# Evaluation and financial analysis of the Jatropha value chain implemented by CIRAPIP/IITA-Benin

FINAL report

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October 2014

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# list of acronyms

| | |
|---|---|
| ASG | Analytik-Service Gesellschaft mbH: A chemical laboratory in Germany. |
| BCR | Benefit Cost Ratio |
| CIRAPIP | Centre d'Information, de Recherche et d'Action pout la Promotion des Initiatives Paysannes |
| EPAC | École Polytechnique d'Abomey-Calavi |
| IITA | International Institute of Tropical Agriculture |
| IRR | Internal Rate of Return |
| JPO | Jatropha (Pure) Oil |
| Listeroid | Engines based on the original Lister engine designed in 1928 |
| MBSA | Mali Biocarburant SA is a biodiesel company based in Mali |
| MFP | Multifunction Platform: A diesel engine that can power multiple devices. |
| NCF | Net Cash Flow |
| NPV | Net Present Value |
| PBP | Pay Back Period |
| PHA | Post Harvest Activities (peeling, drying, packing etc.) |
| PV | Photo Voltaic (solar cells) |
| SVO | Straight Vegetable Oil |

# Preface

This study is based on data collected by a fieldtrip from August 17th to August 23rd 2014. We would like to thank the project staff of CIRAPIP and IITA for their cooperation and the villagers of Ouinhi, Djidja and Tori for their input. Furthermore we would like to thank the Dutch Embassy who facilitated this study.

# Summary

This report gives an evaluation and financial analysis of the project that was initiated by the International Institute of Tropical Agriculture (IITA) and the Centre for Information, Research and Action for the Promotion of Farmers' Initiatives (CIRAPIP) and was executed between 2010 and 2013. The project concerned the development of value chains of Jatropha-based biofuel with involvement of small rural farmers, to contribute to the development of the local economy and improve social conditions and economies of the farmers.

The main conclusions are:

- Different parts of the chains show various levels of return. On the production side Jatropha cultivation can compete with alternative crops but only just and it takes some years to reach an attractive yield. Also the pressing of Jatropha is only just viable and with a rather long time to break even. Most of the profits are in the soap making, mobile phone charging and electricity for lighting.
- Jatropha is likely to be a viable for all parties in the value chain, including farmers, millers and consumers when assessed over a longer period, i.e. when the plants are mature. Currently the oldest plants are only half way to maturity and yields are therefore low.
- Further developments in a number of areas are required for Jatropha to succeed. In particular the use of Jatropha oil to substitute diesel requires more attention to ensure proper function and longevity of the engines. Improvements are required both on the processing side, since the present oil quality is not good enough to be used as fuel in diesel engines, and with regard to engine modifications. The use of silicone moulds for soap making could improve the quality of the soap, and a mixture with palm oil could reduce costs.
- All Jatropha value chains needs further improvements and optimisation: Some options for increasing the profitability have not been tested yet, including the use of mechanical dehullers that have been successful elsewhere. Another option is biogas production from the press cake to double the energy produced from Jatropha. Also briquettes and charcoal can be produced from the press cake.
- The detailed analysis of the various Jatropha value chains all shows that a high level of utilization of the equipment is essential for a good return. For instance utilising only 10% of a press' capacity or running a generator on 20% load is not viable. For services like mobile phone charging and electricity for light solar systems are more profitable when small numbers of people are served. They can also be deployed and scaled up or down quickly and in small steps so capacity is always matched to demand. By combining the Jatropha value chains with solar systems a much higher profitability can be achieved.
- The improvements required are beyond the skills and capacity of the participants in the value chains. Outside support is therefore essential.
- The Jatropha value chains are only viable if there is a local market available: Export prices are far too low to make Jatropha profitable in the current production systems. In the project areas the local demand for Jatropha derived services and products exceed the production manifold.

- There are significant non-monetary benefits of the Jatropha value chains, including local capacity building, job creation, empowerment of women (they should be involved throughout the whole value chain) and increased resilience.
- Other areas in Benin have conditions similar to the project locations, thus indicating a potential for up-scaling of Jatropha value chains.
- The risk for all participants in the Jatropha value chain are low and there are good exit strategies, i.e millers can switch to diesel and soap makers to palm oil. The investment by farmers is limited and removing Jatropha is easy if they should decide to do so.

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# 1 Introduction

The Dutch embassy in Benin has commissioned an evaluation of the Jatropha value chain development project implemented by CIRAPIP/IITA. Between 2010 and 2013, the International Institute of Tropical Agriculture (IITA) and the Centre for Information, Research and Action for the Promotion of Farmers' Initiatives (CIRAPIP) initiated and executed the project of development of value chains of Jatropha-based biofuel, with the financial support of the Embassy of the Kingdom of the Netherlands in Benin. This project is implemented in three pilot municipalities, namely the municipalities of Ouinhi, Tori and Djidja.

The overall objective of the executed project is to contribute to the development of the local economy for improving social and economic conditions of farmers through equitable access to renewable energy through a financially and economically viable and sustainable project. More specifically, the goal was to develop competitive value chains of jatropha oil for:

- The operation of mills and
- The manufacture of soap in the pilot municipalities Ouinhi, Tori-Bossito and Djidja

Results achieved:

The project documents mentioned the following results:

- 281 farmers produce jatropha on about 70 hectares and Jatropha is intercropped with corn, cowpea and groundnut.
- Three Multi functional platforms have been installed, consisting of a press, a mill coupled to a generator, one in each village,
- Millers were trained on the use of jatropha oil for the operation of corn mills,
- Manufacturers of soap based on jatropha oil were trained
- Electricity was produced and distributed in the villages concerned,
- Field schools (Farmer Field School) to train farmers on the cultivation of jatropha, were established.

The challenges mentioned by the project staff that still lie ahead are:

- The control of pests on Jatropha.
- The production of a local press to provide quality after sales service.
- Sustainable management of different segments of the value chain of Jatropha.
- The increase in the area planted to ensure proper availability of the material.
- The effect of prolonged use of Jatropha oil on the wear of parts of the mills.

Jatropha is a cash crop and its sustainability can only be achieved by financial profitability at all levels of the value chain. After three years, it is important to check the financial base of Jatropha in Benin among economic operators (producers, processors, sellers of final products (fuel, soap, electricity etc..) to better understand the economic model that sustains the introduction of jatropha in rural Benin. This report is the result of the investigation executed by the external project team in August-sept 2014.

# 2 Agronomy

The agro-climatic conditions for Jatropha are good in the project area. They are not the best globally but good enough to expect unproblematic growth, good yield and longevity. The map below is a suitability map combined with a yield model to indicate yields that can be expected globally. The methodology behind the suitability map is solid but the yield model is not and the yield figures should therefore only be taken as a rough estimation. Unfortunately this reflects the current situation for Jatropha globally. Basic data on yield, time to maturity, yield at maturity, longevity and the yield curves are missing. Only a few long term data series exist and they are all flawed in different ways.

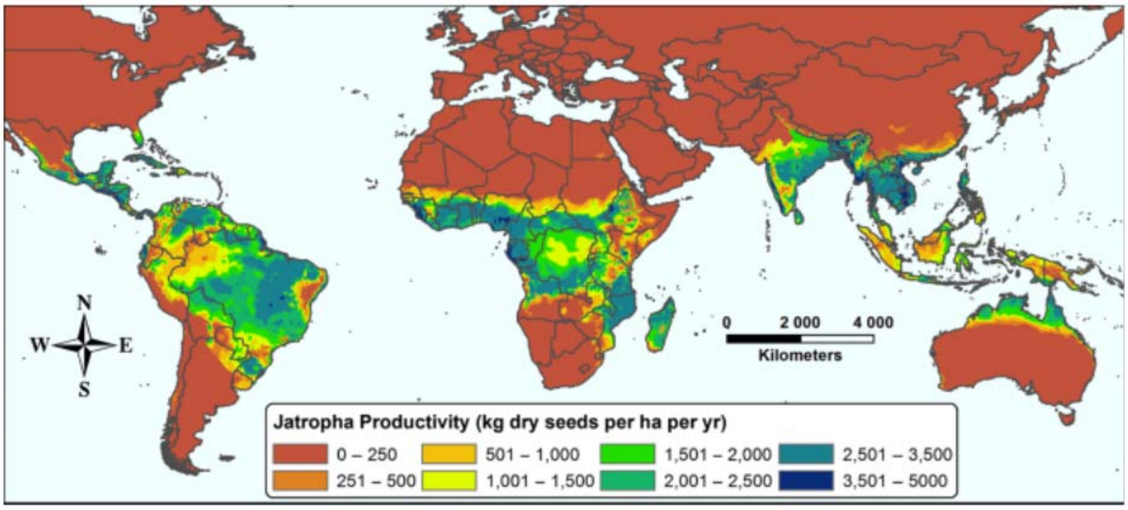



**Figure 1 Estimated Jatropha productivity (kg dry seeds $ha^{-1}$ $yr^{-1}$) for present climatic conditions (Trabucco et al. 2010)**

In the field Jatropha was found to grow well with no signs of nutrient deficiencies. Few signs of diseases and pests were observed. However, according to farmers and project staff pests are a significant problem – particularly during flowering. IITA has in collaboration with the project undertaken thorough research on pests in Jatropha. Since pest problems are widely reported and hardly any research has been done so far this work will be of interest far beyond the project. The research has focused on biological aspects and it does not cover the economic impact of pest and diseases in Jatropha. Consequently it can at this stage not be assessed if pest control is warranted, i.e. is economically feasible.

The Jatropha plants in farmers' fields were well branched which is important for good yield. This is partly due to pruning done by farmers which appears better than in many other projects although not optimal. In particular many plants were allowed to grow to a height that will slow down harvesting and thus reduce farmers' productivity.

Most Jatropha is planted using direct seeding which ensures good root growth and minimum costs. This is in contrast to most other Jatropha cultivating areas where seedlings are prepared in nurseries because direct seeding result in too high mortality rate – often caused by grazing animals or ants. Training farmers in nursery design and management is often a significant expense in Jatropha projects. And it is a bigger commitment than some farmers are willing to make. The possibility of using direct seeding makes up-scaling easier, faster and cheaper.

No fertililizer or manure is applied to Jatropha. Since plant nutrients are removed when the seeds are harvested this is not a sustainable situation. This soil mining can go on for some years but will eventually lead to reduced yield and increasing problems with pest and diseases. Jatropha (when not grown from cuttings) develop a tap root that penetrates deeper than other crops grown in the area. It therefore has the ability to tap into soil nutrient reserves unreachable by other plants. Therefore Jatropha yields may not be affected for some years. Since the yield is low initially it can be rational for the farmers to rely on soil mining while the yield ramps up and only start investing in soil fertility amendments when a good income is being earned from Jatropha.

Almost all plant nutrients remain in the seed cake and a simple solution is therefore to return the seed cake to the field. That means zero income from the seed cake but also that no fertilizer needs to be purchased.

In the economic models we have assumed zero income from the press cake under the assumption that it is returned to the fields or in case it is sold that the income is used for purchasing fertilizer.

If the press cake is used in a biogas digester the plant nutrients remain in the slurry and in chemical forms that are easier to access for plants. In this way income can be generated from the press cake without having to purchase fertilizer. A downside is that slurry is more bulky and difficult to transport than press cake.

## 2.1 Yield

Different types of research plots have been established under the leadership of IITA. From interviews and inspection of data files and research protocols it appears to be of good quality. The focus has been on improving existing Jatropha systems and the comparisons have therefore been between “farmers’ practice” and the “improved systems”. This is fully in line with the original project design and objectives. However, in the context of the TOR of this evaluation it would have been useful to have a direct comparison with non-Jatropha systems. In some of the reports trial plot data have been compared to yield statistics from the local authorities. However, it is not known how the soils in the trial plots compare to the plots sampled by the local authorities so such a comparison is meaningless.

The few long term yield data that exist for Jatropha indicate that maturity is only reached after five to eight years. At maturity the yield stabilize and is expected to drop only slightly for the next two to three decades. In the project area yield data have been measured for three years and the plants are therefore only about half way to maturity. For better researched crops the current yield could give an indication of yield at maturity. However, for Jatropha there is disagreement about the yield curve till maturity as illustrated in the figure below. The implication is that no firm conclusions can be drawn from the established trials yet and that it is advisable to continue the trials till the plants are mature.

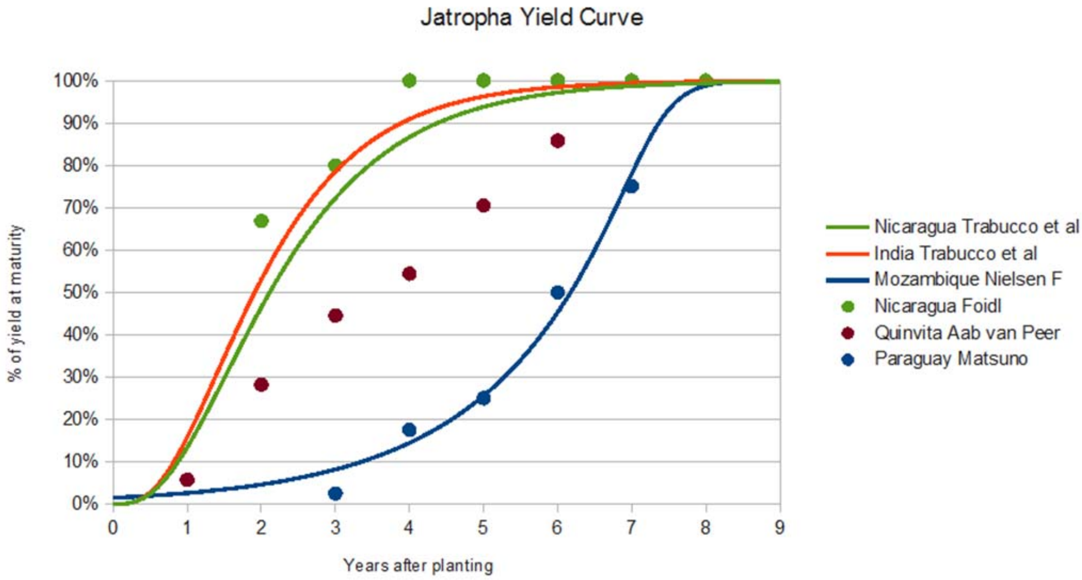



**Figure 2 Jatropha yield curves from long term data series (Nielsen et al. 2013)**

Based on known yield data it our assessment that 3 t/ha (dry seed) can be achieved in the project area under good conditions. Under smallholder conditions in Benin other crops achieved only a fraction of the potential yield and there is no reason to think that will be different for Jatropha. Smallholders under comparable situations have reached 800-1200 kg/ha and we therefore expect a yield at maturity of 800 kg/ha for low input systems and 900 kg/ha for high input systems.

All figures so far have been about yield per hectare. However, in the project area farmers are mainly labour constrained. This was confirmed in interviews at all three locations. Yield per working hour is therefore the important yard stick. Measurements elsewhere in Africa have shown that over the lifetime of a Jatropha system almost all labour is spent on harvesting: about half of it on picking the fruits and half on manual dehulling.

If the yield per hectare is low too much time is spent moving and looking for fruits. Higher yield per hectare will increase efficiency but only up to a point. In the figure below it can be seen that a yield higher than about 800 kg/ha does not increase the productivity, i.e. return per working hour.

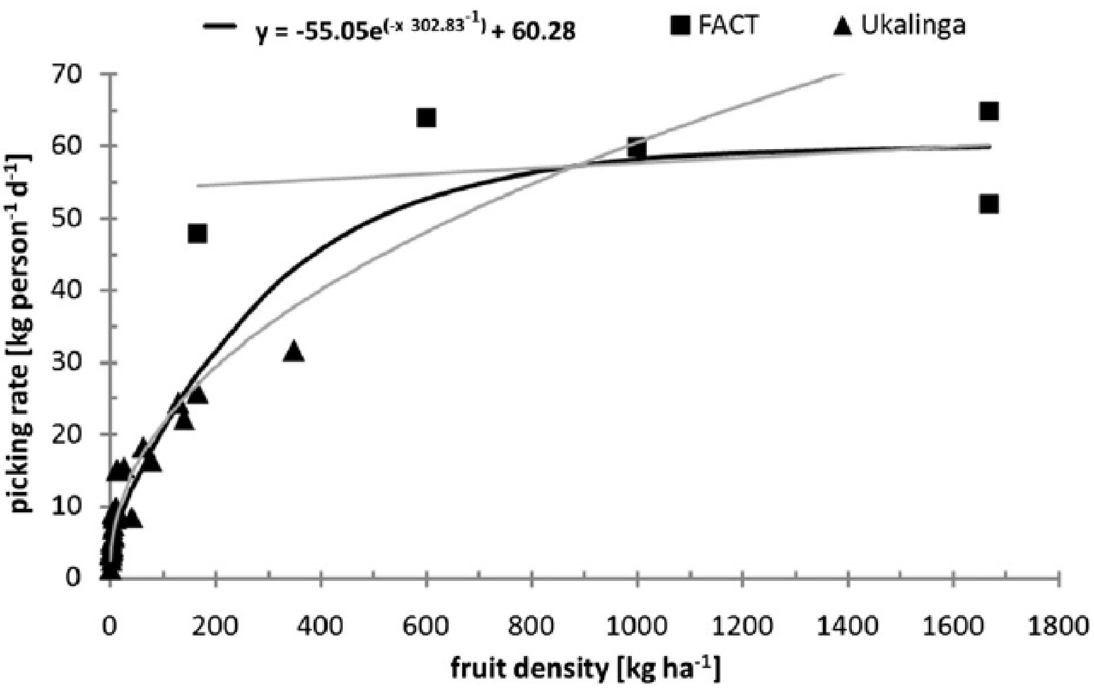



Figure 3 Rate of picking (seed) as a function of fruit density during harvest. (Borman et al. 2013)

The expected yield in the project area is sufficient to maximize the farmers return to labour, even for low input systems. Increasing the yield per hectare is therefore not the best approach for making Jatropha more attractive to farmers. Instead mechanical dehullers appear much more promising since they substantially increase the amount of seeds produced per working hour. On the processing side biogas production has the potential for making higher seed prices viable, which again will increase the farmer’s return to labour.

