FACT Foundation promotes the development and use of biofuels in developing countries for local communities

Jatropha curcas oil production for local development in Mozambique

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Abstract
Most research on *Jatropha curcas* for bio-fuel production has focused on mechanised plantation agriculture aimed at the international market. One of the few projects that have focused on Jatropha for local development among small-scale farmers is the FACT-ADPP Jatropha project in Cabo Delgado, Northern Mozambique. The project attempts to substitute diesel used locally for maize mills, water pumps and other machinery with Jatropha oil. Instead of converting the oil to bio-diesel, engines are converted to run on pure Jatropha oil.

The project has been running for three years and farmers are now producing significant amounts of *Jatropha curcas* seeds. However seed production is still rising and it is too early to predict the yields that will eventually be reached. Oil presses and modified engines are in operation.

The population density is low and shifting cultivation dominates. The soils are sandy and no fertility enhancing techniques or inputs are used. Draft animals and mechanisation is absent. Cash crops and paid employment is almost non-existing. Liquid fuel consumption in the area is mainly diesel for mills and kerosene for lamps.

Initially the focus was on plots with Jatropha but following farmers' preferences the focus is now on hedges around fields. Pest problems emerged early as a major concern and remains so. The main pest is the golden flea beetle; *Aphthona* spp which reduce growth but rarely kill the plants. Research on IPM is in its infancy and currently only chemical pesticides are known to be efficient. However, pesticides are not a feasible option for the farmers.

Research that has been undertaken includes agronomic aspects, pests, seed pre-treatment, economics, carbon and energy-balance, diesel engine modification and impact on diesel engines running on pure Jatropha oil. The comprehensive research component is executed in collaboration with national and international research organisations, NGOs, companies and universities.

This presentation will provide an overview of our current agronomic knowledge, an assessment of the potential for Jatropha as a vehicle for local development as well as the knowledge gaps that remain to be filled.

Keywords: *Jatropha curcas*, bio-fuel, local development, Mozambique

Introduction

The pilot project “Jatropha for local development” was conceptualised in 2005 and started to be implemented in Mozambique in 2007. Its goal is to test the feasibility of enhancing local development by using locally produced Jatropha oil to run local diesel engines converted to run on pure Jatropha oil, as well as for the local production of soap and and lamp oil (ADPP & FACT Foundation 2006). The project is unique and has recently received much interest from various actors interested in up-scaling the approach.

In this paper we provide an overview of the experience that has been gained so far, of uncertainties that remain and factors that are considered to be crucial to success. This last issue is important when considering up-scaling because many important factors are specific to the project area.

The development and testing of the concept of using locally produced Jatropha oil for local development has naturally evolved through a number of overlapping phases. At first technical issues had to be solved in the area of agronomy and mechanics. However, a system that works technically also needs to fit in the social context, e.g. it must be compatible with the local farming systems and be socially acceptable. Next, it must not only be economically viable but attractive compared to alternatives. For the concept to be considered for up-scaling it must in addition be environmentally acceptable.

At the current stage the project has showed that the system works at a technical level, it fits well with the local farming systems, it is socially acceptable and does not show signs of negative social bias. It appears to be economically attractive in the current project setting and it appears that even with the current low prices for fossil fuels it will be economically attractive without project support. Initial research on environmental impact indicates that the green house gas balance will depend on the future economic development in the area.

The project has a research component significantly larger than what is common in development projects. It has therefore been possible to undertake collaboration with a number of institutions including IIAM (Instituto de Investigação Agrária de Moçambique), UEM (Universidade Eduardo Mondlane), University of Copenhagen and Eindhoven University of Technology.

"Jatropha for local development" is one component of an integrated development program. Other components focus on horticulture, conservation farming, improved wells and hand rope pumps. Farmer's willingness to join the program depends on the attractiveness of the whole package and on expected benefits. This is particularly important in the context of Jatropha which will only reach reasonable yields after some years.

Organisational issues are not covered in this paper but do of course play a major role in the achievements of the project. Important in this respect have been ADPP (with the Farmers' Clubs), GAIA Movement, and FACT Foundation.

