Perspectives of Jatropha Production and Processing by Small-scale Producers

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Introduction

Since 2005, HIVOS has supported projects in Honduras, Mozambique, Peru, Tanzania, Zambia and Zimbabwe that are using Jatropha for local development. The focus has been on providing energy to rural areas, with added benefits coming from value-added products and organisational innovations, towards enhancing the local economy and resilience. From the experience with these and other projects as well as a large amount of research findings, a clearer picture is emerging about the role Jatropha can realistically play in development.

In this workshop, the focus is on Jatropha systems managed by small-scale farmers. Plantations and industrial approaches are only considered where they have a direct bearing on small-scale farmers.

There have been many failures but also some success stories. In some areas of Mali, Jatropha production has now reached a stage where it is both attractive to farmers and profitable for commercial processors. This model is spreading to other countries in the region.

In Northern Mozambique, small-scale farmers produce Jatropha seed at a price that
makes it an attractive alternative to other cash crops and paid labour, while at the same time keeping processing profitable. More organisations and companies have entered the area and have also started expanding Jatropha cultivation and processing.

The question is therefore not about whether Jatropha works or not. Instead, the interesting question is where and under what conditions does it work, and how can we make it work better.

**Jatropha production and processing today**

At this stage, many aspects of Jatropha production that were unknown a few years ago have now been proven or shown convincingly to work under field conditions.

For instance, several studies have shown significant Greenhouse Gas (GHG) savings can be obtained from Jatropha production. Even in the situation of the oil being exported to Europe for biodiesel production, nitrogen fertiliser being applied to the crops and no energy being extracted from the press cake, the GHG savings still fulfil current EU demands (Paz and Vissers, 2011).

Several studies have documented that Jatropha can be grown without impacting the local food production negatively.

Today there is sufficient knowledge to cultivate Jatropha with few inputs at sites with the right agro-climatic conditions. Poor site selection has been the root cause of many failures, leading to low yield and severe pest problems. Unfortunately, looking at Jatropha production around the globe, most of it has been planted in areas where it is unlikely to ever perform well (Trabucco et al., 2010 - see Figure 1).

Jatropha is being propagated, maintained and harvested by small farmers throughout the tropics, with no special equipment and minimal training. However, none of this is optimised – not only because of poor extension services but also because much knowledge is still lacking.

Various ways of processing Jatropha have been undertaken under field conditions. Different presses have been tested and in some cases new models developed. Different
methods for cleaning the oil have been tried successfully, as has the processing of oil into biodiesel, soap, lamp oil, pesticide, etc. Processing of the press cake into briquettes to substitute firewood or into biogas is being carried out successfully, as has the application of press cake as fertiliser. Field testing of simple processes for detoxification of the press cake so it can be used for fodder is also underway. Fertiliser made from press cake is on the market in small quantities.

![Figure 1 Estimated Jatropha productivity (kg dry seeds ha\(^{-1}\) yr\(^{-1}\)). There is wide agreement that this map by Trabucco et al.2010 provides a realistic estimate of yields under “typical” farming conditions.](image)

Overall we can say that at this stage, Jatropha systems have been shown to work at the technical level, while also being socially, environmentally and culturally acceptable. Nevertheless, experience shows that Jatropha has not proven to be an attractive option to farmers at most places where it has been tried out. This issue is often formulated in terms of a lack of “economic viability”; but as we will see in this paper, this is too narrow a view.

**Substituting fossil fuel with Jatropha oil**

Up until now, all Jatropha systems have focused on substituting fossil fuel with Jatropha oil. As a consequence, the price that can be paid for the seeds is limited by the fossil
fuel price and the cost of processing. In practice, the price that can be paid to farmers per kg of Jatropha seeds is around 10-15% of the price of 1 litre of diesel.

The farmers' production costs are mainly determined by the time it takes to harvest the seeds. So far, all harvesting is being carried out by hand. One person can typically harvest and de-hull around 40 kg seeds per day. Given the limitations to seed prices described in the previous paragraph it can be seen that – under current production systems - Jatropha is only attractive if the wage level is less that the price of 4-6 l diesel.