# 3 Processing and technical aspects

## 3.1 Introduction

Experience shows that technical issues related to oil extraction, filtering, storage and engine conversion have major implications for the viability of Jatropha value chains.

The importance of technical issues is generally underreported because most projects are young and have not yet started processing significant amounts of seeds.

The selection of agronomic and technical issues that are included in this study are based on their importance in answering the three core questions:

i. Viability of the Jatropha value chain;
ii. Potential for replication (scaling up); and
iii. Financial support required for a second phase – in case a continuation is recommended.

## 3.2 De hulling – cleaning and preparation before pressing

The jatropha fruits contain on average 65% seed weight and 35% of hull weight. Therefore in most cases the fruits are being dehulled manually in the fields where they are collected, and from there transported to pressing centres. This avoids transporting 35% of hull weight in vain.

On the other hand, manually dehulling, as done in the project, is very time consuming and the key activity to determine a viable seed price for the farmers. Typically manual dehulling takes as much time as harvesting. Mechanised dehullers therefore have the potential to double the farmer's productivity per hour.

Two potential improvements could be made:

- Introduce a manual operated dehuller (from the Full belly project, like in Honduras, see FACT Jatropha Handbook), which can be operated in the fields itself, reducing largely the dehulling time.
- Transport the full seeds to a centre , where a motorized (electrical or diesel) dehuller is installed. GERES has been experimenting with two different types of motorised dehullers, which gave quite satisfactory results. Capacity around 600 kg fruits/hr. GERES has made their experience and data available .

The seeds entering the press should be free of contamination, especially small pebbles or sand, which can wear out the press worms. It is recommended to sieve the seeds (manually or mechanically ) before the seeds are fed to the press.

Preheating of seeds, as was experimented by GERES, using the exhaust gas of the diesel engine, is not required. In general up to now, no other pre-treatment measures are recommended.

## 3.3 Pressing

The present Tinytec presses imported from India, which are of the strainer type, with mechanical feed in system, without pre-treatment of seeds is in general an acceptable press (based on other experiences (See FACT Jatropha Handbook 2010)

The performance efficiency as reported by the project is not optimal yet, ie 5 kg of seeds required for 1 l of HVB, (data from interviews in the field). In the Jatropha final report other data is mentioned, see Table 1.

**Table 1: Technical coefficients for jatropha oil extraction**

| Coefficients techniques | |
|---|---|
| Débit réel : | 73.4 kg/h |
| Rendement d'extraction HVP | 0.174 L/kg |
| Rendement d'extraction HVB | 0.245 L/kg |
| Teneur en sédiments de l'HVB | 29.5 % du vol |
| Consommation énergie électrique / litre d'HVP | 0.011 litre gasoil /Litre |

Source :*Projet Jatropha CIRAPIP/IITA, Ouinhi, 2012*

It is unclear whether these values have really been obtained in the project. Tests done by GERES come to a better efficiency 4 kg of seeds needed (based on the interview with GERES). This coincides with the table above.

The press was running (for demonstration to the evaluation team). The presscake looked quite good (this is an indication for a proper adjustment of the press). The oil was connected through a plastic tube with the filter system which was put on later on. The engine temperature was rather cold (measured around 40 degrees by the project team). The temperature of the seedcake was 60 degrees, which is also at the low side when trying to obtain an efficient oil output, but fine regarding phosphor build up.

The Tinytec press is rated 125 kg/h according the manufacture (for general oil seeds) and reduced capacity for jatropha at 80-90 kg/h (see report Beerens & de Jongh on pressing). During the evaluation mission, two of the three presses were not working properly.

The project team from CIRAPIP mentioned that only 37,5 to 42,25 kg of Jatropha seeds are pressed per hour, while interviews with mill operators from CIRAPIP stated that 75-88 kg/hr is processed. The difference may be due to different levels of experience by different operators. Even the high number is within the capacity of the press.

Operating of these presses, including fine tuning of the oil outlet screen is a delicate activity. Also the humidity of the seeds needs to be around 6%, when less, the cake will clog the whole press very fast, making pressing impossible. Therefore training in operating the press by experienced operators is required to make optimum use of the press. Longer term operation is required (then the 20 mandays total pressing in this project) to find out whether presses and/or operators can be improved.

The project team decided to go for development of a local press in partnership with the University (EPAC (UAC)), based on the Tinytec design, aiming at lower costs and easier access to spare parts.

This press was designed by the University and a first prototype was installed in the field. See Figure 4:

**Figure 4: LEFT: The Tinytec press operating in the field (Ouinhi and Tori), RIGHT: The newly designed prototype in the field (Djidja).**

The new press looks sturdy and might be appropriate, but our general experience with developing such type of industrial equipment is that it is not easy to develop a real efficient and durable product, especially not at short term, even in industrialized countries. After developing a design and prototype by the University, subsequently a second phase of trials with longer time practical experience is required, preferably by a local manufacturer who wants to engage in the development. This is however a costly process, and he would need support for that.

**Recommendations**

- Training of operation by experienced operators is required to make optimum use of the installed Tinytec presses. Longer term operation is required for at least one year, preferably 2 years, to find out the real operation performance of the presses, including wear and tear and O&M requirements, and train the operators adequately.
- Related to this is determining the exact oil extraction performance of the presses.
- Since there is already experience with other types of presses, which perform rather well in African conditions, like the Double Elephant press series, it would be worthwhile to import a number of different well known presses and set up a line of tests using these types of presses, to determine which press would be most appropriate, regarding performance, price, O&M requirements, supply chain of spare parts, etc.

## 3.4 Oil Quality

Running engines on JPO requires that the oil is of a high quality. Experience shows that a good and consistent oil quality can be difficult to achieve. Of particular concern for JPO are phosphorous level, acid number, total contamination and oxidation stability. Within the CIRAPIP/IITA project, presently, there is no oil quality testing system present, nor are norms for quality applied. Which means that the critical values of the 4 variables are unknown, and therefore the oil quality is also unknown. A low oil quality will reduce the longevity of the engines and can in some cases destroy them within a short time. To obtain a first impression of the JPO quality, a sample of the produced JPO has been taken by the evaluation team and was submitted for quality testing at the German ASG laboratory.

Table 2: Test results of the sample from ASG lab in Germany

| Parameter | Result | Specification Min. | DIN 51605 Max. | Unit |
|---|---|---|---|---|
| Total contamination | 50 | - | 24 | mg/kg |
| Acid number | 10,01 | | 2,0 | mg KOH/g |
| Oxidation stability | 4,1 | 6,0 | - | h |
| Phosphorous content | 20,5 | - | 3,0 | mg/kg |
| Calcium content | 6,7 | - | 1,0 | mg/kg |
| Magnesium content | 6,4 | - | 1,0 | mg/kg |
| Oxyd ash (775 0C) | < 0,005 | - | - | % (m/m) |
| Water content | 1153 | - | 750 | mg/kg |

See Appendix 6 Report No: 2206404-1 ASG

The test results of the sample of the oil taken by the team and sent to ASG lab in Germany show that the oil quality is not fit for using in diesel engines. Especially the phosphor level and acidity are far too high. When this low quality JPO is going to be further used in the diesel engines, they will finally clog and stop working.

This oil quality however is sufficient for making clean soap, which is profitable for a sales price of the JPO of 800 CFA/litre, see spreadsheet Low Input case. (PBP 6 years)

**Recommendations for further steps to improve oil quality**

The quality can be improved in two ways:

**1 By treating the pressed and filtered oil.**

Processing steps to improve oil quality, regarding reducing level of phosphor and acidity like degumming and neutralization could be added, in order to bring the oil quality up to the desired standard. (like the DIN V 51605)..

The most simple improvement is to degum the oil that has been filtered by the existing plate filter to get rid of the phospholipids and thus reduce the phosphor contents and colloidal impurities. Degumming consists of heating the oil up to 70 Degr. C. and stirring it for about one half hour after 2% clean water has been added to the oil. Then the mixture is cooled of and the formed gums are removed. The remaining liquid is cleaner oil.

For this simple drums can be used, which are heated up above open fire. The gums can probably be used to make soap from as well.

Neutralization of the acidity can be done in a similar way, by adding caustic soda.

In the ***Medium Input Case,*** (see section on financial issues) this investment has been made and in addition to control the quality, costs for sending sample tests to a good lab abroad four times a year have been included.

The application of these methods in an efficient way requires training by an experienced person.

Probably the quality will improve and when reaching the norms of DIN51605 it can be used 100% in the diesel engines (after modification).

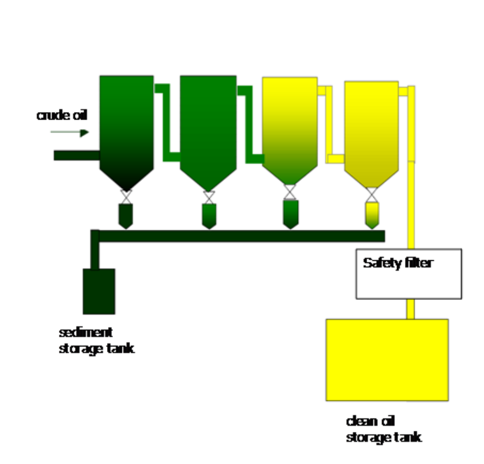
If quality is improved but not fully to the norms of DIN51605, then the JPO can be mixed with fossil diesel fuel, to a maximum of 20% and used as a blend fuel for the diesel engines. The diesel engines do not need to be modified in for this blend fuel.

(From a market point of view, this can only be profitable when the fossil fuel price is considerably higher than the JPO price of 730 CFA, since logistic (transport) and marketing costs are involved.) Moreover, when the mixture of the two fuels are at rest for some time, the oil will separate from the diesel, because of the difference in specific gravity, with the result that the engine will run for a while on 100% JPO, which is not the intention.

**2 By improving the process of settling and filtering after pressing**

Investing in an extra filter step and an extra sedimentation step could help to improve the quality, see Figure 5. Below. This could be a quite costly investment, and is not included yet in the Medium Input case, but could be included in a future High Input Case.

The present way of pressing the oil and cleaning it in the CIRAPIP/IITA project is rather elementary. Only the strainer press and a plate filter is used to obtain clean oil. No sedimentation nor fine filtering with candle filtering is done. The test sample shows that the contamination level of solid particles is still too high, which confirms the observations of the mission team.




| | | |
|---|---|---|
| Example flow diagram of a sedimentation system. | Set up of bag filters at Diligent Tanzania | Combined unit with bag and candle filter at Diligent Tanzania Ltd |

Figure 5: Example filtration systems

Source (FACT Foundation 2010)

***Factors influencing the JPO quality***

The factors that influence the quality of the oil can be influenced during the growth of jatropha seeds and processing itself. E.g the level of phosphor is already determined by the agronomic conditions during growth of the seeds. Which are exactly the factors that influence the level of phosphor during this stage is unknown sofar. It has been found that when the seeds are being pressed at too high temperature (above 70 degr. ) the level of phosphor will increase. Likewise, the level of acidity is influenced by several factors during the whole development process, which are also not quite known. The only way to know the levels of phosphor, acid, total contamination and oxidation stability is too check regularly the processed JPO by measuring these levels with sample tests, which is not done presently.

GERES is currently executing these tests. They were performed by a laboratory in Bohicon, but this lab has unfortunately closed. Now the tests are executed in Mali. The project ALTERRE-Mali installed a laboratory in Koutiala that can do these type of analysis. For a test of phosphor levels for example, the charge is 5,000 CFA / sample. See appendix with a list of tests they perform and contact details.

***Comparison between quality of present JPO and fossil diesel***

In the "Rapport Final d'Activités de la Phase Pilote" it is stated that an average of some 10 tests, the runs on JPO (Jatropha Pure Oil) lasted 1 hour and 57 minutes on one liter, and the ones on diesel 1 hour and 18 minutes. That would mean that the JPO is 50% more efficient than the diesel that was used, which is different from the test executed by GERES who came to the reversed conclusion. Theoretically, the energy content of JPO is slightly lower than diesel (36 MJ/kg compared with 42.3 MJ/kg for diesel) and the combustion of JPO is slightly better because of higher oxygen content, but not enough to make up for the calorific difference. So, from the above it can be concluded, that although the quality of the JPO is not exactly known, it is still about 50% better than the diesel fuel used in the test by the project This means that the quality of the diesel fuel is itself very bad, probably due to dilution with petrol, or even worse, with water (which is a 'real life condition').

**Recommendations:**

- To build up a quality assurance system in Benin, with adequate equipment and trained staff to do the required testing of the variables that determine oil quality, like phosphorous level, acid number, total contamination and oxidation stability. The laboratory where this could take place should be independent from the producers.
- Authorities to describe a standard which JPO quality should meet, like DIN V 51605, and prescribe the number of test to be done.
- Authorities should consider to pay incentives for each liter of JPO produced according the required quality level. (Comparable for incentives on kWh delivered by other renewable energy, like solar or wind.
- To improve gradually the oil quality of the pressing centers by following the steps as described above with investments and capacity building.

## 3.5 Suitability of Diesel engines to run on JPO

Besides good quality JPO also the diesel engines itself must be appropriate and adapted to run on JPO. The engines in the project are remakes of the Lister type, one cylinder, which are the better types for running on JPO. The engines purchased by the project are Indian made JKSon CS 8/1 indirect injection engines but several other brands are used by millers. Nevertheless there are requirements on operating temperature, type of fuel injection pump, and then the required adaptations.


**Figure 6: LEFT The JKSon engine driving a maize mill, watercooled and elevated tank, filled with SVO, RIGHT: example of a 2 cylinder Listeroid diesel engine, adapted to run on JPO in Bilibiza Mozambique, ref. draft missions report Niels Ansoe 2011**

Even for running on fossil diesel fuel the temperature of the engine should be sufficiently high (order of 80-90 degrees Celsius) to get a good combustion of the injected fuel. Temperatures measured by the project team during the mission showed that these were too low in 2 of the three engines measured, namely:

| | | |
|---|---|---|
| Engine cooling water after +1h running on Jatropha | In: 29°C<br>Out: 40°C | Measured; engine running Jatropha press, Ouinhi |

| | | |
|---|---|---|
| Engine cooling water after +1h running on Jatropha | In: 30°C<br>Out: 48°C | Measured: engine running grain mill, Tori |

This is probably caused by either a missing thermostat or a thermostat that is not properly set to regulate the temperature.

When JPO is used as fuel, the high viscosity of the JPO, which varies with temperature, can cause great problems with the engine. To overcome problems, a number of measures are normally taken:

- For starting up the diesel engine at normal (low temperatures) a two tank system is installed, wherewith the engine can be stared up with fossil diesel and after being heated up, changed over to JPO.
- The JPO should be pre-heated before entering the injector pump by a heat exchanger (with the hot cooling water)
- Especially in case the engine is of a DI (Direct Injection) type, the injectors itself should be replaced, and the injecting time setting and the pressure should be adapted to obtain a better combustion.
- Some minor adaptations, like increased diameter, good quality, fuel lines and extra JPO filter.

None of these adaptations was being done on the Lister engines in the project. And although the engine operators experiences with JPO are quite positive up to now, especially compared with the bad quality diesel fuel, this is a highly misleading perception. Experiences in the field show, that short term running on JPO does not pose any problem, but engines can get blocked or break down, when 500 operation hours are reached (see FACT Handbook 2010, section 5.2.2).

**Engine Service Intervals**

Project staff, millers and mechanics are convinced that the service interval for engines can be extended 50% when using JPO instead of diesel. For instance several millers mentioned that they have their engines serviced every 4 months when using diesel but with JPO a 6 month interval would be fine. This is not supported by experience elsewhere. To the contrary at least direct injection (DI) diesel engines often require oil changes more often when running on JPO. The reason is that some fuel always leak into the lubrication oil along the cylinder walls during the compression cycle. Diesel can evaporate from the lubrication oil and is vented back into the engine intake. However, the high viscosity of JPO hampers evaporation and can lead to a build up of JPO in the lubrication oil that will eventually destroy its lubricating properties.