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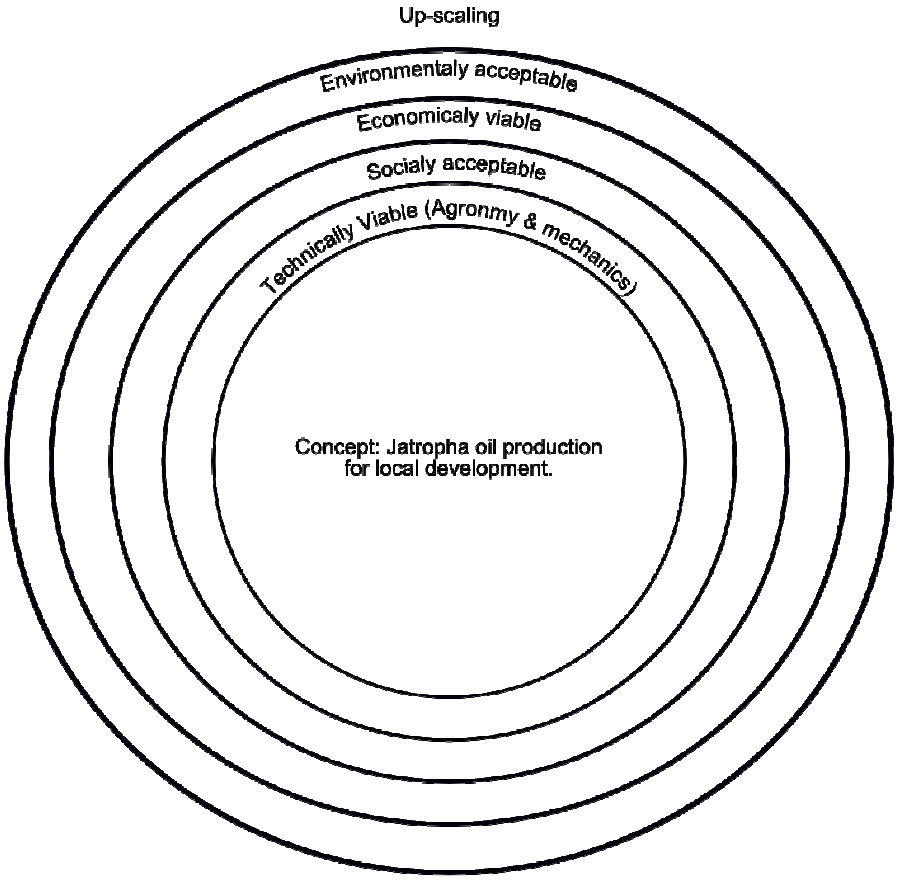

Figure 1: Only by being viable and acceptable technically, socially , economically and environmentally is Jatropha oil production for local development interesting for up-scaling

Project Area

The project area is located in the costal zone of Cabo Delgado province in an area with a population density below 18 people/km^2. The dominant soils are Cambisol and Acrisol with some Chernozem (INIA-DTA, 2002, FAO classification). Most of the project area is within agro-climatic zone R8 (INIA, 2000) with annual rainfall around 800mm (INIA-DIA, 1999). The bedrock is close to the surface and water-logging is common in low-lying areas during the rainy season.

Shifting cultivation with permanent dry season settlements is the dominant land-use practise. During the cropping season farmers move to huts in their fields to avoid long walking distances and to protect the crops against wildlife. It is a subsistence economy that relies on food self-sufficiency. No external inputs are used. Cash crops have lower priority than food crops and are produced in small amounts to pay for soap, salt, clothes etc.. There are virtually no off-farm employment opportunities in the area. Sesame is currently the most important cash crop. The major crop and staple food is cassava followed by maize, rice and millet. Only 22.6% of the households report that they produce enough food. The rest are under nourished and 2% report having lost a family member from malnutrition during the last year (ADDP, 2009).

Cultivation is strictly by hand and available labour is therefore the limiting factor that restricts cultivation. The labour peak is caused by weeding which according to farmers constitute 35% of the total labour hours during the rainy season. Chasing wild animals takes 30% of the labour hours.

76% of the population are Muslims and 72% belong to the Macua tribe. Depending on the season between 16% and 42% of the population have access to water from protected wells (ADDP, 2009).

Technical Viability: Agronomic Issues

When the project started, there was little and often conflicting information about best agronomic practices. Formal research was planned from the beginning but the project could not wait for the result of the trials, so an action research approach was used in parallel with formal research. Emerging problems would guide the research and results from research would guide the implementation as these became available. Observation plots were established at different locations and the early Jatropha plantings organised by Caritas at Msika in Manica province were monitored regularly.