This rule of thumb assumes that no taxes are levied on the Jatropha oil or biodiesel and that land has no costs. If this is not the case, the wage level has to be even lower before Jatropha becomes attractive.

In Peru, the HIVOS-supported Cedisa project was located in an area where the minimum daily wage is USD 7-9 (Prakash, 2012) whereas the FACT-ADPP Jatropha project in Mozambique faced minimum wages of 1 USD (de Jongh and Nielsen, 2011). Not surprisingly, the Peruvian farmers earned just half the minimum wage when cultivating Jatropha, whereas in Mozambique, Jatropha provided a better income than paid employment and alternative cash crops.

In Karnataka State, India, it has been shown that with the current production systems, a doubling of the Jatropha oil price is required for it to become profitable to small-scale farmers (Estrin, 2009).
Figure 2 shows that most low-income countries that fall within the ecological zone for Jatropha are in Africa and Southeast Asia. However, in Asia, higher population density and land prices often make Jatropha less attractive than alternative crops.

It is therefore clear that as long as Jatropha systems only focus on direct substitution of fossil fuel while harvesting is done manually, they will only be viable in areas with low wages, low land costs and no taxation on Jatropha oil/biodiesel. This is to a large extent limited to African countries.

The experience by HIVOS and others support this conclusion as Jatropha has been found to be most viable at locations characterised by:

- Low input cultivation systems (i.e. limited use of fertilisers, pesticides and machinery);
- Agricultural production that is labour-limited and where the price of land is therefore low;
- High fossil fuel prices which often implies remote and isolated areas;
- Locations where value-added products can be produced and sold or consumed (e.g.
biogas produced from press cake at a central processing facility requires sufficient off-take nearby); and

- Agro-climatic conditions that favour Jatropha, avoid pest and diseases and usually make pest management superfluous.

For people who expected to find a quick solution to the global dependency on fossil fuels, this conclusion is disappointing. However, from a development perspective it is exciting because there are few other promising options for development and energy provision in the locations where Jatropha is most promising.

The conditions that favour Jatropha production never cover a whole country. For instance, fossil fuel prices vary with the accessibility of an area. Similarly, the alternatives to Jatropha production vary per location: Farmers close to urban centres usually earn more from producing vegetables for the urban markets than they can earn from Jatropha.

Introducing new production systems in remote, underdeveloped areas poses a number of challenges. Infrastructure is poor, making transport more difficult and all inputs more expensive than elsewhere. The skill level is low and experience has shown a high turnover rate of skilled labour is to be expected. For instance, good managers and press operators often seek opportunities in less remote areas after a short while. Staff costs are low, but this must be weighed against the shorter longevity of equipment and machinery due to the harsher environment, lack of quality spare parts and consumables, poor maintenance and breakdowns caused by the low skill level.

The dilemma experienced by HIVOS and others is that the more favourable an area is for Jatropha, as measured by wage level and fossil fuel prices, the more difficult it is to implement and maintain a Jatropha system. For instance, while the FACT-ADPP Jatropha project in Northern Mozambique is one of the most promising areas, it has faced some of the longest delays in implementation, a lot of downtime of processing facilities and transport vehicles due to a lack of essential spare parts, and problems of staff leaving when they had gained enough experience to get employment at locations with better living conditions. The long-term viability of the Jatropha system is therefore
in no way guaranteed.

The semi-subsistence farming systems that are common in these remote areas also pose special problems. Yield per hectare is of minor importance because all farming operations are manual and labour therefore is the limiting factor. Crops that have low per-hectare yield can be very attractive if they require little labour – the importance of wild food and bush meat illustrate this well. Furthermore, the opportunity cost of labour varies with the seasons, from almost zero to infinity; i.e. new crops that can be managed at times of the year when little else happens on the farms are embraced, whereas nobody will allocate labour to even highly profitable crops if it compromises their food production. Economic analyses that use fixed opportunity costs are a poor representation of this reality and do not capture the all important issue of seasonal compatibility.