**Recommendations:**

- Adapt a number of diesel engines in a way that they can run on good quality JPO. But this requires an experienced engineer to determine which adaptations are needed, due to the large variety of diesel engines in use.
- Then perform endurance tests for at least 500 hrs on JPO with adapted (rather new) diesel engines, under controlled conditions (with measurements)

# 4 Usage of the oil

## 4.1 Soap (and creme)making

Groups have been trained in soap making in all three villages. On average the groups make soap twice a month, with a batch of 3 litres of oil. This makes around 40-50 pieces of soap. Some women groups existed already and were (and are) making soap from palm oil. The groups make soap from pure jatropha oil and also from jatropha sediment, see Figure 7. All groups indicated that the soap that is made from the sediment of the oil has better characteristics (i.e. more antibacterial) than the soap made from pure soap. The soap has a black appearance, see Figure 7. The soap that is made from sediment is also sold for a higher price (200 CFA/piece) than the one made from pure soap (150 CFA/piece). This is an important aspect to take into account when looking at press efficiency. In West Africa the use of traditional black soap is widespread (about.com 2014). This could be a reason why the soap that is made from the sediment is preferred.


**Figure 7: Soap made by the project, and packaging**

The soap is sold within the village, and according to the groups the market is not fulfilled yet. If they would have more oil available they would be able to sell everything, twice, triple or 5-fold from what they sell now (interviews in Ouinhi, Djidja and Tori). Other potential markets for the soap are hotels, but the quality of the soap, mainly the appearance (cutting) and packaging, would have to increase. The profit that is made per batch, around 2,500 CFA is satisfactory for the women groups. The price of industrial soap is between 150-300 CFA per bar. Although it makes less profit, the groups also make soap using palm oil due to a lack of sufficient amounts of jatropha oil. Out of the ingredients that are required, perfume has the highest costs (15% of total costs). The usage of locally available scents may lead to reduced costs and therefore higher profits. Experiences in other countries revealed that it is common with soap from pure Jatropha oil not to harden well. At the moment paraffin and starch are used, probably to make the soap more firm. Instead of paraffin, palm oil can be used which is available locally. Mixing different types of oil is common, olive oil soap for example also often contains palm oil. The advantages are the local availability, the quality improvement and the increased profit. The quality of cutting can also be increased by using different moulds. Silicone moulds are not expensive (for example available on https://www.etsy.com/shop/MoldHouse) and they can be ordered in different shapes. Using these moulds would take away the need for cutting the soap which causes problems currently. Potentially also the need for a stamping machine is removed if a mould can be ordered with the brand name in it.

Another improvement that is required is packaging. Packaging is now made of cardboard, but another possibility would be using banana leaves or bamboo, see Figure 8 for examples from Tanzania.

Figure 8: Alternative packaging, LEFT; made by KAMA Tanzania, RIGHT: (Polyvore 2011)

**Challenges identified**

- Packaging
- Quality of cutting
- Marketing if other markets (outside village) have to be targeted, such as hotels.
- Safety material, the women received safety gear (gloves and mouth cover) but after the safety gear is worn out, it is unclear if they will purchase new gear themselves.

***Recommendations***

- Improve packaging
- Improve quality of cutting the soap
- Test with locally available scents to reduce costs of perfume
- Mix with palm oil to reduce paraffin requirement
- Use silicone moulds

## 4.2 Electricity generation

### Value Chain: Electric Light

At two project locations, namely Tori and Ouinhi electricity is produced with JPO and distributed to subscribers within the villages. A listeroid engine is driving a 3-phase generator and the resulting 230V is distributed to light bulbs in the subscribers' houses as well as a few public places.

Over the last decade Solar (PV) systems have dropped in price to a level where they are often the most efficient solutions to off-grid lighting systems. Also in Benin PV dealers are found even in remote areas.

To assess the feasibility of JPO versus PV for off-grid lighting systems in Benin detailed financial analyses have been made. Only equipment and services currently available in Benin are used in the analysis. Prices, performance numbers etc. are the ones currently experienced in Benin.

Figure 9 Electricity made from Jatropha oil is powering this public lamp post in Tori.

### Equipment

Electricity from JPO is produced with a JKSon CS 8/1 diesel of 8hp pulling a STC-8 3-phase generator of 8 kW. This is the current set up in Tori and Quinhi. The equipment is readily available in Benin and elsewhere.

The PV system utilise 130W panels of various brands, 100Ah 12V solar batteries and 30A solar chargers. 1500 W DC-to-AC inverters are used to supply the grid. This equipment is available in local shops in Tori.

The local grid is made with the cheapest installation cable attached to trees and available poles. These cables types are made for indoor use (low UV radiation exposure) and fixed mounting, i.e. no flexing. Since this is current practise and quality cables are significantly more expensive, these cables are used in the financial analysis. We account for this in the analysis by setting the wire loss at 5%.

Metering systems are omitted as this is current practise. Also protection against over- and under-voltage and lightning is omitted for the same reason.

### Scenarios

Four scenarios are analysed; two for JPO and two for PV. The financial analysis covers all equipment and maintenance till the doorstep of the consumer, i.e. wiring is included but light bulbs are not as they assumed to be purchased privately by the subscribers.

For JPO the starting point was the current situation in Tori, i.e. 105 subscribers paying 600 CFA/month per 11 W CFL bulb.

In the second scenario it is assumed that the generator set runs at 100% capacity, which would require 484 subscribers.

Figure 10 Solar equipment shop in Tori

For the PV scenarios it is assumed that the capacity is utilised 100%. This is close to reality because PV much more modular than the JPO scenarios and can therefore be sized to fit the actual number of subscribers.

The first PV scenario is based on a quotation from a local solar equipment shop in Tori. We asked to design a PV system that will supply the 105 subscribers in Tori with the electricity that they currently get from the generator.

To verify that system designed by the local solar equipment shop is realistic we designed a PV system based on solar radiation data for Benin and our assessment of electrical efficiency of the local grid, battery charging systems etc. We found that the design by the solar equipment shop is quite conservative, i.e. it is possible to deliver the required energy with less equipment. The PV 2 scenario is therefore more cost efficient. In the design we have used pessimistic values for the electronics efficiency of the solar controllers, the battery charge-discharge efficiency, and the inverter efficiency. This is to account for the fact that most PV equipment in Benin is of low quality. We use a maximum battery discharge depth of 50% to ensure longevity of the batteries. Over provisioning of panel size, batteries and solar chargers follow common practise.

One caveat in the PV 2 scenario is that we use average solar radiation data. Due to the over provisioning one full day of heavy cloud cover, e.g. during the rainy season will not affect the systems' ability to provide the scheduled 4.5 hour of light. However, several consecutive days with heavy cloud cover may result in shorter time with electricity. Daily solar radiation records are required to reach definitive conclusions on this issue and such an analysis has not been undertaken.

The generator set requires an operator when it is running. For the PV systems this is not required. For both the JPO and PV systems the cost of regular service by qualified technicians is included.

## Time frame and longevity of equipment

A 10 year period has been used for the analysis because all the equipment is expected to last at least this long. PV panels are rated at 25 years and the listeroid engines can easily run 5-10 more hours than they do during the 10 year period, assuming they are well maintained. Batteries for the PV systems is the exception and replacements are expected every five years.

Service costs and spare parts are accounted for in all scenarios.

## 4.3 Other potential value chains

Other potential value chains that might be looked into are: Production of biogas from jatropha press cake, making briquettes from press cake, making charcoal from press cake.

### 4.3.1 Production of biogas from jatropha press cake

Jatropha press cake contains rests of oil (10% of the oil in the seeds according people from GERES). When tested, the energy contents of seed cake is about 25 MJ/kg. This is about 2/3d of the energy contents of JPO which is 37 MJ/kg. But there is much more seed cake than JPO. So when this energy is extracted from the seedcake in the form of biogas, the total available energy (from JPO + biogas) somewhat doubles. This biogas can be used for various purposes, like replacing part of the fossil diesel fuel in diesel engines, for cooking and for lighting.

A small biogas system, installed next to an MFP unit, could decrease diesel consumption with some 50-75%. In addition, the effluents from the biogas system can be used as organic fertilizer in nearby vegetable gardens. Basic conditions that would have to be met are a continuous supply of biomass (e.g. animal manure and residues of vegetable origin) and sufficient availability of water.

One project is known in Mali, where FACT Foundation in cooperation with MBSA has started a project to field-test the production of biogas and its use as an MFP fuel in five villages. In 2012 they have installed three biogas units and started up. It are complete village biogas systems of 25 m3 each, providing biogas to the village MFP. The digesters can produce some 12 m3 of biogas per day, which is sufficient to replace some 6 litres of diesel during a full day of operations. Extension of the services of the MFP's with presses (50 kg/h) and battery charging stations (5 batteries/day). The use of the produced biogas allows processing prices charged by the MFPs to be reduced, and money to be set aside. Also, the digester effluent is recognised as a valuable fertiliser for vegetable gardens. The experiences sofar are modestly positive. Introducing a new technology, biogas production in this case, always has its own challenges. (see www.fact-foundation.com)

*Daily feed of a 12 m3 PVC plug-flow digester*

Ref: FACT Foundation-ADPP: Manual for the construction and operation of small and medium size biogas systems, Bilibiza Cabo Delgado, Oct 2012

An example of a large biogas system used for cooking in Tanzania, can be found in the FACT Jatropha handbook. Section 5.3, by Janske van Eijck.

*Stove run by biogas at Diligent Tanzania Ltd.*

### 4.3.2 Making briquettes from press cake

With a low pressure briquetting machine, the press cake can be further compacted into briquettes .These briquettes have a high energy content, but give a lot of smoke when burned. They are therefore not suitable for indoor purposes, but are excellent for industrial burners. See FACT Jatropha handbook. Section 5.3, by Janske van Eijck.

| | | |
|---|---|---|
|  |  |  |
| Example of press cake briquettes | Another type of presscake briquettes at Diligent Tanzania Ltd. | Briquetting press at Diligent Tanzania Ltd. |

### 4.3.3 Making charcoal from press cake

Burning the press cake without oxygen, will turn it into charcoal. This is also practiced in Tanzania. See FACT Jatropha handbook. Section 5.3, by Janske van Eijck.

| | |
|---|---|
|  |  |
| Charcoal production at TEMDO Arusha Tanzania | Charcoal briquettes at Diligent Tanzania Ltd. |

# 5 Gender issues

A gender approach, considers the different opportunities that are provided to men and women, the social role that they are assigned and the relation between them (Adetonah 2012). IITA has performed research on gender issues in the project. A survey has been executed between 18-26th October 2012. In total 113 farmers (61 male and 52 female) have been surveyed, which is 37 per village. Three main research questions are answered by the draft report that is made in 2012; 1) what is the impact of women, youth and children by the project, 2) are there also benefits for women and children, and 3) how are is the income from the jatropha distributed in the households? (Adetonah 2012).

**Figure 11: Women group in Tori**

From the surveys it became clear that more than 80% of the collectors consist of females, children and elderly and most of the producers are men. This is partly so because women cannot own land in Benin, and it is therefore more difficult for them to start jatropha cultivation. From the surveyed population, 40 of the 49 collectors where female, and 52 of the 64 producers where male. Most of the farmers in the survey (>58%) cultivate other crops than jatropha as main activity, and more than 86% is cultivating the jatropha in an intercropping system. At the time of the survey the majority of the jatropha seeds (65%) was collected from the villages (from hedges around houses), and the remaining 35% from the fields. The seeds are mostly collected directly (63%) and 27% is traded (buying-selling). The lack of women as jatropha producers and the overrepresentation of them as collectors, shows the weak integration of women in the whole value chain (Adetonah 2012).

From an analysis of the household budget, it was observed by Adetonah 2012, that so far only 10-11% of the surveyed people obtained more than 30% of their income from jatropha sales. The revenues from jatropha are not evenly distributed among men and women. Women earn on average nearly 50,000 CFA from selling jatropha seeds, while this average is 14,000 CFA for men. This is a major part of the off-farm income, and women could potentially loose almost half their income if there would be no market for jatropha anymore. This could potentially be harmful because from the surveys it appears that particularly women spend more than 40% of their income on food, while only 13% of the income of men is spend on the same. The largest part of the income of men (24%) is spend on modes of transport (bicycle).

The main challenges for women are the dehulling and conservation (Adetonah 2012). Dehulling takes a lot of time, the women are executing this activity the whole day (interviews in Ouinhi). Since the seeds are dried outside, they have to be brought inside quickly when it rains. The main challenge for men are the pests and insects that attack the jatropha on the field (Adetonah 2012).

Both men and women are interested in the immediate income generating activity of seed sales. Furthermore the fact that jatropha can be planted on the same land in intercropping was mentioned as very beneficial. Some other potential benefits that are mentioned by the jatropha stakeholders in the survey are;

- The creation of revenue generating activities especially for women (soap amongst others).
- Jatropha could improve the financial accessibility of rural populations to food through the additional revenues it could bring to the people.
- The creation of jobs for young people, including through the intensification of products that are derived from jatropha.

In Djidji the soap making group consists of 57 people, 54 women and 3 men. Currently women are mainly involved in seed collection and soap- and crème making. Women can earn their own income from jatropha and this can empower them greatly.

## 5.1 Recommendations

Women should be more integrated throughout the whole value chain, in production and in processing. This will also enhance capacity building. Furthermore, small business units such as mobile phone charging (see Figure 12) could be managed by women. Other products that are derived from the jatropha seeds such as seedcake briquettes or charcoal are other potential areas where women could be involved. Mechanised dehulling equipment can help to lower the time consumption of dehulling, a task that is mainly performed by women.

Figure 12: Mobile phone charging unit in Tori

# 6 Financial analysis jatropha value chains

The discount rate that is used is 10% (Bouffaron et al. 2012). Other values are mentioned in the respective sections.

## 6.1 Feasibility of cultivating jatropha

Two scenario's are made, one where farmers include applying fertiliser and pesticides to their land, with corresponding yield of 900 kg/ha. And a scenario where farmers do not include fertiliser and pesticides and obtain a yield of 800 kg/ha. Labour is rated at 1,500 CFA /day, this is in fact quite high because the opportunity cost for labour is low. Other values that are used in the calculations are provided below.

| | | | | |
|---|---|---|---|---|
| wage rate | 1500 | CFA/day | | |
| Yield (no inputs) | 800 | kg/ha | | |
| yield growth | 1 | 15% | 120 | |
| | 2 | 25% | 200 | |
| | 3 | 40% | 320 | |
| | 4 | 60% | 480 | |
| | 5 | 70% | 560 | |
| | 6 | 80% | 640 | |
| | 7 | 90% | 720 | |
| | 8 | 100% | 800 | |
| | | | | |
| yield (inputs) | 900 | kg/ha | | |
| yield growth | 1 | 15% | 135 | |
| | 2 | 25% | 225 | |
| | 3 | 40% | 360 | |
| | 4 | 60% | 540 | |
| | 5 | 70% | 630 | |
| | 6 | 80% | 720 | |
| | 7 | 90% | 810 | |
| | 8 | 100% | 900 | |
| | | | | |
| discount factor | 10% | | | |
| land rent | 0 | | | |
| tools | 0 | | | |
| Seed selling price | 150 | CFA/kg | | |
| fertilizer expenses | 21000 | CFA | (100 kg | 210 CFA/kg) |
| pesticide expenses | 7333.33 | 2l | | only the first 5 years |
| packing expenses | 292.5 | | | |
| harvest efficiency | 30 | kg per day | | |

| | | | | |
|---|---|---|---|---|
| labour days | | All values from interviews at the three locations in Benin | | |
| clearing | 30 | | | |
| planting | 4 | days | (28 in other calculations) | |
| weeding | 10 | days | (30 in other calculations) | only first four years |
| pesticide application | 4 | days | | |
| fertiliser application | | | | |
| dehulling | 10% | of harvesting time | | |

