below). The changes have been much less drastic in Tanzania mainly due to the fact that the large plantations in that country failed in an early stage. Tanzania's worst case was Bioshape, which managed to clear over 2000 ha of so-called "degraded Miombo woodland" (term used in its business plan) before it closed down. In reality this turned out to be predominantly virgin coastal forest and undegraded Miombo woodland (van Eijck et al, submitted). The two remaining large jatropha projects in Tanzania both use outgrower hedge models that rely predominantly on long established hedgerows. The largest plantation in Tanzania that is currently being planted up is 300 ha, and the next biggest measures a mere 60 acres. Most Tanzanian projects involve just a few hectares. Two or three projects promote intercropping with edible crops on agricultural smallholder land on a small scale, aiming at increased total yields and incomes per ha. This does not go beyond the introduction of a few rows of jatropha on a few handfuls of smallholder plots.

Looking at the seven projects in Mali, information about the previous land use function was provided for a total of 3,900 ha. Out of this amount, the largest land use change has involved the conversion of savannah and agricultural land to jatropha cultivation. Around 3500 ha of savannah is being converted by the Ma_PR5 project, and 300 ha agricultural land by the Ma_Pr3 project. Ma_Pr6 has converted different types of land: 200 ha unproductive land, 100 ha prairie, 75 ha savannah and 25 ha agricultural land (in total 400 ha), see Table E in the Appendix for details.

The four regions of Kayes, Koulikoro, Ségou and Sikasso show a varied picture. In Kayes just 14 ha of jatropha land was previously already agricultural land, 2 ha was forest and 2 ha came from other lands such as prairie, savannah or open shrub land. In Koulikoro 4,400 ha was already agricultural land, but the largest portion, 10,000 ha was previously uncultivated land (was that bush? shrub? or desert? - we do not know); 5 ha was forest and 3 ha was in use for animals (passage). The total area of jatropha cultivated in Ségou is much smaller, here 55 ha was previously uncultivated land and 260 meters of jatropha hedges were planted on agricultural land. In Sikasso finally, around 20 ha was planted on existing agricultural lands, 15 other types such as prairie, savannah or open shrub, and around 3 ha was fallow land, see Table F in the Appendix.

In Mozambique the land conversions by the plantations have not been so substantial when we view them in relation of what they *could* be, due to their slow pace of implementation, except for Mo_Pl2 and Mo_Pl3 which have planted 1500 and more than 2000 ha, respectively. Mo_Pl2 is located on previous uncultivated land which is not fertile; the project might even contribute to soil upgrading/regeneration. Some forest was cut, which was utilised as wood fuel for local people. Mo_Pl3 is located on a former tobacco estate; this suggests that no major ecosystem values were affected there either. Researchers executing an RSB certification pilot with this project felt justified to disregard net GHG emissions from land use change (Froger et al., 2010). The record of the other projects is more mixed. Mo_Pl2 (the outgrower-based project) is operating on virgin forest land and converting this into agricultural food plots surrounded by jatropha hedges, but its total size is relatively modest. The ecological value of the land occupied by the other projects is variable. Potentially, however, ecosystem values could be affected in the future in Mozambique due to the sheer size of the planned investments.

6.2 Project managers' opinions about ecological impacts

The project managers were also asked for their own opinion as to whether their project contributed to any decrease of biodiversity. Their responses are tabulated in Table 19.