In practice, the seasonal compatibility with existing cropping systems has been found to be mixed and site-dependent. The preparation of seedlings, pruning and sometimes planting have in many projects been undertaken outside the agricultural season, at a time when the labour demand for other crops is limited. However, harvesting of Jatropha has at most locations coincided more or less with the harvesting of food crops. In some cases, delayed harvesting has been practised with some loss of seeds as a consequence. Surprisingly, farmers in Northern Mozambique preferred to harvest food crops and Jatropha simultaneously even when advised to postpone the Jatropha harvest. They explained that Jatropha harvesting is a light task that conveniently breaks up days with demanding tasks. There is currently no agreement about the impact on oil quality of leaving seeds on the branches until they are dry and shrivelled (de Jongh and Nielsen, 2011; Veen, 2011). A recent study at nine sites in Ethiopia, Kenya and Tanzania found that farmers did find that Jatropha harvesting interferes with crop harvesting (Ehrensperger et al., 2012). However, the harvest volume has been limited so far and farmers opinion may change when the plants mature over the coming years.

Another aspect that is difficult to capture in economic analysis is: resilience. Experience indicates that Jatropha can yield in years where dry spells wipe out annual crops like maize. As such, it can provide a safety net for farmers. One caveat is that this only
comes into play where farmers produce for external markets.

Complementary benefits have turned out to be an important reason for farmers to plant Jatropha. In particular, it is appreciated as a hedge to demarcate property and in some cases to keep animals out. However, in the latter case the plants are spaced so closely that severe competition occurs which reduces the seed yield to negligible amounts. In some cases, thorny trees are planted together with Jatropha in hedges and this makes it more difficult to harvest Jatropha seeds.

It was stated above that yield per hectare is of minor importance in semi-subsistence agricultural systems. This does not imply that it is irrelevant, as a higher yield per hectare reduces the labour for weeding, and speeds up picking. Larger seeds would speed up both picking and de-hulling rates even if the yield per hectare stays the same.

High-yielding seed is the main goal pursued by the commercial Jatropha research and much of the government-based research too. However, the experience from other crops shows that we should not expect high-yielding seeds to have much impact under low-input farming (Fess et al., 2011). Yield is usually constrained by nutrient and water deficiency as well as the limited management. To increase yield under low-input conditions, variety selection should be carried out under low-input conditions. This appears to currently not be done at a serious scale. Several of the HIVOS-supported projects included variety testing at a small scale, but this work has not been continued after the support ended.

There are several options for getting out of the straightjacket imposed on current Jatropha systems by, on the one hand changing fossil fuel prices, and on the other reducing the labour requirement for harvesting.

**Adding Value**

Farm-gate prices can be raised if more value is added to the Jatropha oil. Besides the market for seeds for processing, there is a smaller market for quality seeds for planting. Most projects have tapped into this market and managed to get a four to ten times higher price for selected seeds. Due to the infancy of Jatropha breeding, “improved
“seeds” have in practice meant little more than cleaned seeds from a known source that are guaranteed to have a high germination rate. This market is currently negligible due to the waning interest in Jatropha. As improved seeds from commercial supplies are likely to become available on the market in a few years, it is unlikely that farmers will ever again be able to obtain the high prices seen a few years ago.

**Jatropha soap**

Several projects have experimented with local soap production and found it to be more profitable than fuel production. This has the added benefits of reducing the quality requirements for the oil and therewith the processing costs, as well as involving more people in the processing.

Basic soap production is simple and, apart from temporary unavailability of caustic soda, it has proved both viable and manageable under even the most difficult circumstances. At most locations, it has fetched a higher price than the cheapest industrial soap on the market due to its white colour and sometimes due to its perceived medical properties, stemming from the poisonous substances in the oil. This has however also led to concerns over the safety of Jatropha soap. Fortunately, recent tests of Jatropha soap in Germany found that it fulfils government regulations there for cosmetic soap (Tatjana Vollner, 2011). More comprehensive tests are required. If they satisfy the requirements for “medical soap”, Jatropha soap can fetch a higher price.