It was found that in Manica Province *Jatropha curcas* generally performed well for the first 12 months or more before severe flea beetle (*Aphthona* spp.) attacks devastated them. In some cases, plots with over 1000 plants suffered 100% mortality rates. Other factors may have played a role too, including water-logging in the relatively heavy soils common to the province. The rainfall in central Manica is over 1200 mm/year whereas the project area in Cabo Delgado receives about 800 mm/year. This experience influenced the decision to focus the project in Cabo Delgado province where *Jatropha curcas* appeared to have few pest problems.

The initial experience made it clear that pest infestations are an important issue despite the widely-held opinion at the time that Jatropha had no pest problems. Pesticides containing Chlorpyrifos or Cyphenothrin were used successfully in trial plots but pesticides were ruled out as an option for the small-scale farmers targeted by the project.

Initial observations showed that flea beetles were the major pest in Jatropha in Central and Northern Mozambique (no observations were made in the South of the country). At least two species could be distinguished visually. In Manica province, a yellow flea beetle (*Aphthona dilutipes* Jacoby) was common and appeared to cause much more damage than the red-brown flea beetle (*Aphthona sp. n. dilutipes*) found elsewhere (Nielsen 2007, Gagnaux 2009). Communication with researchers in Kenya, Tanzania and Zimbabwe confirmed that the red-brown flea beetle is found there too. Until recently the author was not aware of the yellow flea beetle appearing outside Manica Province but recently it has been reported in Malawi and Zambia too.

Collaborative research on pest in Jatropha was initiated with Eduardo Mondlane University. The study found that Jatropha planted towards the end of the rainy season had more pest problems than Jatropha planted at the beginning of the rainy season (Gagnaux, 2009).

Initially batches of seeds sourced mainly from Zimbabwe and Malawi showed low germination rates and a trial on seed treatment was therefore made in collaboration with IIAM (Jamice 2007). The trial compared provenances from Guatemala, Bilibiza and Gorongos and their reaction to soaking in water for 24 hours, 48 hours and removal of epidermis. It was concluded that none of the treatments increased germination rates compared to the control. Seed sourced after the trial have shown consistently had germination rates above 90% and the problem is therefore ascribed to the seeds used initially.

Jatropha has been promoted as an ideal crop for exhausted soils. However, demonstration plots established on exhausted soils show that although Jatropha survives, it yields almost nothing under such conditions.

Planting from cuttings were tried successfully but because they do not develop a tap root the project recommend to farmers farmers to only use seeds. Still many farmers like cuttings because of the fast growth, easy planting and familiarity with using them for propagation. Direct seeding was at first ruled out due to the bad experience reported in the literature and through personal communication. However, informal testing has given good results

at most localities and is therefore considered a viable alternative to the labour-intensive nurseries that are otherwise being used for producing seedlings.

Seeds have been sourced from Tanzania, Malawi, Guatemala, Nicaragua, Zimbabwe and collected at different localities in Mozambique. The main seed source for the project in Cabo Delgado is a local naturalised stand of Jatropha with a good seed yield and healthy appearance. This is a pragmatic choice that makes sense given the lack of information about the performance of other provenances. Currently, provenances from Guatemala (Octagon Ltd.), Tanzania (Diligent Ltd.) and Montepuez (Mozambique) being compared in trials in Cabo Delgado (RCBD, 4 replications)(Nielsen, 2008). If the foreign provenances prove superior, they will eventually be promoted as seed sources. Another trial in collaboration with IIAM at Mandonge Research Forest in Manica province was terminated after two years as the plants had grown less than their equivalent grow in two months in Cabo Delgado.

Initially, farmers were recommended to plant plots of Jatropha but when it became apparent that they preferred hedges the focus of the research activities changed to hedges too.

Farmers use a planting distance of 0.8 m (6 random samples of 10 plants) which is much more than what is reported as optimal in the literature. Trials with closer spacing have been established and are expected to yield the first data in 2010. The trials include plants established from cuttings, direct seeding and seedlings. All trials are being established in demonstration plots where farmers themselves can compare and make their own conclusions. Systematic measurement of farmers' Jatropha hedges and plots is done simultaneously.

Pruning is recommended to encourage branching and thus higher yield. No formal trials on pruning have been established. Farmers' usually do not like to prune, finding it is wasteful to cut into healthy plants. The result is lower yields than necessary and more weeding because of a relatively open canopy. In some cases pest damage to the terminal buds result in branching and yield is therefore maintained. However, the harvesting is obstructed by the tall plants.

Overall, the agronomic obstacles have been dealt with sufficiently to reach a working system. However, significant improvement and optimisations can be made with simple means like seed selection, closer spacing and appropriate pruning.