Table 19: Response of project managers on environmental impact of their project

Project	*decreased biodiversity*	*Remarks on environmental issues*
Ta_Pr1	no	
Ta_Pr3	little	some few farmers had to slash the land for jatropha cultivation
		Yes by planting jatropha, also the intercropping system conserves the soil and increases soil fertility hence protection of soil micro organisms thus biodiversity conservation . Also the use of farm yard manure reduces the risks of soil pollution
Ta_Pr9	no	No because trees were not cut in the plantation area, it was just an agricultural area. Planting of trees contributed to increased biodiversity
Ta_Pr2	no	contributed to increased biodiversity but can't say much about it
Ta-Pr5	no	Biodiversity is increased by the seed cake that is returned to the field which makes the land fertile and thus increased biodiversity by the plants that will grow
Ma-Pr1	no	increased biodiversity through the jatropha plantings
Ma-Pr5	no	increased biodiversity through the jatropha plantings, micro organisms in the soil and against desertification
Ma_Pr4	no	increased biodiversity, very favourable for the natural environment, jatropha is planted on fallow land so increased biodiversity
Ma_Pr2	no	increased biodiversity by additional biomass, also no trees were cut
Ma-Pr6	no	increased biodiversity because jatropha is planted on fallow land and erosion is reduced.
Mo_Pl1	no	No, the area was an ex-cotton and cashew plantation. We planted 800 jatropha trees per ha. If anything was cut it was already done before.
Mo_Pl2	no	
Mo_Pl3	little	No. Perhaps a little because of the construction of roads. Because of the roads more people started making charcoal because it is now easier for people to go there and buy charcoal. Charcoal producers along the roads sell to people from cities.
		Yes, the type of food that is produced. Also, we encourage not to burn, because people are used to burning everything. Locals burn grass in the streets, hunters burn, they burn for machamba preparation,
Mo_Pl5	little	There was some land clearing. Some forest was removed. The biomass was used as firewood for the locals.
Mo_Pl6	no	No, it's in our own interest to keep the biodiversity intact.

Allmost all project managers indicated that they do not feel their project contributed to a decrease in biodiversity. All projects in Mali indicate that they even contribute to an increased biodiversity by planting jatropha on fallow land, fertilising food crops with the seed cake, and reducing soil erosion. One project had some reservations: the trees that were cut were used to construct e.g. a road which then facilitated (illegal) charcoal production which in turn can lead to a decrease in biodiversity.

However, we have to add a disclaimer that the knowledge of the respondents on biodiversity is unclear, so without exact measurements we cannot scientifically claim that the projects had no influence, or only positive influences.

6.3 Conclusions:

- Land use changes have occurred with the advent of jatropha, but in none of the three countries it seemed to have involved much more than a few thousand hectares so far.
- It is difficult to draw objective conclusions about what those land use changes actually imply. The respondents themselves are very upbeat about the effects and hardly see any negative impacts, possibly because such effects are not noticeable for them within the short term, or because the maintenance of ecosystem values is not highly prioritised in the face of serious material deprivation of people. It is also quite possible that they do not know exactly what the impacts of the conversion actually are, or will be.
- One finding that stands out is that the converted agricultural land in Mali appears to have been predominantly land under fallow. Despite the opinions of the project managers, this is not a positive development, because land use systems that rely predominantly on natural means of soil regeneration - as is the case here - do need to maintain regular fallow in order to avoid structural soil quality decline. This can only be countered if the projects assure fertiliser applications by the farmers on a sustained basis.
- Another issue that warrants attention is the conversion of savannah land in Mali. This is not barren land, but an ecosystem with value. Assessing the ecological consequences from this ecosystem conversion to jatropha plantings is beyond the scope of this research, but it is an issue that should be investigated further.
- One finding that was somehow not unexpected is that some degree of conversion of valuable forest and woodland occurred. Projects will not be naturally attracted to the kinds of the harsh, infertile environments that have so widely been touted as the ideal sites for cultivating jatropha.

7 Conclusions and recommendations

Agronomy:
The results of the questionnaires give a good overview of seed yields of jatropha that are achieved in current practise, together with the management practices currently being used. Some bias may occur, however, as the information is based on memory and may be influenced by desired yield levels.