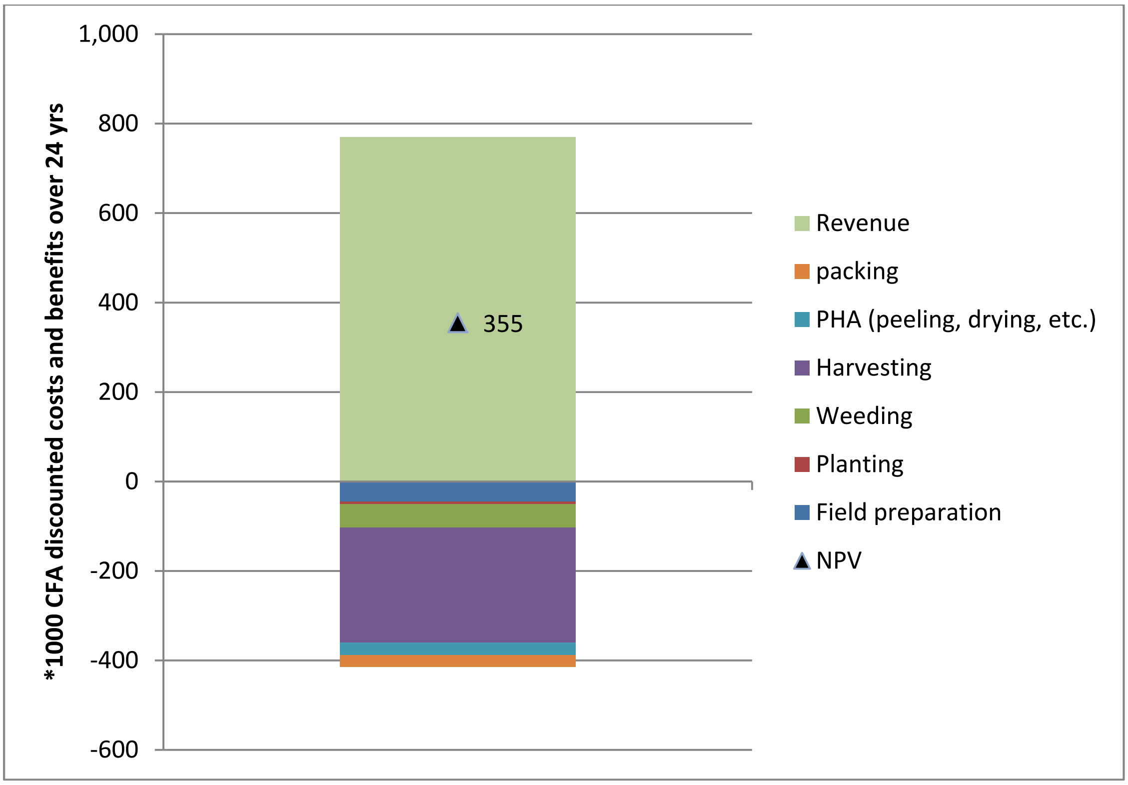



**Figure 13: Cost and Benefits of jatropha cultivation over 24 years using a low input system**

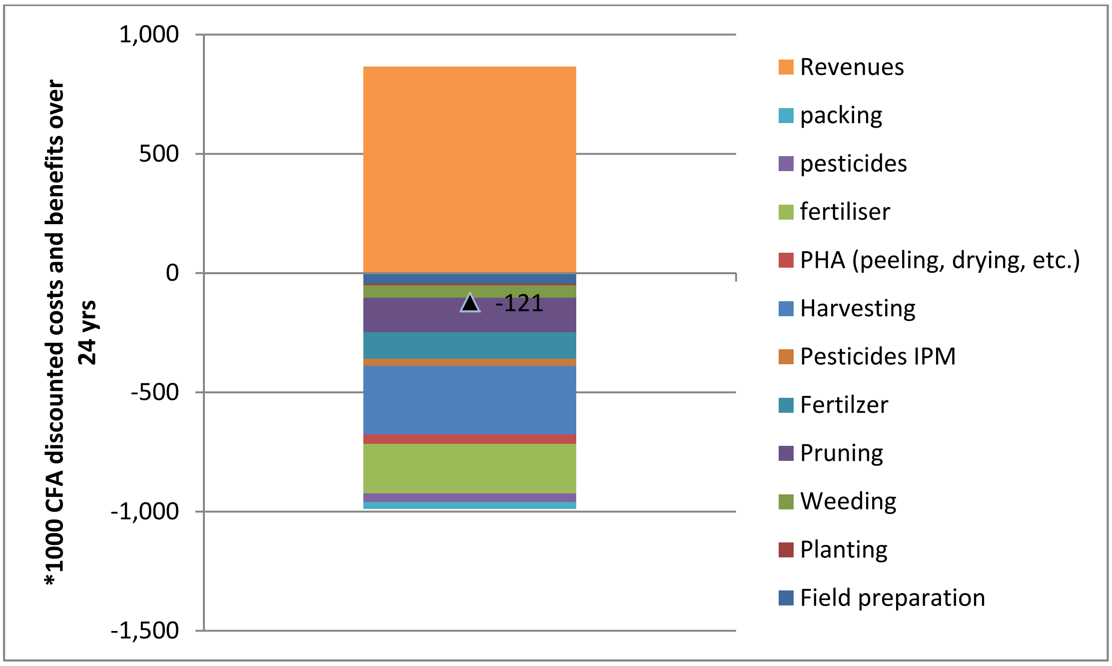



Figure 14: Costs and benefits of jatropha cultivation over 24 yrs using a medium input system

When jatropha is cultivated in a low input system, the NPV, and thus profitability, is positive at 355,000 CFA/24 yrs. However, if jatropha is cultivated with medium inputs such as fertiliser and pesticides, the NPV is negative, even when a low discount rate of 5% is used, see Table 3. Labour is valued at 1,500 CFA per day, which does not reflect the low opportunities to actually obtain that income. If a wage rate of 500 CFA/day is used instead, the NPV in the medium input scenario is positive as well (356,000 CFA/24 yrs).  The price of seeds is 150 CFA/kg. This means, jatropha cultivation can be profitable, as long as the inputs are kept low, and when it is done in areas with low labour opportunities.

Looking at the different activities, it is clear that harvesting is the most costly activity due to the highest time consumption, see Figure 15.

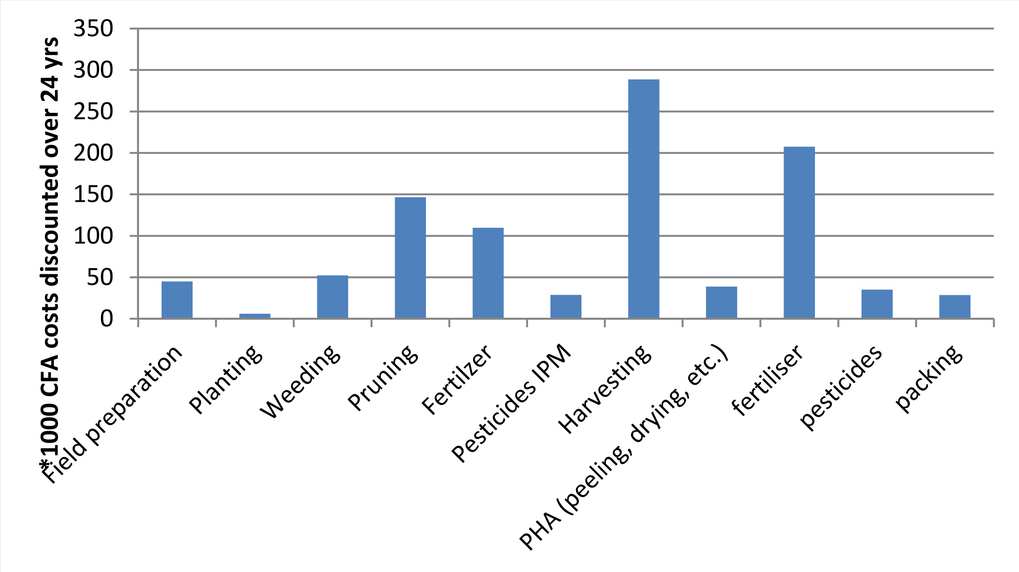



Figure 15: Costs of various jatropha cultivating activities

Table 3: Sensitivity analysis for jatropha cultivation.

| NPV | PBP | IRR | BCR | NPV/year | |
|---|---|---|---|---|---|
| 355,024 | 5 years | 35.8% | 1.86 | 14,793 | low inputs |
| -120,965 | No PBP | 4.7% | 0.88 | -5,040 | medium inputs |
| 658,820 | 5 years | 35.8% | 2.05 | 27,451 | discount rate 5%, low inputs |
| 198,766 | 6 years | 35.8% | 1.65 | 8,282 | discount rate 15%, low inputs |
| -8,967 | No PBP | 4.7% | 0.99 | -374 | discount rate 5%, medium inputs |
| -170,889 | No PBP | 4.7% | 0.77 | -7,120 | discount rate 15%, medium inputs |

There are also seed collectors, who collect from existing hedges e.g. from trees around the house. This activity has to be evaluated against alternatives. For daily work at for example road construction near Ouinhi and Djidja, people are paid 1,200 – 2,000 CFA. This means 8-14 kg of seeds should be collected per day for a reasonable daily wage. In other publications about harvesting efficiency from wild jatropha an average of around 20-30 kg per day is provided (and 50-60 for jatropha monocropping) (FACT Foundation 2010; Van Eijck et al. 2012). So a daily wage from collecting jatropha seeds, looking at labour only, seems to give a reasonable income. However it will only be possible to obtain this income for a few days per season.

Paying for jatropha seeds at a price lower than 150 CFA/kg, is suggested by a potential broker who would like to export oil in large quantities. The amount that can be paid for profitable large scale oil export at current prices, is 5kg of seeds for 150 CFA, or 30 CFA/kg. This would make collection problematic, since it would mean 30 kg have to be collected.

## 6.2 Pressing

Two different cases have been calculated. One Low Input case and a Medium Input case. In Table 4 and Table 5 , the input data is provided that is used in the calculations. The current data that is obtained from interviews, shows that the seeds are bought for 150 CFA, and that the management fee for the operators is 20,000 CFA/month.

The Low Input case represents the near present situation, with a low amount of seeds available, thus only 120 days in a year pressing takes place at a modest pressing capacity of 300 kg seeds per day.

Table 4: technical coefficients used in calculations for pressing for the Low Input Case

| | | | |
|---|---|---|---|
| | **Low Input Case Local Miller type of pressing unit** | | |
| **Investment** | Double Elephant +Diesel | 4.000.000 | CFA |
| | Management fee | 20.000 | CFA/month |
| | | 240.000 | CFA/year |
| | capacity press | 300 | kg seeds/day |
| | days per year | 120 | if only in season |
| | total amount of seeds processed | 36000 | Kg/year |
| | price for seeds | 150 | CFA/kg |
| | SVO produced from 100 kg | 20 | liter SVO |
| | sediment produced from 100 kg | 9 | |
| | Press cake produced | 71 | kg |
| | SVO produced total/year | 7.200 | liter SVO |
| | Sediment produced total | 3.240 | Kg |
| | Press cake produced total | 25.560 | kg |
| | price for SVO | 800 | CFA/liter |
| | price for sediment | 350 | CFA/kg |
| | price for cake | 30 | CFA/kg |
| | price 1 l diesel fuel | 1 | Euro |
| **Maintenance** | Of press and diesel engine | | |
| | ca 7% of investment x 120/300 | 112.000 | |
| **Fuel for pressing** | Ca 7% of produced JPO | 330.624 | |

The quality of the oil is not good enough yet for diesel replacement, but can be used for soap.

The calculation shows that with a sales price of 800 CFA/l the PBP is 6 years and the IRR is 24,2 %, which is reasonable good for this type of operation. In the sales are also included 100% sales of the sediments, and 0% of press cake (due to the need of purchasing fertilizer if this value would be included). Currently a price of 640 CFA/l is charged for the oil. The calculations show that from a price of 700 CFA/l, the operation starts to become profitable (accounting for running expenses). And from a price of 760 CFA/l the PBP is 12 years and the NPV is positive around 380,000 CFA (15 years system lifetime). Adding press cake sales (without accounting for fertilizer prices) makes the activity profitable from an oil price of 650 CFA/l onwards (PBP 13 years, NPV 170,000 CFA).

***The Medium Input Case*** represents a possible future case when 210 tons of seeds are available to be processed per year. Some investments have been done to improve the oil quality, which either can lead to oil quality good enough to let the diesel engines run on, for 100%, or only to a quality which can be used to blend with fossil diesel (max 20%)

Table 5:Technical coefficients used in calculations for pressing for Medium Input Case

| | **Medium Input Case More sophisticated type of pressing unit** | | |
|---|---|---|---|
| **Investment** | Double Elephant +Diesel | 4.000.000 | CFA |
| | Roof for storage of seeds | 2.624.000 | CFA |
| | Simple Degumming unit | 328.000 | CFA |
| **Salaries** | | | |
| | Director 1/3 time @ 2400€/year | 524800 | CFA |
| | Accountant 1/3 time @ 1260€/year | 275520 | CFA |
| | 2 operators @ 365€/year full time | 478880 | CFA |
| | 1 guard full time | 393600 | CFA |
| | | | |
| **Other** | capacity press | 700 | kg seeds/day |
| | days per year | 300 | per year |
| | total amount of seeds processed | 210000 | Kg/year |
| | price for seeds | 150 | CFA/kg |
| | SVO produced from 100 kg | 20 | liter SVO |
| | sediment produced from 100 kg | 9 | kg |
| | Press cake produced | 71 | kg |
| | SVO produced total/year | 42.000 | liter SVO |
| | Sediment produced total | 18.900 | Kg |
| | Press cake produced total | 149.100 | kg |
| | price for SVO | 730 | CFA/liter |
| | price for sediment | 350 | CFA/kg |
| | price for cake (not included) | 30 | CFA/kg |
| | price 1 l diesel fuel | 1 | Euro |
| **Maintenance** | Of press and diesel engine | | |
| | ca 7% of investment | 280.000 | |
| **Fuel for pressing** | Ca 7% of produced JPO | 1.928.640 | |
| **Quality tests** | 4 times/year @ € 250 extern lab | | |

The calculation shows that with a sales price of 730 CFA/l oil the PBP is 7 years and the IRR is 18,9 %, (15 yrs) which is reasonable good for this type of operation. In the sales are also included 100% sales of the sediments, and 0% of presscake.

Calculating with these figures for the Low Input Case gives a cost price of the jatropha SVO, around 845 CFA/l, see table 5. This means that the current cost price of jatropha SVO is higher than the current selling price (640 CFA/l). Even if there are enough seeds available and the capacity of the press can be increased to 700 kg/day (according to the specifications of the Tinytec), the cost price, calculated for the Medium Input Case is still 858 CFA/l. However, more than 19 tons of sediment and 149 tons of seedcake are also obtained. If the revenues from selling sediment for 350 CFA/kg are included, the cost price of jatropha SVO is lowered to around 700 CFA/l. Revenue from seedcake sales as fertilizer (currently for 30 CFA/kg) are not taken into account due to the nutrient balance. Jatropha harvesting extracts nutrients from the soil and these have to be replenished. (with press cake sale the cost price of oil would be lowered to 600 CFA/litre, but the price of fertiliser is higher.)

**Table 5: Cost price of jatropha SVO**

| Case | Seeds processed/day | Days pressed /year | SVO produced in Total l/year | Sales costs SVO CFA/l | Production Costs CFA/l | Prod. Costs incl. Sediment sales CFA/l | PBP in years | IRR in % |
|---|---|---|---|---|---|---|---|---|
| **Low Input** | 300 | 120 | 7200 | 800 | 845 | 687 | 6 | 24,2 |
| **Medium Input** | 700 | 300 | 42000 | 730 | 858 | 701 | 7 | 18,9 |

**Recommendation**: The contribution of the costs of the jatropha seeds contributes between 80 – 85% for respectively The Low Input Case and The Medium Case, which is very high. Thus reducing the purchasing costs would improve the pressed costs a lot. This could be achieved by improving the harvesting output, by hand operated or motorised dehullers. With a slightly decreased purchase price this would allow both the farmers to get more income, and also the press unit.

Only if the capacity of the press is used to a higher extend than currently (only 20 days pressing have been reported), the unit is financially viable. This means the press needs to be used for more days per year (and so a stock of jatropha seeds is required) and even per day a higher amount of seeds need to be processed. If the press is used for 200 days per year and presses 700 kg of seeds per day, a total of 140 tons of seeds are processed per year. Using the press for 300 days at the same capacity means a total of 210 tons of seeds per year. This exceeds by far the current supply of jatropha seeds.

## 6.3 Usage in maize milling machines

For operators of maize milling machines the comparison with diesel is important. In the three locations of the CIRAPIP project diesel fuel is not always available. The price of diesel, which is sold via informal routes, is around 650-1000 CFA/litre. Their experience is that with a litre of jatropha oil their machines run longer than with the same amount of diesel, but the quality of the diesel was probably very bad. Tests conducted by GERES showed a shorter running time with jatropha oil compared to diesel. Therefore, more information is required to calculate the profitability for maize millers.

## 6.4 Soap making

Soap is made from pure jatropha oil and from the sediments that remain after pressing. For both value chains calculations are made.

**Table 6: Input data for soap making from pure oil**

| Soap from pure oil | Qty (l or g) | price (CFA/L or kg | TOTAL | |
|---|---|---|---|---|
| Inputs | | | | |
| Oil | 3 | 640 | 1920 | From interviews |
| Other inputs | | | 1974 | From semester report |
| *Other inputs detailed* | | | | |
| *Coloring substance* | | | *67* | *(from semester report)* |
| *Parfum* | *56.6* | *10500* | *594* | *(from semester report)* |
| *Silicate* | *166.67* | *2000* | *333* | *(from semester report)* |
| *Starch (Amidon)* | *76* | *650* | *49* | *(from semester report)* |
| *Calcium* | *100* | *1250* | *125* | *(from semester report)* |
| *Soda pm* | *125* | *1000* | *125* | *(from semester report)* |
| *Caustic soda* | *500* | *1000* | *500* | *(from semester report)* |
| *Paraffin* | *120* | *1500* | *180* | *(from semester report)* |
| **TOTAL** | | | **3894** | |
| Output | Qty (pcs) | Price (CFA/pc) | TOTAL | *Profit* |
| soap | 33 | 150 | 4950 | 1056 |
| | 43 | 150 | 6450 | 2556 |
| | 50 | 150 | 7500 | 3606 |

The activity of soap making from jatropha oil is profitable. The profit (between 1000-3500 CFA per batch) is not very high but is relatively stable for changes in the number of bars that can be produced from one batch (33 is the lowest, this value is derived from the semester report), the womengroup indicated they can produce between 43 and 50 bars. Also if the jatropha oil price would increase to 800 CFA from the current 640 CFA/l, it would still be a profitable business. The profit from soap making with sediment is even higher and ranges from 1,570-9,120 CFA per batch. See Figure 16 and Figure 17 for the profits per batch.