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1 See also LinkedIn discussion: [http://www.linkedin.com/groupAnswers?viewQuestionAndAnswers=&discussionID=166056133&gid=64306&commentID=96067036&trk=view_disc&ut=3kxBtpadHbWRo1](http://www.linkedin.com/groupAnswers?viewQuestionAndAnswers=&discussionID=166056133&gid=64306&commentID=96067036&trk=view_disc&ut=3kxBtpadHbWRo1)
The profitability of soap production in most countries can be increased if farmers are provided with technical expertise to increase their product range and assistance with marketing, including attractive packaging. For several years, the company Best Natural Products in Arusha, Tanzania, has been using Jatropha PPO (Pure Plant Oil) to produce a range of soap and related products that include: washing soap, toilet soap, hand soap, shampoo, shower gel, liquid detergent, disinfectant, mosquito repellent and bio-pesticide. There, they have a quality control laboratory where the composition of each batch of Jatropha oil is tested, chemicals are weighed accurately and the quality of the products is assured.

In the Gota Verde project in Honduras, “liquid amber” from an indigenous tree is added to provide an attractive aroma. Such natural aromas or small quantities of imported aromatic oils can be mixed with the soap products to improve their appeal and to justify a higher price comparable with luxury soaps.
**Jatropha pesticide**

Bio-pesticide is another profitable product from Jatropha that is already being used in coastal Peru to effectively control four locally occurring plagues. The CEDISA project is also selling Jatropha PPO as bio-pesticide to a GIZ project in Chiclayo at the elevated price of 18 soles (~USD 7) per gallon; i.e. the production cost of PPO is 10.8 to 14.4 soles per gallon, and the local mineral diesel price is 12.5 soles per gallon) (Prakash, 2012). Research has shown that Jatropha pesticide is efficient against a wide range of pests (Devappa et al., 2010). However, the effect on beneficial insects, including pollinators is not known.

**Using the Jatropha press cake for fertiliser**

The press cake has been used with good results for biogas production, for briquettes to substitute firewood and for fertiliser. However, to ensure long-term sustainability, the press cake residues should be returned to the Jatropha fields; this will ensure an almost closed nutrient loop if the volatilised nitrogen is compensated through nitrogen-fixing intercrops. At most locations, it does not make business sense to sell the press cake and buy fertiliser to compensate for the lost nutrients. On the other hand, there are logistical obstacles to bringing bulky press cake back to the farmers' fields, and farmers prefer to apply it to high-income crops like vegetables. The result is long-term depletion of the soil where the Jatropha grows, and therefore reduced yields.

INIA in Peru has experienced some problems with the use of press cake as fertiliser because it is toxic and kills worms that aerate and fertilise the soil. However, the main toxin, *phorbol ester*, takes about a week to break down in the soil and therefore does not pose any long-term environmental issue (Devappa et al., 2010).

**Jatropha press cake in digesters**

The press cake can be used for biogas production in simple anaerobic digesters. The basic technique is well known and widespread. At several locations, biogas is now being produced from Jatropha press cake at an experimental scale. Biogas digesters provide a very good way to extract the energy in the press cake as methane and also return most of the nutrients back to the plants as the slurry. The biogas can be used for
heating or in engines to drive pumps or machinery, or to generate electricity. However, it must be used within the vicinity, since removing the carbon dioxide and compressing the biogas are not feasible options for small-scale digesters.

Biogas digesters using Jatropha press cake have operated successfully in several countries. In a pilot project in Way Isem, Indonesia, called the Self-Sufficient Energy Village (SSEV), around 40 ha of Jatropha plantations supplied seeds to an oil expeller run by a co-operative. Twenty anaerobic digesters of 1,200 L capacity were given to the villagers so that they could produce biogas from Jatropha press cake and use it to replace firewood for cooking. They then mixed 2 kg of Jatropha press cake with 18 L of water, to be fed on a daily basis into the digester to produce one cubic meter of biogas -- which is equivalent to 0.6 L of kerosene or 3.5 kg of wood (ERIA, 2010).

Mali Biocarburant is using Jatropha press cake in combination with cattle manure to produce biogas for five multi-functional platforms, giving 20-50% reduction in fuel. In Tanzania, Diligent has fed the press cake into a 60 m³ biogas digester, using mainly human wastes; the gas is then used for cooking mid-day meals for the workers. The performance of biogas digesters operating solely on Jatropha press cake is not yet well established.