Seed yields were low and generally below 600 kg/ha or 0.7 kg/meter hedge. These low yields were partly because of the young age of trees that do not yet efficiently use the available resources (radiation, water, fertility). Yields were also limited by drought and reduced by pests and diseases. In the near future, increased yields can be expected based on increased age of the trees. A doubling of jatropha seed yield to 0.65 - 1.3 ton ha^{-1} can be expected based on the technical development in Africa and on comparison with cereals and other perennial crops. Yield may further be improved by genetic improvements, accompanied by good crop management to utilize the yield potential. For the countries in our study, a yield of about 3.5 ton ha^{-1} is to be expected if technology is implemented to similar degree as in Europe or North America.

Results of the questionnaires did not allow a quantitative analysis of the effects of specific crop management on seed yield as there were too many factors involved that all have an effect on seed yield. To study best management practices and their effects on seed yield, experiments have to be carried out in which only one or a few aspects are varied, and where results can be verified objectively.

Economics:
On the whole, the application of the data format enabled the compilation of a reasonably good perspective on the current revenue and cost situation of different jatropha activities, but some inaccuracies are inevitable.

Economic benefits from jatropha cultivation for biofuel purposes have been disappointing for all parties involved, mainly owing to low and unreliable seed yields from a plant species that has not yet been subject to systematic professional breeding, but also due to the sharp decline in international reference prices for fossil and palm oil since mid-2008.

For smallholders, jatropha is an unviable crop except in environmentally and economic disadvantaged areas where people do not have attractive alternative income earning opportunities for their land and labour. There is little point in promoting the crop in relatively more prosperous rural areas. In rural sub-Saharan Africa there are extensive disadvantaged areas.

Even in highly disadvantaged areas with some scope for jatropha, it seems generally unwise to promote it among smallholders as a *field* crop for the time being, even in intercropping arrangements, unless there is a clear symbiotic relation between jatropha and another crop (as with vanilla) that leads to higher total income per ha. Currently, jatropha hedges – possibly intercropped with other useful hedge species - are generally speaking the only feasible and desirable option for small-scale jatropha outgrowers. However, this could change in the future when more reliable and higher yielding varieties become available. Given current plant breeding efforts, this could be a matter of years.

For plantations the financial outlook is currently also poor, especially since upfront investments are very high while returns are uncertain and slow in arriving. Large plantation establishments should not be encouraged as long as prospects for higher yielding and more reliable varieties of plants are not available.

Among the oil processors –those who source their seeds from small independent outgrowers – the best performing ones have yet to reach their break even point. However, there are encouraging signs that these firms are vigorously pursuing economies of scale through increased sourcing volumes, as well as making efforts to optimise their process efficiency and improve the valorisation 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 organisations 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. With a business model well attuned to local conditions, a well organised outgrower-based chain may yet have potential for viability in the longer term.

Social aspects:
The data format yielded comprehensive insights into many social aspects from the perspective of jatropha project managers. Having additional information at hand from a complementary survey among workers therefore proved valuable. Food security dynamics proved highly complex to get a grip on. It almost warranted a separate survey on its own.

There are very few projects that have completely executed their plans, and this has affected their performance on the social front. Most projects did start with sound socio-economic plans such as the provision of education, employment, training, and sometimes improved energy access and contributions to women's empowerment. Many plans however have not (yet) materialised.

The worst social impacts are associated with projects that have discontinued: communities have been left worse off than before the projects came, due to the permanent loss of land-based resources as well as their income from plantation employment. Such impacts appear to bear all the hallmarks of being irreversible.

The land problems encountered indicate the need for better oversight. It must be made mandatory for large plantation projects to draw up realistic legally binding exit strategies as part of their official business plans. Effective governance in the actual implementation of these agreements is equally needed. 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 – valuable as these are in their role of investigators, legal advisers, advocacy campaigners and more.

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 organisations so that they can take on part of this monitoring role.

Due to the currently relatively low amount of hectares planted, other socio-economic impacts have remained rather modest. Even so, more than 1700 (permanent and temporary) jobs have been created which is very positive since most projects are located in poor rural areas with low opportunities for employment. All projects pay legal minimum wages or more, and working conditions are acceptable, or even good. Positive gender impacts have been noted by several projects. On the whole, there also seem to have been positive impacts on food security.