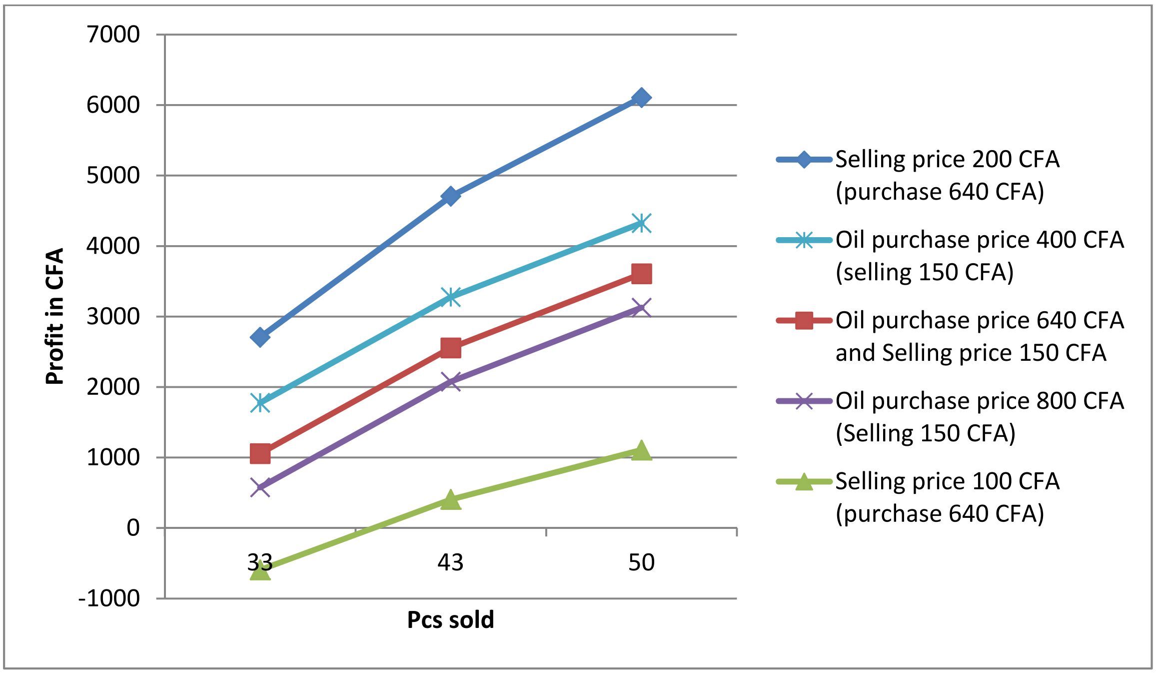



Figure 16: Sensitivity analysis, profit for variety of selling prices and oil purchase prices (pure soap)

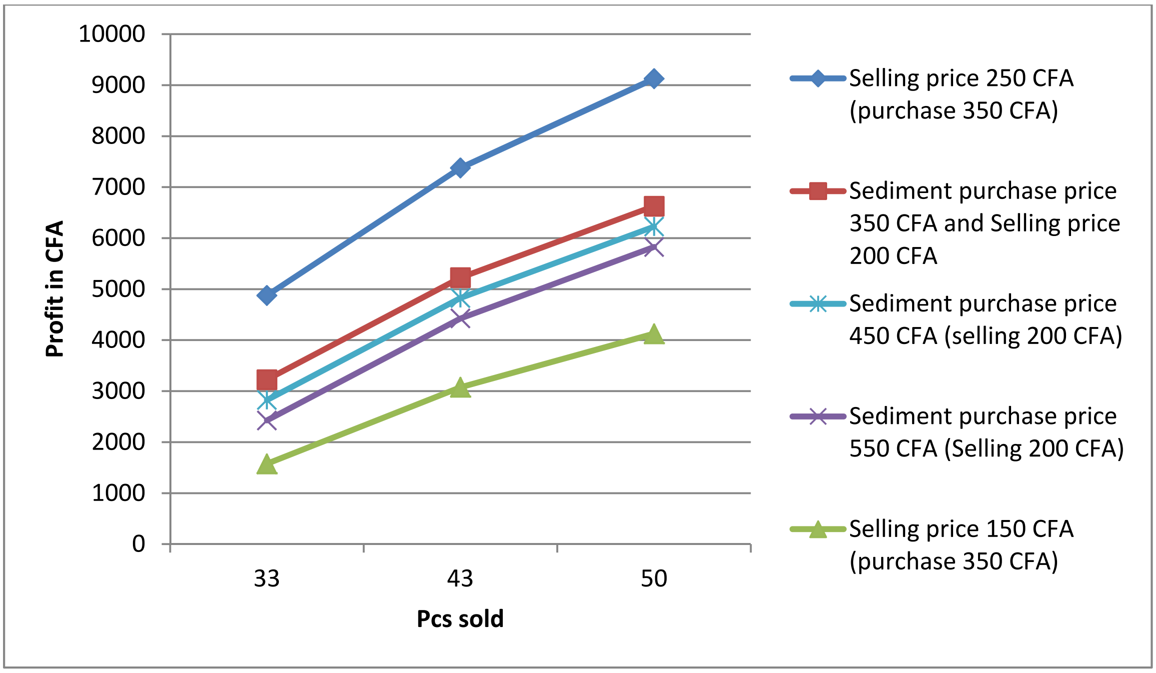



Figure 17: Sensitivity analysis, profit for variety of selling prices and sediment purchase prices (sediment soap)

The soap making activity is performed when the previous batch is sold. The groups explained that this can take place up to twice a month. The investment costs are quite low, per batch less than 4000 CFA. Even if the soap making activity is performed twice a year the NPV is positive, see Table 7. The Benefit Cost Ratio of producing soap once a month is 1.66 for soap from pure oil and 2.55 for soap from sediment, which is very high.

Table 7: NPV calculations per year for soap making activity

| | batches/year | NPV | Months |
|---|---|---|---|
| Soap from pure oil | 2 | 4,709 CFA | 6 |
| | 4 | 9,596 CFA | 3 |
| | 6 | 14,482 CFA | 2 |
| | 12 | 29,140 CFA | 1 |
| Soap from sediment | | | |
| | 2 | 9,310 CFA | 6 |
| | 4 | 18,282 CFA | 3 |
| | 6 | 27,253 CFA | 2 |
| | 12 | 59,579 CFA | 1 |

## 6.5 Electricity production

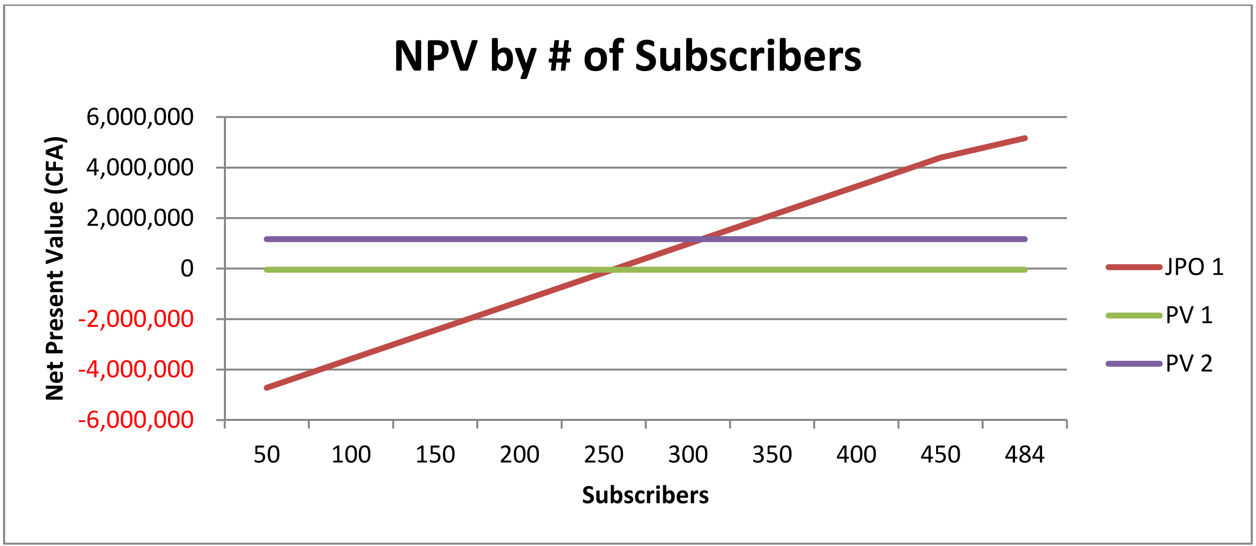
An Excel based model has been developed for assessing the NPV of the four scenarios. The following parameters which reflect the current situation in Tori, have been used when calculating the NPV and investments that are depicted in the following three graphs.

Table 8 Parameters used for NPV calculations

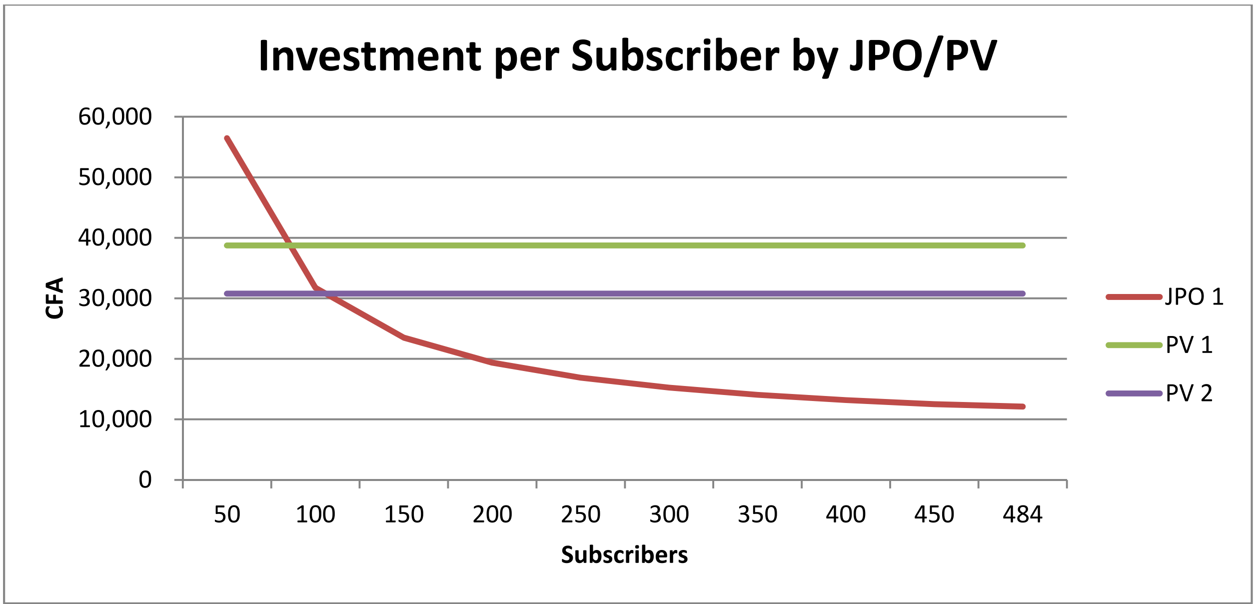
| Parameters | | |
|---|---|---|
| **Annual discount rate** | 10% | |
| **JPO price** | 640 | CFA/l |
| **Bulb wattage (CFL)** | 11 | W |
| **Monthly subs. Cost, 1 bulb** | 600 | CFA |
| **Wire per bulb** | 20 | m |
| **Power cable** | 350 | CFA/m |
| **JKSon CS 8/1 engine, 8 hp** | 1,050,000 | CFA |
| **8kW Generator, incl switches** | 1,423,750 | CFA |
| **1500W DC-AC inverter** | 91,700 | CFA |
| **Solar panel, 130W** | 75,000 | CFA |
| **Battery, 12V 100Ah** | 80,000 | CFA |
| **Solar controller, 30A** | 25,000 | CFA |
| **Salary of genset operator** | 20,000 | CFA/m |
| **Daily production time** | 4.5 | h |
| **Service interval** | scenario dependent | |
| **PV short circuit rating** | 8.51 | A |
| **Electronics efficiency (controller)** | 70% | |
| **Battery charge-discharge efficiency** | 80% | |
| **Wire loss in local grid** | 5% | |
| **Inverter efficiency** | 80% | |
| **Battery max. discharge depth** | 50% | |
| **Battery longevity** | 5 | years |
| **Daily solar radiation, tilted (GTI)** | 5100 | wh/m² |

| | | |
|---|---|---|
| **Engine output** | 8 | hp |
| **Engine consumption, no load** | 0.25 | l/h |
| **Engine consumption, full load** | 1.57 | l/h |
| **Inverter capacity** | 1500 | W |

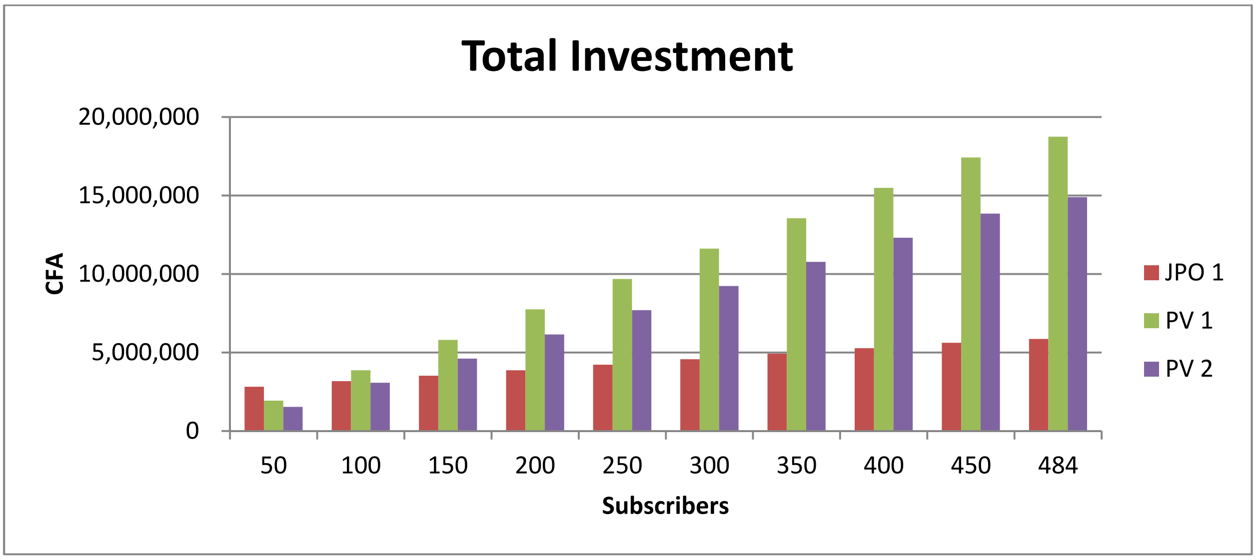
Table 9 NPV by number of subscribers




Below 250-300 subscribers PV has a higher NPV. The full capacity of the JPO generator set is sufficient for 484 subscribers. In other words the JPO generator set only surpass PV if more than 50-60% of the capacity is utilised.




PV has the reputation of requiring higher up-front investment than alternative technologies. However, in the current context this is only true when there are more than ~150 subscribers.




JPO generator set benefit from scale of operation, PV does not.

Due to the different advantages of the two technologies a combination may be beneficial. For instance when Jatropha cultivation is introduced in an area a small PV system could initially be installed. When the local Jatropha production and number of subscribers is sufficient it can be substituted with a JPO generator set and the PV system moved to a new area. Both investment costs and risks could be reduced in this way.

## 6.6 Mobile Phone Charging

Mobile phone charging is an important service in rural areas and the market is expanding rapidly. The energy requirements are relatively low and can easily be provided by solar power. It is therefore of interest to assess if it is viable to use JPO for this service.

Compared to electric lighting systems, solar mobile phone charging has the advantage of not requiring a battery bank for intermediate storage when charging is done in the day time. This both eliminates an expensive recurring cost and avoids the energy loss from the charging/discharging cycle.

To further reduce energy conversion losses, avoid electrical hazards and reduce equipment costs the power from solar panels can be converted directly to 5V DC used in USB phone chargers. For this task cheap DC to DC buck converters are ideal. They come in sizes ranging from 1 to 30+ USB ports. The price per USB port is typically 1300 to 4500 CFA. Charge current range from 800 mA to 2.5A per port. Even cheap buck converters have a very high efficiency in the 88-96% range.

To assess the viability of using JPO versus solar chargers for mobile phone charging a small and a large solar system have been compared. The large system is based on one standard 130W panel:

Table 10 Cost of solar phone charger system with daily capacity of 130+ charges

| Investment | price | | Units | | |
|---|---|---|---|---|---|
| Solar panels, 130W | 75,000 | CFA | 1 | 75,000 | CFA |
| DC-DC buck converters, 30x1.5A USB ports | 3,000 | CFA per port | 30 | 90,000 | CFA |
| USB cables w multiple phone adapters | 3,200 | CFA | 30 | 96,000 | CFA |
| **Total:** | | | | **261,000** | **CFA** |

The price of the panel was obtained from a solar equipment shop in Tori. The prices for converters and cables are typical international prices plus 50%.