Technical Viability: Engineering Issues

Small hand operated presses have many advantages; they are simple to maintain, easy to operate, are affordable for many communities, can ensure that the soil fertility is maintained by returning the press cake, and they create jobs locally.

However, testing of a Bielenberg and a Piteba hand press showed that clogging of the presses is too big a problem to make it viable. The production of less than one litre of oil per hour was found too low by people from the local community. Furthermore, there is a danger of fatal poisoning if the press is used for producing cooking oil without thorough cleaning.

Problems with impurities in the oil from contaminated equipment and too high phosphorous content from pressing unripe (green) fruits are more likely to occur under village conditions compared to an industrial press with an experienced operator.

No international standard exist for Jatropha oil quality for combustion engines and the project therefore relies on the DIN V 51605 norm for rapeseed oil (FACT 2009). Quality control is only feasible with a centralised oil production facility.

These factors contributed to the decision of collecting the Jatropha seeds from the communities at a central location where they are pressed with motorised screw presses (Sayari and DoubleElephant types) by a skilled operator.

A central oil pressing facility increases the transport costs significantly and makes it difficult to return the press cake to the farmers.

A survey of existing diesels in the area was undertaken to determine the main uses of diesels and to select common types for modification to enable them to run on pure Jatropha oil. Chinese Feidong engines similar to English Lister engines were selected for modification. The are commonly used for maize grinders.

Commercial kits for converting diesel engines to run on pure plant exist in developed countries but are not suitable for the project area due to high complexity and price. The project therefore started a research project with the aim of developing low-cost conversion kits from locally available materials. This has resulted in a first prototype that successfully was tested in the Netherlands for over 500 hours on rape seed oil. A second prototype is currently being tested in Mozambique.

There is no experience with long-term use of Jatropha oil in diesel engines. To be attractive the modified engines should perform similar to conventional engines. The project is therefore monitoring converted engines together with the quality of the oil.

Tear and wear will be measured by disassembling a modified engine at the end of the test.

Firm conclusion about the technical feasibility of running diesel engines on pure Jatropha oil cannot be made yet.

Social issues

Acceptability of Jatropha has not been an issue because it was known to farmers in the area as a medicinal plant and was already used by some farmers for fencing homesteads and fields. Some farmers find that Jatropha hedges are better at keeping wild animals out of the fields than other plants.

Jatropha planting has proved popular with farmers and the number of farmers clubs participating and the area they have planted exceeds expectations. At present an estimated 250000 plants are growing (Afonso & de Jongh, 2009). A study in collaboration with the University of Copenhagen found no gender bias or cultural obstacles to the adoption of the Jatropha system (Vang, 2009). The data are however based on few interview and more comprehensive surveys are required to verify this.

Theft of plants and seeds is a problem in several areas and farmers therefore prefer to plant Jatropha close the homestead where they can keep an eye on them.

Since labour is the major limiting factor in the farming systems it would be desirable to have Jatropha's labour requirements peak at other times than food crops. At some localities in the project area Jatropha yields peak twice annually, namely in January to March and to a lesser extent in October. At other localities the second peak is absent. The first peak coincide with the peak demand for weeding of food crops. Fortunately, Jatropha does not shatter much, so the ripe seeds can be left on the plants for several weeks. This makes Jatropha more compatible with food production than sesame which is the main cash crop in the area (Nielsen, 2009).

Economic issues

The project is buying the Jatropha seeds at 5 MZN/kg until the end of the project. With the current price on fossil fuel, this is almost twice the price that will make Jatropha oil competitive with fossil fuel based on estimated costs of seed collection and oil extraction. Farmers have in group discussions told that Jatropha is attractive to them even at 2 MZN/kg. Farmers who are not participating in the project are currently paid 2.5 MZN/kg.

With mechanical screw-presses, 4.5 kg seeds are required to produce one liter of oil so a farm-gate price of 2.5 MZN/kg allocates 11.25 MZN/l to raw materials; this is half or less than half of the sales price of diesel in the area which is 22 to 40 MZN/l depending on how isolated the community is.

After two or three years, the shade from Jatropha will suppress weeds and most labour will be required for harvesting.

In field tests it was found that farmers can harvest 1-3 kg/h including decortication, or more than 5 kg/h excluding decortication (Nielsen, 2009).

If the farm-gate price is 2.5 MZN/kg, this translates to 20 to 60 MZN/day. This provides a favourable rate when compared to the 30 to 35 MZN/day that is the going rate for hired labour.