Environmental impacts:
The data format was useful in that it signalled the extent of land use change, and identified the former land uses. The interpretation of the environmental effects thereof, however, requires considerable background knowledge on the part of researchers. The respondents voiced their opinions, but cannot be expected to return scientifically informed information.

Land use changes have occurred with the advent of jatropha, but in none of the three countries it seemed to have involved much more than a few thousand hectares so far.

It is difficult to draw conclusions about what those land use changes actually imply. The respondents themselves emphasize positive effects such as combating soil erosion or fertilisation of food plots with seed cake from jatropha.

However, some findings give cause for concern: the converted agricultural land in Mali appears to have been predominantly land under fallow. This is not a positive development, because land use systems that rely predominantly on natural means of soil regeneration - as is the case here - do need to maintain regular fallow in order to avoid structural soil quality decline.

Another impact which could be problematic is the conversion of savannah land in Mali, since this is an ecosystem with value. The ecological consequences from this ecosystem conversion to jatropha plantings should be investigated further.

There has also been some conversion of high-biodiverse forest and woodland. Projects will not be naturally attracted to the kinds of harsh, infertile environments that have so widely been touted as the ideal sites for cultivating jatropha; they prefer to go where attractive yields and revenues per ha can be obtained. Oversight is thus needed to avoid that projects plan their activities in such areas. Land zoning plans can contribute to this as well.

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9 Appendices

Additional tables are included for

- Alternatives for jatropha in live fences/hedges in Tanzania
- Analysis of social issues
- Analysis of environmental issues
- Background on 11 Mozambican biofuel projects

Table A: Opportunity costs of Jatropha hedges: beneficial shrubs and trees commonly used in (or as) Tanzanian hedges

Latin name	English and/or *local name(s)*	Characteristics	Main benefits
Dovyalis caffra	Kei apple, *Mchongoma*	Thorny evergreen shrub, usually growing 3-5 m tall. Prefers well drained soils. Found at altitudes above 1200m.	Extremely hardy plant, cultivated as a border, hedge or live fence. Regular trimming may be needed to maintain a good hedge. Leaves are used as fodder. The fruit is edible and makes excellent jam.
Euphorbia tirucalli	Finger plant, pencil plant, *Minyaa*	Succulent shrub or tree growing up to 6 m or more, commonly occurring in bushland, thickets and coastal shrubland, at altitudes from sea level to 1600m.	Frequently planted as a hedge in dry areas around cattle *bomas* (Maasai cattle enclosures).Because of its poisonous nature, the latex is used as fish poison, arrow poison, insecticide and gum (used for catching birds). The young branches serve as fodder, the wood as fuel. Roasted young branches can be chewed as a remedy against sore throats and stomach complaints. Boiled root solution acts as an emetic against snake bite and against sterility in women.
Leucaena leucocephala	*Lusina*	Semi-deciduous shrub or tree that grows 5-20m tall depending on variety. Planted widely in the tropics from sea level to about 1600m. Plant thrives in sun and well drained soil.	Leaves and shoots valuable as fodder, mulch and green manure. Wood is used for poles, general timber and as fuel. Also a good shade tree, and helps to fix nitrogen.

Yucca gloriosa	*Massale*	Evergreen shrub or tree-like plant 2/2.5m to 7m tall. Spike-like leaves.	Used in rock gardens, along roadsides, and as hedges. Important cultural significance in marriage and peace-making ceremonies among members of the *Chagga* tribe.
Azadirachta indica	Neem, *Mwarubaini kamili*	Tree	About 60 different uses. Has important medicinal value.
?	*Kavilea*	Common tree, flowers yellow.	Wood is useful as timber
Cactus, various types	*Mpome*	Hardy plant well adapted to dry climates and poor soils, spikes.	Excellent impenetrable hedge plant, useful for keeping domestic animals in, and wild ones out.