A smaller system based on a 20W panel:

Table 11 Cost of solar phone charger system with daily capacity of 20+ charges

| Investment | price | | Units | | |
|---|---|---|---|---|---|
| Solar panels, 20W | 23,000 | CFA | 1 | 23,000 | CFA |
| DC-DC bucket converters, 10x1.5A USB ports | 3,000 | CFA per port | 10 | 30,000 | CFA |
| USB cables w multiple phone adapters | 3,200 | CFA | 10 | 32,000 | CFA |
| **Total:** | | | | **85,000** | **CFA** |

The price of the 20 W panel is estimated by using the rule of thumb that the price per watt is the double for a 20W panel compared to a 130W panel.

It takes a few hours to charge a phone and 3-4 batches of phones can be charged in one day. The amount of energy required per charge and therefore the capacity of the systems varies with the phone model and the state of phone battery. A sample of cell phone batteries had an average capacity of 3.0 Wh. A 130 W PV panel produce an average of 663 Wh with the daily solar radiation tilted (GTI) of 5100 Wh/m$^2$ that is average for the project area. We estimate that one phone can be charged per rated PV watt, e.g. a 130 W panel is sufficient for charging 130 phones every day. That leaves 5.1 Wh to charge every 3 Wh battery. These figures are in line with commercial turnkey systems that advertise a capacity of 30+ smart phones per day for a 35 W panel in systems with battery banks.

The components in the solar charge system are rated for a 25+ year lifetime. Even with relatively low prices for charging and including salary for the operator, break-even is achieved in 1-2 years so there is clearly a possibility for a profitable business. In the figures below a 20 W PVand a 130 W PV under different utilization rates are compared. The daily salary for the operator is set at 1500 CFA.

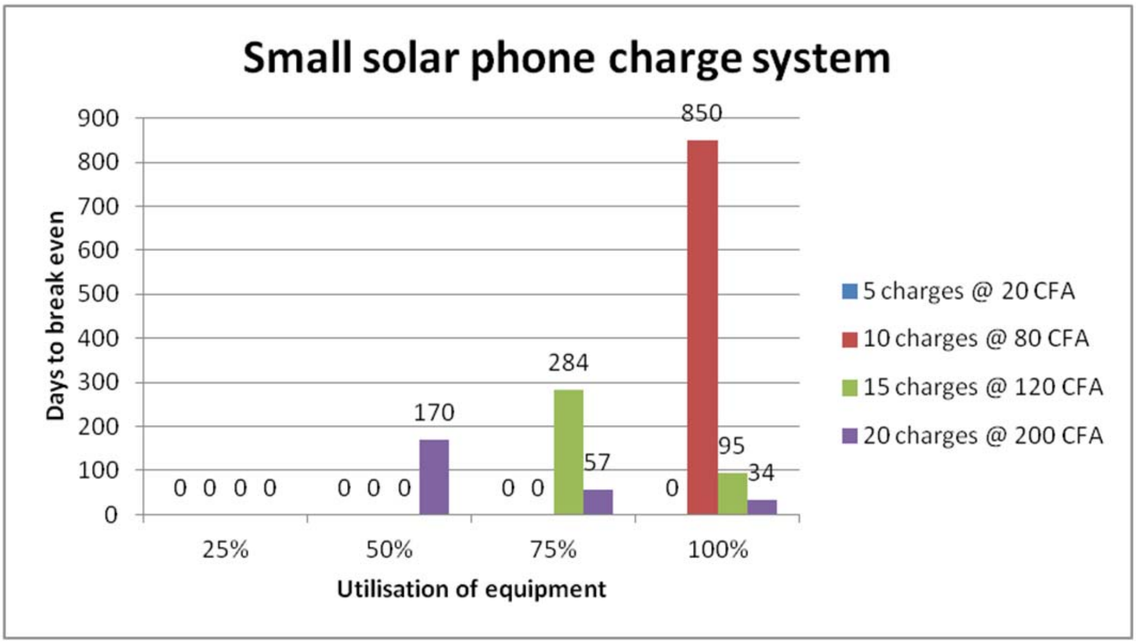



Figure 18 Days to break-even for 20W PV mobile charging system. Operator earns 1500 CFA/day.

With a small PV system and a utilisation rate of 75% a price of 100 CFA per charge will achieve break-even in about one year.

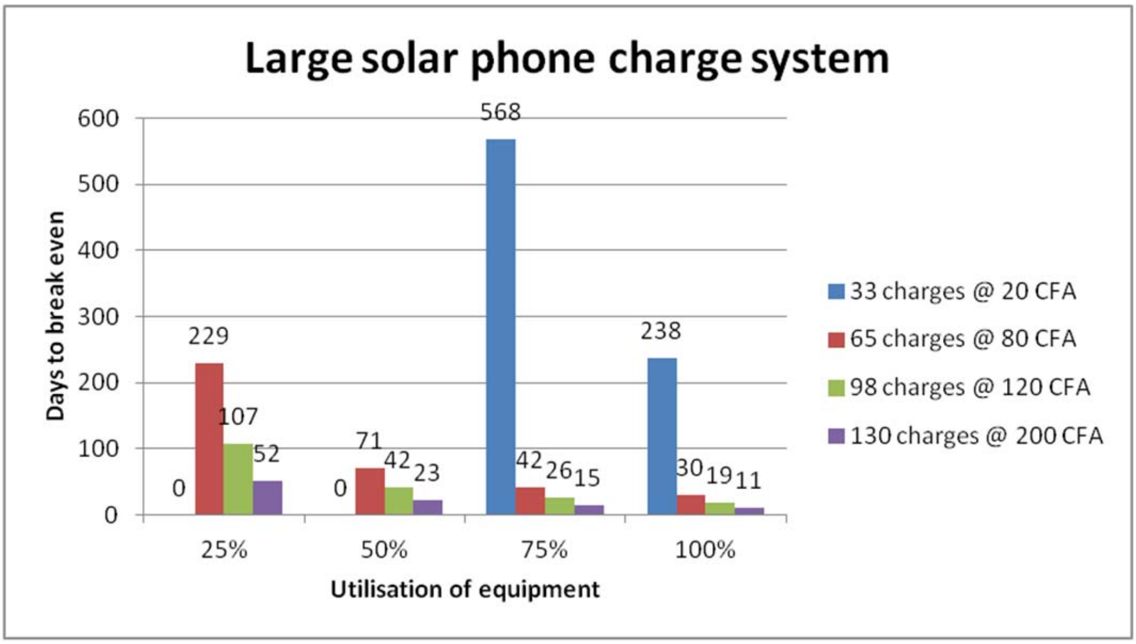



Figure 19 Days to break-even for 130W PV mobile charging system. Operator earns 1500 CFA/day.

With a larger PV system and the same utilisation rate a charge of about 70 CFA is enough to reach break-even in one year. With two years to break-even and 100% utilisation rate the rate can be as low as 15 CFA.

Since mobile phone charging does not require full time attendance it can be an addition to another business, e.g. shop keeping. If no salary for the operator is included then a price as low as 3 CFA per charge is sufficient to achieve break-even in two years.

To compare the PV systems with JPO for mobile phone charging, the fuel cost of generating the same energy as a 130W PV panel was calculated. The equipment currently used in the project and with the parameters used for the calculation on JPO for lighting have been used (see spreadsheets for details).

With a JPO price of 600 CFA/l and the generator running at 100% of capacity, the daily fuel cost is 80 CFA to produce the same amount of energy as a 130W PV panel. If the generator runs at 50% of capacity the cost is 94 CFA. In other words the fuel cost for charging a phone is less than 1 CFA. It will take 7.5 to 9 years before the cumulative fuel costs reach the price of the full 130 W PV charging system. This assumes that all costs of the full JPO system and the operator are already covered.

Mobile phone charging based on JPO is therefore competitive with PV based charging if it is an additional service that adds no extra costs to the system, except the additional fuel required. It is further required that mobile phone charging is done simultaneously with other activities to ensure a sufficient load on the engine.

With the current setup the generator cannot run when milling is done. The engine has to run on different speed for the two operations. With the right gearing this problem can be solved. However, the electricity generation requires a very constant engine speed which may be difficult to achieve when milling is done. As a consequence mobile phone charging is only feasible in the evening when the generator is running for four hours to produce light.

Since 2-3 mobile phones being charge draw the same power as an 11 W light bulb, the maximum number of subscribers for light will be reduced.

A phased approach combining solar and JPO based mobile phone charging is likely to be the most cost-efficient way of providing rural energy services. For example when Jatropha is introduced into a new area a solar charging system can be installed to provide energy services instantly. When the Jatropha production is sufficient a JPO based system can be installed and the solar system moved to a new area. When the demand for light and mobile phone charging eventually saturates the capacity of the JPO system, a solar system can be introduced again to cover the e excess demand until it is big enough to warrant introduction of another JPO system.

## 6.7 Overall comparison

Table 12 shows an overview of the financial analysis for the different value chains. Not all activities have the same system lifetime, therefore a column with NPV per year is added.

**Table 12: Overall comparison different value chains**

| | | Initial investment CFA in year 0 | NPV | PBP | IRR | BCR | NPV/year CFA | system lifetime yr |
|---|---|---|---|---|---|---|---|---|
| CULTIVATION | Low inputs | 66,600 | 355,024 | 5 years | 35.8% | 1.86 | 14,793 | 24 |
| | Medium inputs | 113,083 | -120,965 | No PBP | 4.7% | 0.88 | -5,040 | 24 |
| PRESSING | Low inputs | 10,082,624 | 2,788,529 | 6 years | 24.2% | 0.95 | 185,902 | 15 |
| | Medium inputs | 42,989,440 | 2,920,842 | 7 years | 18.9% | 0.99 | 194,723 | 15 |
| SOAP | pure, 2 batches | 7,788 | 4,709 | 6 months | 26.2% | 1.62 | 4,709 | 1 |
| | pure, 12 batches | 46,728 | 29,140 | 1 month | | 1.66 | 29,140 | 1 |
| | sediment, 2 batches | 7,268 | 9,310 | 6 months | 67.5% | 2.32 | 9,310 | 1 |
| | sediment, 12 batches | 40,488 | 59,579 | 1 month | | 2.55 | 59,579 | 1 |
| ELECTRICITY | 300 subscribers | 5,865,843 | 972,849 | 8 years | 17.4% | | 81,071 | 12 |
| | 484 subscribers | 7,646,063 | 5,165,984 | 5 years | 31.7% | | 430,499 | 12 |
| MOBILE CHARGING* | 2-3 phones equals 1 light bulb | 80-94 CFA/day fuel | | | | | | |

*calculations are based on electricity generation, no NPV calculated.

From the last column it is clear that the profitability varies largely with the capacity of the units, more specifically the running hours for the pressing unit and the number of subscribers for electricity. Cultivation is only profitable if a low amount of costly inputs are used, or if there are so little opportunities for labour that wages lower than 1,500 CFA/day are attractive to the population (which is not unlikely). Soap making is always profitable, although profits remain relatively small. Electricity generation can be very profitable, however, only if the number of subscribers is over 300. Pressing is feasible when oil is sold for 800 CFA/l, and the press is used close to its capacity.

Availability of seeds is currently a bottleneck. Newly established jatropha will take up to 8 years to mature which means there is a gap of at least a few years, even more because it also takes time to convince people to start cultivating jatropha. However, if the availability of jatropha seeds would not be a bottleneck, the different value chains can be profitable.

# 7 Conclusions and recommendations

The analysis indicates that the Jatropha value chain as implemented by the project is viable overall, i.e. it is ecologically sound and financially viable.

Different parts of the chains show various levels of return. On the production side Jatropha cultivation can compete with alternative crops but only just and it takes some years to reach an attractive yield. Picking seeds from already existing trees is very profitable, considering the low alternatives. The pressing of Jatropha is only just viable and with a rather long time to break even. Most of the profits are in the soap making, mobile phone charging and electricity for lighting. This constitutes a threat to the Jatropha value chain because soap makers can switch to oils like palm oil and engines can run on diesel. If this should happen the significant non-monetary benefits of the Jatropha value chain will be lost. These include the resilience farmers enjoy because the price of Jatropha seeds follow the price of diesel which is not influenced by local bumper harvests or other events affecting prices for other agricultural crops.

Jatropha is likely to be viable for all parties in the value chain, including farmers, millers and consumers when assessed over a longer period, i.e. when the plants are mature. Currently the oldest plants are only half way to maturity and yields are therefore low. The jatropha that is planted in the past three years will slowly mature, but will only provide full harvest from year 5-8 onwards. GERES has made a GIS map of the area which indicates how old the jatropha plants are, see Figure 20 in Appendix 5. This shows it will take more time before there will be enough supply of jatropha seeds.

All Jatropha value chains needs further improvements and optimisation. In particular the use of Jatropha oil to substitute diesel requires more attention to ensure proper function and longevity of the engines. Presently the oil quality is not sufficient for using in diesel engines (based on the sample test result) and need to be improved. Changes are required both on the processing side and with regard to engine modifications. The present oil quality however is good enough for making clean soap.

To ensure long term sustainability of the Jatropha value chain it is paramount to increase the return for farmers and press owners. The best option is to introduce simple mechanical dehullers that have been successful elsewhere in the region. They can double the productivity of the farmers because manual dehulling of Jatropha takes about the same time as picking the fruits. As a result the price for the seeds can be reduced by 25% while still increasing the return per working hour. Such a price reduction will have significant impact on the profitability of the Jatropha presses. Some options for increasing the profitability have not been tested yet, including biogas production from the press cake to double the energy produced from Jatropha. Also briquettes and charcoal can be produced from the press cake.

The improvements required are beyond the skills and capacity of the participants in the value chains. Outside support is therefore essential.

The Jatropha value chains are only viable if there is a local market available: Export prices are far too low to make Jatropha profitable in the current production systems. In the project areas the local demand for Jatropha derived services and products exceed the production manifold.

There are significant non-monetary benefits of the Jatropha value chains, including local capacity building, job creation, empowerment of women and increased resilience. However, it is important to increase the participation of women throughout the whole value chain.

Other areas in Benin have conditions similar to the project locations, thus indicating a potential for up-scaling of Jatropha value chains.

The risk for all participants in the Jatropha value chain are low and there are good exit strategies, i.e millers can switch to diesel and soap makers to palm oil. The investment by farmers is limited and removing Jatropha is easy if they should decide to do so.

The detailed analysis of the various Jatropha value chains all shows that a high level of utilization of the equipment is essential for a good return. For instance utilising only 10% of a press' capacity or running a generator on 20% load is not viable. For services like mobile phone charging and electricity for light solar systems are more profitable when small numbers of people are served. They can also be deployed and scaled up or down quickly and in small steps so capacity is always matched to demand. By combining the Jatropha value chains with solar systems a much higher profitability can be achieved.

An optimal sequence of introducing Jatropha in an area may look like this:

1. Jatropha cultivation is introduced together with small solar systems for mobile phone charging and light. The price consumers pay is relatively high but they are informed that the price will drop as the Jatropha production ramps up. This can be used to ensure commitment to getting Jatropha production ramped up as fast as possible. A guarantee of purchase and minimum price per kg. of Jatropha seeds is in place. The seeds are transported to a press in an area with a Jatropha processing unit. Some oil is returned to be used for local soap production.
2. Manual dehullers are introduced at the community level. The first years the Jatropha yield is too low to warrant the introduction of dehullers at the farm level.
3. The solar system for mobile phone charging and light is expanded as demand grows. Press operators are being trained elsewhere in anticipation of the introduction of a press locally.
4. As Jatropha production increases manual dehullers are offered to farmers at a commercial price. It is expected that the first farmers will buy their own dehuller three years after planting Jatropha. Some may set up a local dehulling business for small producers.
5. When the local production of Jatropha reaches a level that justifies introduction of a press, one is installed locally. It is expected that the quality of the oil initially is too low for fully substituting diesel in engines. Regular oil quality testing is done. Blending with diesel may be practiced if the oil quality is almost good enough. Otherwise soap production is the main market.
6. When/if the oil quality is sufficient to use it as a 100% diesel substitute, and the consumer demand for electricity is sufficient, a generator and/or mill is installed. The solar systems are moved to a new area where Jatropha is to be introduced and the cycle is repeated. The solar system has a 25+ year lifetime and the same equipment can therefore be used repeatedly to start up new Jatropha production areas.
7. If the demand for electricity outstrips the capacity of the JPO generator set, solar systems will be used to bridge the gap until the demand is high enough & the local Jatropha

production sufficient to warrant the installation of another press unit & generator set. In this way idle capacity is avoided.

In areas with high Jatropha production it may eventually be feasible to acquire small biodiesel processing plants. Biodiesel can be used in un-altered diesel engines and can therefore serve a much larger market than (pure) Jatropha oil.