Diligent’s biogas digester is of the Fixed Dome design made of bricks and cement. Several low-cost, light-weight digester designs are now available, and have proven their reliability in tropical climates.

Plastic bag digesters provide another low-cost design that has performed well. Both FACT and Mali Biocarburant are using plug flow digesters made of long, semi-buried plastic bags. These digesters are easy to transport to remote areas and can be installed quickly. The Compact Biogas Plant developed by ARTI in the state of Maharashtra in India is a low-cost digester easily constructed from two plastic water tanks that have been installed successfully in the tens of thousands, for producing biogas mainly from kitchen wastes.

2 http://www.completebiogas.com/B_Plastic.html
3 http://arti-africa.org/compact-biogas-systems/
Jatropha press-cake briquettes only make sense for large centralised oil-processing plants where logistics prevent the large quantity of press cake from being returned to the Jatropha fields. Unfortunately, burning the press cake produces a considerable amount of smoke that is pungent. To tackle this problem, Diligent in Tanzania has designed a kiln to make charcoal from the briquettes.

There are several advantages to expelling the oil in a decentralized manner close to the where the Jatropha is cultivated. When de-hulling takes place near the fields, it is easier to return the hulls to the Jatropha plants. Press cake can be used to produce biogas that can fuel the oil expeller. The biogas slurry can be pumped or carried to the plants as organic fertilizer. Moreover, profits will increase because PPO substituted by biogas will be available for sale or for adding value to it before selling by-products such as soap, bio-pesticide, etc. Several projects have tested the use of hand-powered ram presses with mixed results. The productivity is low, clogging can be a problem and much oil is left in the seed cake.

Motorised mobile oil expellers can be combined with Multi-Functional Platforms – MFPs. All other activities except Jatropha oil expelling can be done by the MFP using PPO as fuel; for example, for rural electrification, flour mills, saw mills, expelling of edible oilseeds, crude Jatropha oil filtration, etc. However, there are several drawbacks to mobile expellers as opposed to centralised oil extraction. Biogas production needs large quantities of water since the press cake has to be diluted with at least four times as much water. Biogas digesters installed by FACT at Chimoio and Bilibiza in Mozambique have stopped working, and it appears that the organic reactions in the digesters are sometimes difficult to maintain.

One advantage of a centralised factory is that larger volumes can be processed using more sophisticated presses. Secondly, it is easier to control proper operations and maintenance in a central location. Thirdly, small mobile presses require more trained operators in the field. Nevertheless, considering the overall advantages of small mobile oil expellers, it would be worthwhile to investigate this decentralised approach further. The trade-offs between central and decentralised approaches to processing are site-specific and more operational experience is required before conclusions can be drawn.
Intercropping with Jatropha

Jatropha has successfully been intercropped with soy, groundnuts and many other crops. In Jatropha fields with common spacing, e.g. 3m x 4m, experience shows that after the second or third year shade makes it un-economical to continue intercropping. In some cases, spatial arrangements that allow for continuous intercropping have been used, e.g. the layout by Cedisa in Peru illustrated in Figure 4.

As mentioned earlier, intercropping with nitrogen-fixing plants is essential for avoiding soil depletion. In the areas where Jatropha systems have the highest potential, fertiliser is usually not an option due to price and availability. At most projects in poor remote areas, farmers have opted to – and usually been encouraged to – plant Jatropha only as hedges, and the issue of intercropping has not received the necessary attention.

Mechanisation

To reduce the labour required for harvesting, the de-hulling can be mechanised. Manual de-hulling takes an average of 15 minutes per kg, whereas a hand-operated de-hulling machine can reduce de-hulling time to 2 minutes per kg. Manual de-hulling can also damage the seeds, and is therefore not suited to producing quality seed material. In Honduras, farmers found that they could de-hull just as fast by hand as they could with a “Nicaraguan” mechanical de-huller (Prakash, 2012). BYSA then started local manufacture of the “Universal Nut Sheller”, a more effective hand-operated shelling machine based on the peanut de-huller that was developed under the Full Belly project. This de-huller, made of concrete and steel, is fairly simple to fabricate locally and is now also being manufactured in Mali. It needs about USD 30 for materials and two days of labour to prepare the metal pieces, pour concrete in moulds and assemble. No maintenance is required but the cement cone can break easily if it falls.