Note: This list is not exhaustive, and is specific to Northern Tanzania. Other local species identified by hedge outgrowers in our survey included *Ilandee,(*also called *Kimeru), Shirhto, Ierai and Mijohoro*. However, their Latin or English names and their uses could not yet be established.

Sources: Respondents' answers in Tanzania Jatropha outgrower survey 2012; Dharami, N.(2011) *Field Guide to Common Trees & Shrubs of East Africa.* 2nd ed., Struik Nature: Cape Town; Hines, D.A., and K. Eckman (1993) *Indigenous multipurpose trees of Tanzania: Uses and economic benefits for people*. Ottawa: Cultural Survival Canada and Development Services Foundation of Tanzania; dr. Karoli Njau, Nelson Mandela African Institute of Science and Technology, Arusha, personal communications in 2012-13; http://treetop-ics.blogspot.nl; personal observations.

Social aspects

Table B: Details of land acquisition process by the surveyed Jatropha projects in Mozambique

Data requirements	*MoPl1*	*Mo_Pl2*	*Mo_Pl3*	*Mo_Pl4*	*Mo_Pl5*	*Mo_Pl6*
Land transferred in terms of ownership	no	no	no	no	no	no
Previous land ownership/user	-	-	-	Tobacco company	State cotton farm	State cotton farm
Assessment of previous land rights	yes	-	yes	yes	-	yes
Assessment of informal use of the land	yes	-	yes	yes	-	yes
Land conflicts	4 families relocated	no	no	After stopping Jatropha activities	no	no
Language used (influencing transparency)	Portuguese, Makua	-	English, local	Portuguese	-	local
Documentation of the land acquisition process	Only agreement for relocated families	-	no	yes	-	yes
Engagement in stakeholder analysis	yes	-	yes	yes	-	yes
Stakeholders	Project, local government, community	-	Project, local government, community	Project, local government, community	-	Project, local government, community

Table C: Land compensation by the surveyed projects in Mozambique

Data requirements	***Mo_Pl1***	***Mo_Pl2***	***Mo_Pl3***	***Mo_Pl4***	***Mo_Pl5***	***Mo_Pl6***
Compensation of previous land users	yes	-	yes	yes	-	no
Type of land compensation	Monetary	-	material	intangible and material	-	-
Amount of land compensation	3000 - 11000 Mtc	-	construction material and land clearance	job creation and community development	-	-
Price paid for land	-	-	-	-	-	-

Table D: Treatment of secondary land users by the surveyed projects in Mozambique

Data requirements	***Mo_Pl1***	***Mo_Pl2***	***Mo_Pl3***	***Mo_Pl4***	***Mo_Pl5***	***Mo_Pl6***
Change in land access for secondary land users	no	no	no	yes	-	no
Land compensation of secondary land users	-	-	-	-	-	-
Involvement of secondary land users	yes	-	yes	no	-	yes
Identification of secondary land users	yes	-	yes	no	-	yes

Environmental aspects

Table E: Previous land occupation in Mali for seven surveyed projects

N°	Name of company	Name of project (REMOVED ON PURPOSE)	Previous land use	Nr of hectares	Total surface (%)	Use of previous vegetation
1	Ma_Pr1		Agricultural land		70%	
2	Ma_Pr2		Unproductive land		100%	Was incorporated into soil
3	Ma_Pr3		Agricultural land	300	90%	Trees and bushes, not stated how they were used
4	Ma_Pr5		Savannah	3500	100%	The previous vegetation was composed of herbs; has been buried in soil
5	Ma_Pr4					
6	Ma_Pr6		Agricultural land	25	5%	Used for fertilisation of other cultures
			Prairie	100	25%	
			Savannah	75	20%	
			Unproductive land	200	50%	
7	Ma_Pr7		Agricultural land			Incorporated into the soil or compost pit
Total				**3900**		