## 7.1 General Observations

- The pilot project has been designed to answer the question "can a Jatropha value chain be viable?" The choices of sites, approaches and trial design reflect this focus. As a consequence it is not particular good at answering questions about potential for up-scaling and large scale economic impact.
- Conditions that have elsewhere been beneficial for local Jatropha value chains are present in the project area, including:
    - Good agro-climatic conditions for Jatropha;
    - Few and low paid alternative income sources;
    - Labour limited low-input agriculture;
    - Local demand for energy services, e.g. milling and electricity;
    - Local market for other Jatropha products, e.g. soap
    - Expensive and poor availability of fossil fuel (location specific)
- The learning aspect of the project has received too little attention. The approach has been that researchers & technicians design, while farmers adopt. No systems/procedures have been in place for capturing farmer's learning, e.g. their experience with Jatropha in different configurations/intercrops/pests/soil types etc. Although within farmers groups the learning aspects has received attention.

## 7.2 Agronomy

- Jatropha is growing well in the project area. The agro-climatic conditions are right.
- Based on our observations and a quick analysis of the available data we expect Jatropha yields to stabilise around 800-900 kg/ha which is roughly half of the yield figures that have been applied in the cost-benefit analysis so far.
- Jatropha is expected to reach full yield after 5 to 8 years. In the project area Jatropha cultivated as a crop are less than 4 years old. Consequently there is significant uncertainty when assessing the potential and viability of Jatropha in the long term.
- Good research on pest & diseases in Jatropha has been undertaken. However, the economic impact of pest & diseases has not been assessed. Globally hardly any research has been done on pest & diseases in Jatropha and this work will therefore be valued elsewhere.
- The trials have compared improved Jatropha cropping systems to past practises of Jatropha cultivation. Direct comparisons with alternative cropping systems have not been undertaken.
- In project documentation trial data for Jatropha systems have been compared with crop statistics collected by the government. However, this cannot be done reliably. For instance it is not known how the nutrient status of the soil in trial fields compare to that of fields sampled for the crop statistics.
- In the cost-benefit analysis the press cake is sold for cash and no nutrients are added to the Jatropha. This is not sustainable. Either the press cake must be returned to the fields or

nutrients must be obtained in other forms, e.g. by buying fertilizer. For the cost-benefit analysis we suggest omitting the income from selling press cake.

- Experiments should be executed with bigger planting distances than the current 7m to allow a proper yield of the intercropped food crops.
- Dehulling by hand takes as much time as harvesting the seeds. Experiments with dehulling equipment should be undertaken. GERES is quite advanced in testing motorised dehullers. In Mali and elsewhere simple hand powered dehullers are used successfully. There are several designs that can be tested in the project area.

## 7.3 Processing

- The technology aspects have received less attention than the cultivation aspects so far.
- Based on our observations and experience elsewhere we have reservations about the lack of quality control and the simple processing of oil for use in engines, omitting sedimentation tanks, degumming, neutralization and fine particle filters. An oil sample has been tested at the ASG laboratories in Germany and the results confirmed that the present quality of the oil was not good enough to use it as fuel for diesel engines. Further processing steps required to improve the oil quality have been mentioned.
- There are quite some technological challenges; two of the three presses are not working properly at the moment.
- A link with a professor is established to design a local press, but also connections with other oil seed presses may be useful.
- There is scope for increasing the efficiency of the presses. GERES appears to be more advanced in this area and they are open to sharing their experience.
- Any improvement in processing should try to avoid reducing the amount of sediment for soap making since this is a profitable product.
- There are more options for the seedcake to be used (biogas, briquettes, charcoal).
- The processing could be separated from the rest of the value chain so that in the end it can be an autonomous business unit.
- The installation of a maize mill could lead to competition with other maize millers

## 7.4 Jatropha oil in engines

- Testing off JPO in engines has been of short duration, often just a few hours per engine. Experience shows that problems caused by poor JPO quality and inappropriate engine setup typically occur after 500+ hours of operating on JPO. Step should therefore be taken to ensure oil quality, appropriate engine adaptations and long term testing with JPO in 1-2 engines.
- A long duration test on a single engine using jatropha oil for more than 500 hours in cooperation with a mechanic is recommended.
- High engine temperature and often pre-heating of the JPO is required to ensure good combustion and engine longevity. We found most of the engines currently running on JPO are too cold and no pre-heating systems are installed.

## 7.5 Soap making

- The soap making is a profitable business but for proper marketing purposes it was indicated that packaging has to improve.

- To target other markets than the surrounding villages (possibly hotels) improved quality of the soap, especially appearance and therefore cutting of the bars is required. This can be done by using silicone moulds.
- Important to point out the importance of using safety gear.
- Test with locally available scents to reduce costs of perfume
- Mix with palm oil to reduce paraffin requirement

## 7.6 Gender

- Women groups involved in the project seem to function well and to have been empowered by the project.
- There is some good data provided by IITA on gender aspects in this project.
- Women can be more involved throughout the whole value chain.

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# 1 Data obtained from interviews, conversion & efficiency factors used in calculations

| Factor | Value/Range | Source |
|---|---|---|
| *Yield* | | |
| Expected Jatropha yield at maturity (mono-cropping or equivalent) | 2500-3000 kg/ha | Extrapolation from botanical collections worldwide. (Trabucco et al. 2010) |
| | 2375 kg/ha | Project documentation (intercropping cost-benefit analysis converted to mono-cropping equivalent) (CIRAPIP and IITA 2014:56) The only reference given is (Legendre 2014) which again relies on four sources only: (Benge, Mike 2006; Heller 1996; Henning 2000) |
| Current Jatropha yield | 800 kg/ha for 4 year old Jatropha | Interview: GERES. They stated that is is difficult to get yields above 1 t/ha |
| | 200-700 kg/ha for 2 year old Jatropha | IITA level 1 trial plots, all sites. Measured data. |
| Total amount of seeds processed in 2013 | 2.9 – 12 t | 2.9 is mentioned in project documents |
| | 12 t | Estimate based on data from interview with CIRAPIP senior staff. |
| Seed price | Zero | Collected in the local areas. |
| Germination rate | <65% | Interview with GERES |
| Cost of clearing land | 30 man days per ha | Interview with farmers in Tori |
| Cost of planting Jatropha | 4 man days per ha | Interview with farmers in Tori |
| Cost of weeding | 10 man days per ha | Interview with farmers in Tori |
| Intercropping spacing | Old system:<br>2 m between plants<br>4 m between rows | Intercropping impossible after 2 years so not ideal. Interview with CIRAPIP/IITA staff & |

| | | |
|---|---|---|
| | | farmers |
| | Current system:<br>2.5 m between plants<br>7 m between rows | Continuous intercropping possible |

### *Fertilizer and Pesticides*

| | | |
|---|---|---|
| Fertilizer recommendation for maize | 100 kg/ha NPK | Only some use it (interview w CIRAPIP & IITA) |
| Price NPK | 1050 CFA for 5 kg =<br>210 CFA/kg | Interview with farmers in Ouinhi |
| | 12000-16000 CFA for 50 kg =<br>240-320 CFA/kg | Interview with farmers in Djidja. They mix it with urea (price?) |
| Pesticide application tested | Only Neem tee tested in CIRAPIP/IITA project | Interview with CIRAPIP & IITA |
| Pesticide tested by GERES | Cymetox Super, produced by Kumark Ltd. Ghana. Active ingredients cypermethrin and dimethoate. 2 l applied per ha with good result. Price for 12 l: 44000 CFA. | Interview with GERES. Broad specter insecticide that will also kill beneficial insects. Moderately toxic. Dimethoate absorbed through skin contact. Allowed on food crops. |

### *Seed prices paid to farmers*

| | | |
|---|---|---|
| De-shelled Jatropha seeds | 150 CFA/kg | CIRAPIP/IITA project |
| | 125 CFA/kg | GERES prices: started with 60, increased to 90 and now 125. |
| | Up to 250 CFA/kg paid by outside buyers | Interview with GERES. |
| Jatropha fruits in shell | 75 CFA/kg | Farmers find this too low and prefer to manually de-hull the seeds. Interview with GERES. |
| Jatropha seed cake sales price | Not fixed yet | Interview with GERES |
| | Zero | Interview with farmers in Djidja. |

| | | |
|---|---|---|
| Transport costs | zero | Covered by project so far. Farmers near facilities carry the seeds to the press. |
| Harvest time | Main: May to July<br>2nd: November to January | Interview with CIRAPIP |

### *Jatropha Harvesting*

| | | |
|---|---|---|
| Productivity | 1/5 ha harvested in 3 days by one family. | Interview with farmers in Ouinhi. |

### *Alternative Income Options*

| | | |
|---|---|---|
| Maize price | 20-40 CFA per ca. 6 kg, i.e. 3-7 CFA/kg | Interview with CIRAPIP & IITA |
| Cashew nuts | 250 CFA/kg | Interview with farmers in Djidja |
| Income from manual labour, e.g. road construction | 1500-2000 CFA/day | Interview with farmers in Ouinhi |
| | 1200 CFA/day | Interview with farmers in Djidja |
| | 3000 CFA/day: half in cash, half in food | Interview with farmers in Tori |
| Fire starters produced from residues after palm oil extraction (see photo) | 200 CFA for a ~ 500gr firestarter that last 1-2 weeks | Interview with local leader in Tori who is selling fire starters. |
| Palm oil | 600 CFA/l | Interview with local leader in Tori. |

### *Conversion Factors*

| | | |
|---|---|---|
| 1 l diesel produce the same energy as | 0.67 l JPO | Measured by CIRAPIP in the field on un-modified engines running mills. Quick low precision experimental setup. (CIRAPIP and IITA 2014:21) |
| | 1.06 l JPO | The Jatropha Handbook (FACT Foundation 2010) |

| | | |
|---|---|---|
| | 1.13 l JPO | Measured by GERES in the field on un-modified engines running mills. Good experimental setup with constant load and 10 h running time. |

### *Pressing*

| | | |
|---|---|---|
| In 1 day of 8 hours a TinyTech can process | 600-700 kg/day = 75-88 kg/h | Interview: CIRAPIP, 2 mill operators |
| In 1 day a press operator using a TinyTech press can process | 300-350 kg Jatropha seeds | Interview: CIRAPIP |
| In 1 hour a press operator using a TinyTech press can process | 37.5 to 42.25 k Jatropha seeds | Interview: CIRAPIP |
| A TinyTech process is specified to process up to | 125 kg/h | TinyTech company website |
| Tinytech press purchase price | 7870374 CFA with pre-heating<br>6202884 CFA, no pre-heating | Figures provided by CIRAPIP |
| Local press (based on Tinytech design) | 4000000 CFA | |
| The utilisation efficiency of the TinyTech press is | 60% to 71% | Calculated from data by CIRAPIP and manufacturers specification |
| Press worm temperature | 38°C (entry end)<br>65°C (exit end) | Measured in Ouinho |
| 100 Jatropha seeds produce | 71 kg cake<br>9 kg sediment<br>20 l JPO | Interview with CIRAPIP |
| | 25 l JPO | Interview with GERES. Initially they needed 6 kg but are now down to ca. 4 kg. |
| Oil remaining in seed cake | 10-11% | Interview with GERES. |
| Time to process last years harvest in the project | 20 man days: 2 people x 10 days | Interview with CIRAPIP. |

### *De-hulling*

| | | |
|---|---|---|
| Indian motorized de-huller | 600 kg/h<br>95% efficiency | Interview with GERES |

| | | |
|---|---|---|
| Locally manufactured motorized de-huller | 150/h<br>90% efficiency | Two copies of the Indian machine build locally.<br>Interview with GERES. |

### *Electricity*

| | | |
|---|---|---|
| Price of generator + switches and cable | 1423750 | Data provided by CIRAPIP |
| Price of listeroid engine | 1050000 CFA | Data provided by CIRAPIP |
| Replacement rate of light bulbs | 33% evey year | Interview with CIRAPIP |
| Price of 11 W CFL | 1000 CFA | Interview with farmers in Tori |
| | 1500 CFA | Solar power shop in Tori |
| Price of 10 W(?) LED | 4500 CFA | Solar power shop in Tori |
| Subscription price | 600 CFA/CFL/month | Data provided by CIRAPIP |
| Electricity subscribers | 55 + 33 = 88 | Interview with CIRAPIP staff |
| Production | 4.5 h every night x 105 CFL x 11 W: 1155 W = 1897 kWh per year = 158 kWh per month | Observations and interviews at Tori |
| Fuel consumption | 2.5 – 3 l diesel per night ~<br>900 – 1100 l/y ~<br>1.7 - 2.1 kWh/l diesel | Observations and interviews at Tori |
| | 3 kWh/l diesel | Web, multiple sites, experience with small generators at 70% load factor |
| Cost of solar system that can substitute JPO electricity generation (1897 kWh/y) | 26 x 130W panels: 1950000 CFA<br>13 x 100 Ah batteries: 1040000 CFA<br>6 x 30A controllers = 150000 CFA<br>Total = 3140000 CFA | Quotation from local solar power shop in Tori. |
| Price of 2x4m$^2$ cable for solar system | 2000 CFA/m | Quotation from local solar power shop in Tori. Cables of this dimension are typically rated at 55A |
| Expected life time of solar battery | 4-5 years | Information from local solar power shop in Tori. |

### *JPO for Engines*

| | | |
|---|---|---|
| Engine cooling water after +1h running on Jatropha | In: 29°C<br>Out: 40°C | Measured; engine running Jatropa press, Ouinhi |
| | In: 41°C<br>Out: 85°C | Measured: engine running grain mill, Ouinhi |
| | In: 30°C<br>Out: 48°C | Measured: engine running grain mill, Tori |
| Diesel price | 600 CFA/l in towns<br>900-1000 CFA/l in countryside | Interviews with GERES |
| | 800-1000 CFA/l | Interview with millers in Djidja |
| | 650-850 CFA/l | Interview with millers in Tori |
| JPO sales price | 640 CFA/l | Interview with millers, CIRAPIP and IITA. Same at all locations. |
| | 550 CFA/l at factory gate.<br>Remote areas will pay more. | GERES |

### *Milling*

| | | |
|---|---|---|
| Profit per 1 l diesel | 600 – 800 CFA | Millers |
| Working hours per day | Up to 10 h | Interview with millers. Probably rare considering the large number of mills. |
| Fuel consumption per day | 6-7 l | Interview with millers in Tori. |
| Price for milling | 170 CFA per bowl of ca. 6 kg, i.e. 28 CFA/kg | Millers. They stated that they charge less from poor people. |
| Engine service interval on diesel | 1 month when working a lot | Interview with millers in Tori |
| | Up to 4 months | Interview with millers in Ouinho and Djidja |
| Engine service interval on JPO | Up to 6 months | Interview with millers in Ouinho and Djidja |

| | | |
|---|---|---|
| Price for engine service | 3000 CFA standard<br>10000 CFA comprehensive | Interview with millers and mechanic in Tori |
| Profit when using JPO | Up to 1900 CFA | Interview with millers in Ouinhi |
| | 1600 CFA | Interview with millers in Djidja |
| | 2500 CFA | Interview with millers in Tori |
| Profit when using 1 l diesel | 1100-1200 CFA | Interview with millers in Ouinhi |
| | 1300 CFA | Interview with millers in Djidja |
| | 1300 CFA | Interview with millers in Tori |

***Soap***

| | | |
|---|---|---|
| Bars of soap produced from 3 l Jatropha oil | 45-50 | Interview: Women's group, Ouinhi and Djidja |
| Bars of soap from 4 kg sediment | 43-50 | Interview with soap makers in Tori |
| Price for sediment | 350 CFA/kg | Interview with soap makers in Tori |
| Price of caustic soda | 500-600 CFA/kg | Inteview with farmers in Djidja |
| Other ingredients for 3 l oil or 4 l sediment | 3500-4000 CFA | Inteview with farmers in Djidja |
| | 4000 CFA | Interview with farmers in Tori |
| Profit from soap of 3 l JPO | 2500-3000 CFA | Interview: Women's group, Ouinhi |
| Profit from soap of 3 l palm oil | 1000 CFA | Interview: Women's group, Ouinhi |
| Profit from soap of 3 l sediment | > 2500-3000 CFA | Interview: Women's group, Ouinhi |
| Profit from 4 kg sediment | 4000 CFA | Interview with soap makers in |

| | | |
|---|---|---|
| | | Tori |
| Profit from lotion of JPO | Less than soap of JPO | Interview: Women's group, Ouinhi |
| Sales price for 1 bar of industrial soap | 150-200 CFA | Interview: Women's group, Ouinhi |
| | 250-300 CFA | Interview with farmers in Tori |
| Sales price for 1 bar of JPO soap | 150 CFA | Interview: Women's group, Ouinhi and Tori |
| | 50 CFA for "hotel size" | Interview with GERES |
| Sales price for 1 bar of Jatropha sediment soap | 200 CFA | Interview: Women's group, Ouinhi and Tori |

***Finance***

| | | |
|---|---|---|
| Interest rate, micro-loans | 10000 CFA can be borrowed for up to 6 month. 300 CFA interest per month = 36% p.a. | |
| ***Export*** | | |
| Jatropha seeds sold for export (oil extracted in Benin) | Min 20.000l per week,<br>25 CFA/kg to farmer<br>5 CFA/kg for transport<br>25-30 CFA/kg for port costs and tax (1% export tax) | Interview with Mrs. Paulette Kidjo, SICREP. |
| | | |

## Agronomy

- Seeds obtained locally, no attempt to identify or select superior seeds (CIRAPIP).
- Small amounts of seeds obtained from Mali for testing (IITA)
- Farmers have been asked to choose between seedlings and direct seeding. They opted for direct seeding.
- Farmers have planted their own Jatropha on poor soils (CIRAPIP)
- Farmers have not pruned sufficiently and timely (CIRAPIP & own observations)

## Trial approach

3 levels:

- Level 1: 1 x 1 ha trial per 10 villages
- Level 2: 1 x 400m2 trial in each village
- Level 3: Individual farmer plots, farmer designed & managed

Extension works on level 1 and 2. At level 3 farmers learn from farmers trained at level 2.