Instead of selling the seeds farmers can produce oil on their own and use it to substitute diesel for local machinery like maize mills and water pumps. Hand-pressing Jatropha seeds yields slightly less than 1 l/h and due to the low efficiency of hand-presses, 5.5 kg of seeds are required to extract 1 liter of oil. With harvesting yielding 1-3 kg decorticated seeds per hour and a local diesel price of 22 to 40 MZN/l the value of an 8-hour working day is 19 to 47 MZN, which is comparable to alternative income options. Notice that depreciation of equipment is not included in the calculation.

The more isolated a community is the higher the diesel price and hence the comparative advantage of producing Jatropha oil for local use. Alternative cash crops also fetches lower prices in isolated areas due to higher transport costs.

Since oil extraction is just starting the economics of oil production, including transport for seed collection, is only estimated. Experience from Tanzania is that transport cost is a major determinant of the economic viability (van Eijck, 2009).

The indication is that Jatropha production is both economically viable and attractive compared to alternative income sources in the area. Notice that it is assumed that Jatropha oil is meant for local consumption and therefore remains tax free.

The impact of using land for bio-fuels instead of food has gained much attention recently. Within the project area, many farmers already plant Jatropha in small quantities. This is similar for other cash crops. Will they be tempted to grow Jatropha instead of food crops?

To probe deeper into this issue two focus groups were asked about their response to different price scenarios for both sesame which is currently the main cash crop and Jatropha. The response was that time and effort is only devoted to Jatropha and other cash crops when their own food consumption is secured no matter what price they fetch. In practice the implication is that for most families cash crops are a minor part of their farming system, and that the price elasticity of supply is very low.

Environmental Impact

The issue of expanding bio-fuel production leading to expansion of the area under agriculture is currently high on the international agenda. This is unlikely to be an issue within the project area but to the extent that Jatropha substitutes the production of edible cash crops like sesame indirect land-use change can occur elsewhere.

As discussed above, labour ultimately limits the area that can be cultivated and only to the extent that Jatropha requires less labour or can rely on off-season labour is expansion possible. Because Jatropha harvesting can be done when the labour demand for other crops is relatively low, a family can cultivate a slightly larger area when Jatropha is part of the farming system.

However, Jatropha cultivation is likely to reduce the cultivation of sesame slightly and whereas Jatropha plantings are productive on the same plot for probably more than 40 years, sesame is cultivated on the same plot for only a few years after which new land is cleared. These trends together with the fact that cash crops cover a minor part of the cultivated area makes it unlikely that introduction of Jatropha will have a significant effect on the area under cultivation.

In collaboration with the University of Copenhagen the CO_2 balance of the project has been assessed. The research will be published soon and only a few findings are presented here.

The study found that the CO_2 balance of Jatropha cultivation is positive as long as maize fields or fallows are replaced by Jatropha. However, if primary forest is removed to make space for Jatropha the carbon debt will require 1900 years of Jatropha cultivation to be paid back (Vang, 2009).

As argued above introduction of Jatropha in a farming system where the major bottleneck is labour leads to substitution of crops and not expansion of the cropped area so the CO_2 balance of the farming system is not likely to be affected. The substitution of fossil fuel with Jatropha oil will improve the CO_2 balance for the communities.

However, if for instance the intervention increases wealth so herbicides becomes affordable then a significant expansion of the cultivated area could result in a negative effect on the CO_2 balance.

The implication is that the assessment of the environmental impact, including CO_2 balance depends largely on the development scenario being used in the analysis and that it ranges from positive to very negative.

Conclusions

Based on the knowledge gained so far from this pilot-project, it is likely that Jatropha can contribute positively to local development:

- Jatropha oil production for local use is probably technically viable. Jatropha seeds are being produced in significant quantities without requiring external inputs or changes to the local farming systems.
- Oil pressing is starting, and test runs of diesel engines converted to run on pure Jatropha oil are under way but long term testing is required before firm conclusions can be made about durability and reliability.
- It is socially acceptable and compatible with the local farming system;
- It is probably economically profitable and compares favourably to alternative income sources;
- The impact on the CO_2 balance depends largely on the development path the communities will follow in the future. If the current farming practices of shifting agriculture continues the introduction of Jatropha is not likely to change the CO_2 balance of the farming operations. It will however have a positive overall impact on the CO_2 balance of the communities by reducing the use of fossil fuel.
- Some of the factors that have been important for the success of the project so far are likely to be different at other locations. Up-scaling should therefore be based on careful analysis of the local situation.

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