Table F: Previous land use in the case of smallholders in the Malian regions of Kayes, Koulikoro, Segou and Sikasso

Regions	Categories of actors	Previous land use	Total planted surface in ha	Total length of the hedge in m
Kayes	Individual fields of plantation	Agricultural land	3	
	Individual fields of plantation	Other plant formations (prairie, savannah, open scrub)	2	
	Individual fields of plantation	Forests	1	
	Smallholders/outgrowers	Agricultural land	10.5	
	Smallholders/outgrowers	Forests	1	
Koulikoro	Individual fields of plantation	Agricultural land	4	
	Smallholders/outgrowers	Agricultural land	4416	
	Smallholders/outgrowers	Forests	5.00	
	Smallholders/outgrowers	Passage of the animals	3	
	Administrators of projects	Uncultivated land	10000	
Ségou	Individual fields of plantation	Agricultural land	1.82	
	Individual fields of plantation	Uncultivated land	50	
	Individual fields of plantation	Other plant formations (prairie, savannah, open scrub)	1	
	Smallholders/outgrowers	Agricultural land	.	261
	Smallholders/outgrowers	Uncultivated land	4	
Sikasso	Individual fields of plantation	Agricultural land	19	
	Smallholders/outgrowers	Agricultural land	2.25	
	Smallholders/outgrowers	Fallow	2.53	
	Smallholders/outgrowers	Other plant formations (prairie, savannah, open scrub)	15.39	
	Smallholders/outgrowers	Former hedge	.	1200
	Administrators of projects	Agricultural land	17800	344000
	Administrators of projects	Other plant formations (prairie, savannah, open scrub)	2200	
	Administrators of projects	Agricultural land, other plant formations, no cultivated earth	3500	25000

Table G: Background information for 12 Mozambican biofuel projects

Nome dos Projectos	Localização (Província)	Culturas	Área total (Hectares)	Área Total Ocupada	Empregos Criados	Investimento Aplicado	Observação
1. Principle Energy	Manica	Sugar -cane	18.000	130	Permanente: 50	US$ 55 milhões	Paralisado devido à falta de financiamento
2. Sun Biofuel	Manica	Jatropha	5.000	2.590	Permanente: 827	————	Com restrições financeiras para continuar normalmente
3. Moçamgalp	Manica	Jatropha	200	180	Permanente: 86	————	Na fase experimental
4. Niqel	Sofala	Jatropha	10.000	1.000	Permanente: 146 Temporario: 55	7,5 milhões	Apresenta bom nível de implementação da proposta.
5. Galp Buzi	Sofala	Jatropha	1.000	——	Permanente: 101 Temporary:250	————	400 hectares de campo de demonstração dentro do projecto da Companhia Buzi
6. Enerterra	Sofala	Jatropha	18.508	30	Permanente: 2 Temporário: 18	————	Ainda em fase de pesquisa., criados 30 hectares de campo de demonstração .
7. Elaion Africa	Sofala	Jatropha	1.000	————	Permanente: 50	————	Projecto paralisado
8. Grown Energy	Sofala	Sugar –cane and sweet sorghum	15.000	950	Permanente: 199	US$ 74 milhões	Em expansão dos campos de operações agrícolas
9. AVIAM	Nampula	Jatropha	10.000	500	Permanente: 56 Temporario:115	US$ 1,2 milhão	Enfrentando a doença letal na cultura de jatropha.
10. ADPP	Cabo Delgado	Jatropha	250	250	Permanente: 19	————	Apresenta bom nível de implementação da proposta, com envolvimento de 1.800 agricultores locais
11. SAB Mozambique	Inhambane	Jatropha	6.000	6.334	—————	—————	Projecto com bons níveis de progresso. Informação deve ser colectada
12. Projecto Bioenergia	Maputo	Jatropha	6.950	150	Permanente: 35	US$ 1,3 milhão	Investidores à espera do título de uso de terra

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