Trials compare existing Jatropha systems with improved ones, i.e. they do not test if Jatropha is profitable compared to other crops. In the reports the trial data are compared to yield statistics collected at the department level. This is not a valid comparison.

### Processing

- Mechanical de-hullers not tested in the CIRAPIP/IITA project
- Motorised de-hullers tested by GERES.
- No quality testing of the oil done so far by CIRAPIP/IITA project. GERES is using a local lab for testing.
- JPO is filtered in plate press straight after pressing. GERES leave it in sediment tanks for 1-2 days.

### Value-Chain: Soap

- GERES is targeting hotels

### Milling

- Millers told that diesel is sometimes mixed with kerosene and that this damage the engines
- Mechanics who maintain the miller’s engines said they have not opened an engine after it has been running on JPO, so no information about carbon buildup

### Value-Chain: Electricity

- A third of the bulbs replaced every year (CIRAPIP & farmers at Tori)
- Engine RPM controlled manually by operator by sound
- A voltmeter on the alternator is the only monitoring device
- Automatic over current breakers is the only protection in place. No over/under current breaker or frequency monitoring is used.

### Value-Chain: Engine fuel

- No modification of the engines, i.e. no dual tank, pre-heating, adjustent of timing or injection pressure has been made in the CIRAPIP/IITA project.

- GERES has experimented with larger injectors for JPO (experience?)
- Mechanics told injector blocking is the most common engine problem with diesel. It does not occur with JPO. Also poor quality lubrication oil was mentioned by mechanic in Tori.
- GERES add dye to the JPO to avoid it being mistaken for cooking oil. Not done in the CIRAPIP/IITA project

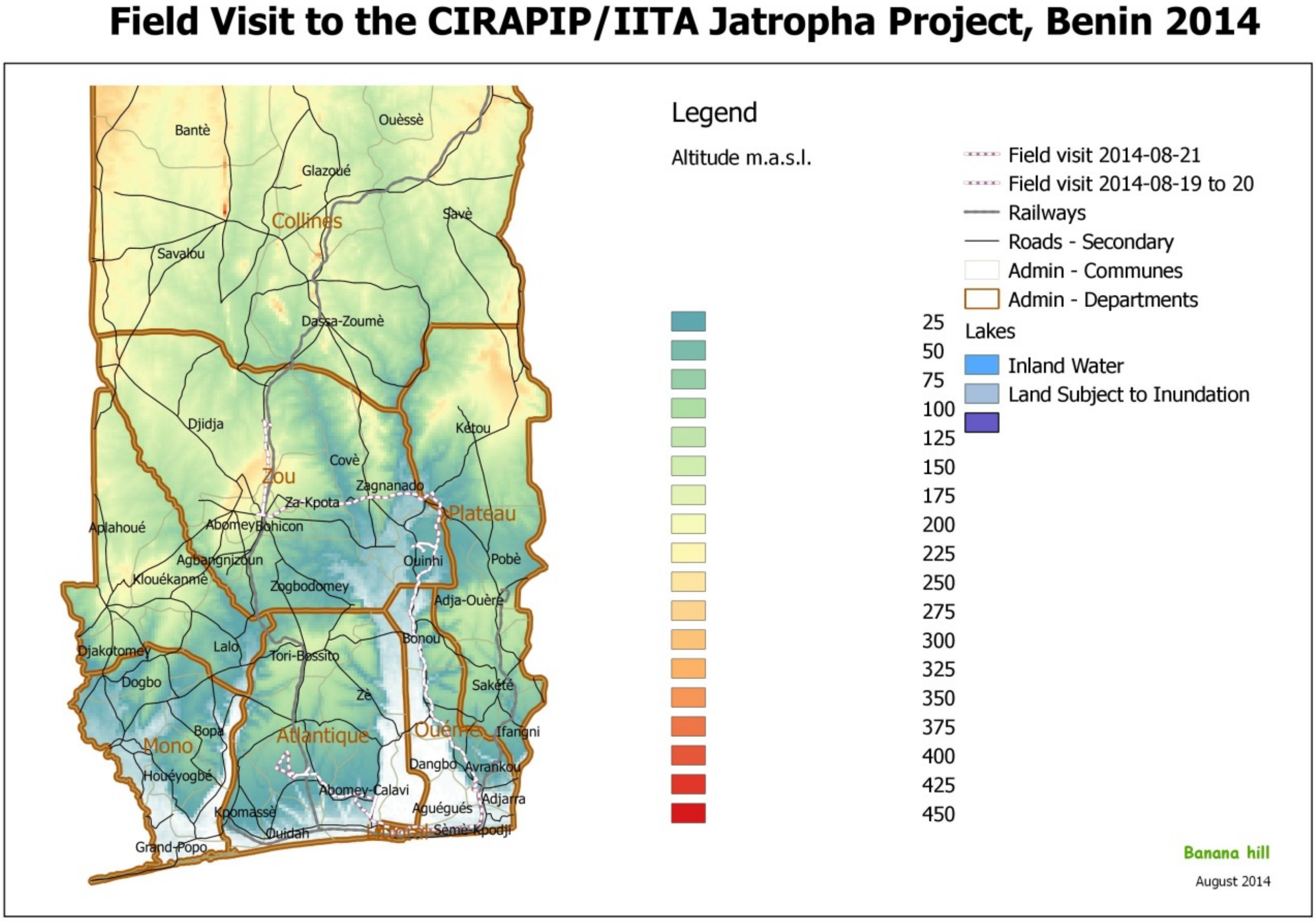
### Alternative Value-Chains

- Stove working on JPO build in one copy and tested. It was stored away, indicating that was not found suitable/attractive. We are not aware of the testing and experience gained with the stove.

# 2 Agenda evaluation mission

| Date | Timing | Activités | Lieux |
|---|---|---|---|
| Lundi 18 | 9 h – 10h30 | Rencontre Ambassade | Cotonou |
| | 11h – 13h | Rencontre CIRAPIP et IITA | Siège CIRAPIP |
| | 13h-14h30 | Déjeuner | Cotonou |
| | 15h30-16h30 | Rencontre au Ministère de l'environnement (DGE : GNANGLE et GBEMAVO) | Cotonou |
| Nuit à Cotonou | | | |
| Mardi 19 | 7h00 | Départ de Cotonou | Hôtel |
| | 10h – 13h | Rencontre avec producteurs, transformateurs, meuniers, fabricants de savons, abonnés | Ouinhi/Ouokon-Zoungomè |
| | 13h-14h | Déjeuner | Ouinhi |
| | 14h-16h | Rencontre avec producteurs, transformateurs, meuniers, fabricants de savons, abonnés (suite) | Ouinhi/Ouokon-Zoungomè |
| | 16h30-17h30 | Rencontre Autorités locales | Ouinhi |
| | 17h30 | Départ de Ouinhi pour Bohicon | |
| Nuit à Bohicon | | | |
| Mercredi 19 | 7h30 | Départ de l'hôtel | |
| | 8h-9h30 | Rencontre avec GERES | Abomey |
| | 9h30-13h | Rencontre avec producteurs, meuniers, fabricants de savons et autres acteurs | Djidja / Asségon |
| | 13h-14h | Déjeuner | Bohicon |
| | 15h-15h30 | Rencontre au CARDER : DPFSA (LANTONKPODE Ludovic) | Bohicon |
| | 15h30 | Départ pour Cotonou | |
| Nuit à Cotonou | | | |
| | 7h30 | Départ de l'hôtel | Cotonou |
| Jeudi 20 | 9h-13h | Rencontre avec producteurs, meuniers, fabricants de savons, abonnés et autres acteurs | Tori/Zounmè |
| | 13h-14h | Pause/Déjeuner | Tori / Zounmè |
| | 14h-16h | Rencontre avec producteurs, meuniers, fabricants de savons, abonnés (suite) | Tori / Zounmè |
| | 16h30-17h | Rencontre avec autorités locales | Tori |
| | 17h | Départ pour Cotonou | |
| Nuit à Cotonou | | | |
| Vendredi 21 | 8h30-9h30 | Rencontre avec opérateur économique | Cotonou |
| | 10h-12h | Synthèse | Ambassade |
| | 12:30-13:30 | Prof. and local press developer | Cotonou |
| | 13h30-14h | Déjeuner | Cotonou |

# 3 Routemap of fieldvisits August 2014



# 4 List of oil quality tests performed by ALTERRE in Mali

**Amandine Caprasse**
Koutiala, le 08 mai 2013
GML1305.ACL.R2.Note laboratoire ALTERRE - analyses

## ALTERRE MALI - LABORATOIRE

### ANALYSES ET ECHANTILLONNAGE

**Introduction**

Dans le cadre de la construction d'une démarche qualité pour les filières Jatropha, le projet ALTERRE-Mali a installé un laboratoire d'analyse à Koutiala.

La présente note précise dans un premier temps les analyses effectuées au sein du laboratoire ainsi que la tarification pratiquée par échantillon. Suite à l'acquisition de nouveaux matériels au sein du laboratoire, le document précise également les analyses qui seront disponibles à partir du second semestre 2013. Enfin, une méthodologie d'échantillonnage détaille les pratiques d'échantillonnage des graines, du tourteau et de l'Huile Végétale Pure (HVP) de Jatropha, prérequis indispensable à une analyse correcte en laboratoire.

Liste d'acronymes

HVB : Huile Végétale Brute[1].

HVP : Huile Végétale Pure.[2]

[1] Correspond à l'huile brute directement en sortie de presse, contenant encore des sédiments.

[2] Correspond l'huile débarrassée des sédiments

**Analyses du Jatropha**

**Type d'analyse et tarification**

Les analyses Jatropha proposées par le laboratoire ALTERRE et leur tarification équivalente sont retranscrites dans le Tableau 1. La tarification ne tient pas compte du conditionnement de l'échantillon ni de son transport jusqu'à Koutiala.

Tableau 1 : Type d'analyse et tarification

| Type d'analyse | Coût |
|---|---|
| Indice d'acide / acidité | 2 000 FCFA/échantillon |
| Teneur en eau et matières volatiles | 1 500 FCFA/échantillon |
| Indice peroxyde | 4 000 FCFA/échantillon |
| Teneur en phosphore | 5 000 FCFA/échantillon |
| Teneur en huile | 5 000 FCFA/échantillon |
| Viscosité | 2 500 FCFA/échantillon |
| Indice d'iode* | A déterminer |
| Teneur en sédiment* | A déterminer |

*Analyses disponibles à partir du second semestre 2013.

Les analyses de l'HVP de Jatropha concernées par la norme malienne « MN-09-01/002 : 2011 » et réalisées en 2013 par le laboratoire ALTERRE sont : l'indice d'acide, la teneur en phosphore, la viscosité, l'indice d'iode et la teneur en sédiment. La mesure de teneur en eau réalisée au sein du laboratoire est une méthode moins précise (méthode à l'étude) que celle préconisée par la norme.

# 5 GIS map of ZOU area (made by GERES)

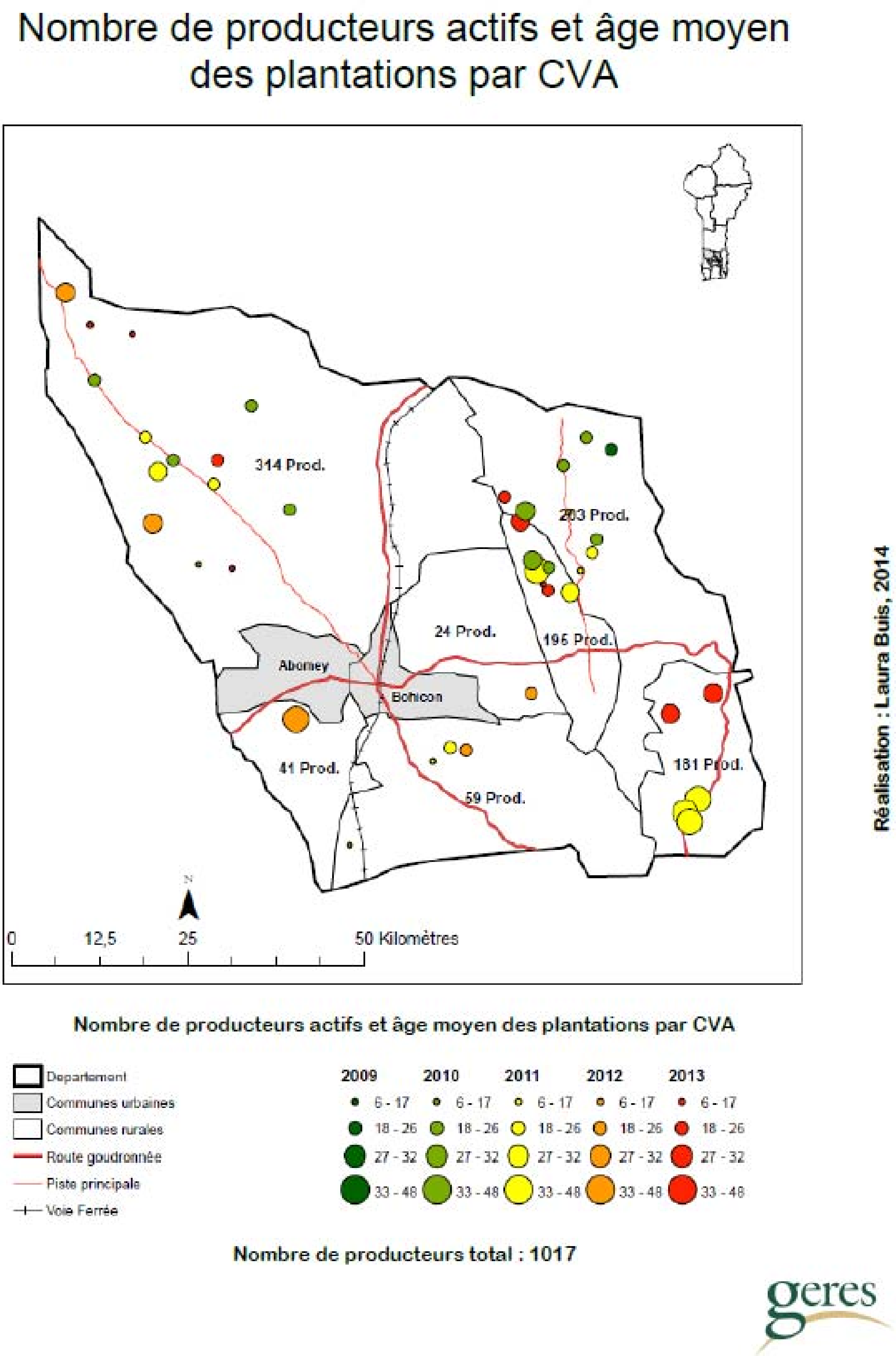



**Figure 20: GIS map of active jatropha producers in ZOU district, made by GERES**

# 6 Test results oil quality

ASG Analytik-Service Gesellschaft mbH
Trentiner Ring 30 • 86356 Neusäss • Germany

Banana Hill
Heerenstraat 32
NL-6701 DL Wageningen

Your reference : F.Nielsen
Your order no. : -
Date of order : 03.09.2014
Sample Receipt : 10.09.2014
Sender : Customer
Start of test period : 11.09.2014
End of test period : 23.09.2014
Report date : 24.09.2014
Page : 1 of 1

## Report No. : 2206404-1

Sample : Jatropha oil
Appearance : Color yellowish, clear, no visible impurties and water, odor typical
Container : PE/PP E - bottle 500 ml
ASG-ID : 2206404_001
Seal No. : -

| Parameter | Method | Result | Specification DIN 51605 min. | Specification DIN 51605 max. | Unit |
|---|---|---|---|---|---|
| Total contamination | DIN EN 12662:1998 | **50** | - | 24 | mg/kg |
| Acid number | DIN EN 14104 | **10,01** | - | 2,0 | mg KOH/g |
| Oxidation stability | DIN EN 14112 | **4,1** | 6,0 | - | h |
| Phosphouros content | | **20,5** | - | 3,0 | mg/kg |
| Calcium content | DIN 51627-6 | **6,7** | - | 1,0 | mg/kg |
| Magnesium content | | **6,4** | - | 1,0 | mg/kg |
| Oxid ash (775 °C) | DIN EN ISO 6245 | **<0,005** | - | - | % (m/m) |
| Water content | DIN EN ISO 12937 | **1153** | - | 750 | mg/kg |

Dr. Thomas Wilharm (General manager)

This report is related only to the samples stated above and may not be reproduced except in full, without approval of the testing laboratory. Storage of the samples: 4 weeks from report date
For further information, please refer to our terms and conditons at www.asg-analytik.de Accreditation acc. to DIN EN ISO/IEC 17025.

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