Motorised de-hullers at central processing facilities provide an option that looks promising but still needs further development and testing. A mechanical Jatropha de-huller has been designed and fabricated by a technical school in Nicaragua. In Peru, DRASAM developed an electric de-huller in collaboration with a local technical education institute based on a Brazilian coffee de-huller. This model has a capacity of
100 kg/hour, cracks the dried fruit and separates the seeds from the husks using a blower. The local production cost of this machine is USD 1,600. It runs on electricity but can be adapted to run on an engine using diesel or PPO (Prakash, 2012).

Figure 4: Agroforestry promoted by Cedisa, Peru

Concluding remarks

The experience with Jatropha systems in poor and remote areas so far indicates that the major obstacles are organisational, rather than technical. This is exacerbated by the fact that in such areas, all links in the production chain and support functions—including agricultural extension, farmers’ groups or cooperatives, nurseries, collection points,
transport facilities, processing plant, product development, sales and distribution systems—have to be established from scratch. At some locations, credit systems had to be established, as well as facilities and expertise to convert engines to run on pure Jatropha oil. This is in contrast to more developed areas, for instance in Latin America and Asia, where Jatropha projects operate within an environment where governmental and private actors already provide many of these services.

The result is that the most promising areas in terms of wage level and fossil fuel price are also the ones that require the broadest level of intervention. Furthermore, the production chains tend to be fragile as there is little redundancy. For instance in Mozambique, the FACT-ADPP project was for a long time the only buyer of Jatropha seeds. It provided the only extension service for Jatropha; transport needs were served by one truck and the processing was done with two presses powered by one generator. It takes very little to bring such a fragile production chain to a halt. The hope is of course that once an example of a working system is in place, other players will be attracted—which has indeed happened in Northern Mozambique.

It is no surprise that projects that have operated in more developed areas have had fewer organisational issues and have been able to build solid and innovative institutions. For instance, the Gota Verde project in Honduras successfully created a system with Jatropha-backed vouchers that were accepted as payment in local shops. This ensured that income from Jatropha strengthened the local economy further (Peter Moers, 2010). But, alas in this relatively well-developed economy (compared to African countries), Jatropha is not competitive.

In more developed areas, agricultural production is not only limited by labour availability but increasingly by land and capital access. Mechanisation is available and yield per hectare becomes an important factor in determining profitability. So far, Jatropha yields have not lived up to the expectations, and mechanisation of Jatropha is still in its infancy.

It is widely agreed that there is potential for increasing Jatropha yields significantly and that it can be done within a short time span (Eijck et al., 2010). Several companies are working intensively on bringing high-yielding planting material to the market and the
expectation is that within a few years it will be widely available. However, these companies do not share enough data to make it possible to assess the level of yield increase that we can expect. However, together with advances in Jatropha agronomy and mechanical harvesting, it is likely to significantly expand the area in which Jatropha is profitable. The effect will however first be visible at least five years from now, because we have to wait for the release of the material and for the plants to mature. It is therefore beyond the time horizon that is the focus of this paper.

Yet, even without improved planting material, significant yield gains can likely be achieved. Most Jatropha projects have reported large variations in yield between farms under different management regimes. Many have also observed a wide yield gap between project-managed and farmer-managed plots. Poor extension service is one reason as well as the belief until a few years ago that Jatropha would yield no matter how it was managed. This was exacerbated by the low level of knowledge about basic requirements, optimal planting distance, intercropping, pruning, etc. The belief in the ability of Jatropha to yield even in the most difficult environment led many farmers to plant it on exhausted soil and waste land.

A combination of better extension services and selective removal of Jatropha planted at unsuitable locations will likely increase yields significantly everywhere.
References


