Discovering new oil fields

Small-scale local biofuel production and use in rural Honduras

Results and lessons from the Gota Verde project in Honduras (2007-2009)

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1. Introduction

The development of the fossil oil sector in the 20th century made available massive volumes of energy at low prices. The parts of the world that were technologically equipped to take advantage of this cheap energy have experienced an unprecedented increase in productivity and living standards. Oil producing countries have seen even stronger wealth increases.

But the age of cheap oil is nearing its end. Many economists predict oil prices to increase drastically in the next decade, due to a stagnating production, higher production costs of the remaining oil fields and an ever-growing oil demand, especially from China[1].

The upcoming era of high energy prices may give rise to the largest redistribution of wealth in the history of mankind. Especially tropical countries with large areas of un(der)used arable land available can improve their competitiveness as a result of higher energy prices. The question if small farmers can benefit significantly from this new situation, has been central in the Gota verde project in Honduras.

The Gota Verde initiative is in several aspects different from many of the other biofuel initiatives that have risen during the past years:

- Its products cannot be found in the ports of Rotterdam and Miami, but in the irrigation pumps, tractors, agro-industrial equipment and vehicles used locally in Yoro, Honduras.
- Its feedstock does not come from huge monoculture plantations, but from hundreds of small plantations and living fences, managed by small and medium-sized farmers and their families.
- The owners of the processing enterprise are not anonymous overseas shareholders, but the very local farmers that cultivate their lands.

The **objective** of the Gota Verde project is to demonstrate that biofuel production on a small scale for local use is an economically and technically feasible activity. The project has built an important local capacity, that is unique in

[1] Demand in Asia is rising at a rate of 2 million barrels a day. Source: http://www.jodidata.org/.

the Central American region, in the cultivation of oil-yielding crops, small-scale production of biofuel and its local use.

The Gota Verde project has been implemented by a consortium of six European and two Honduran organizations, coordinated by the Social Trade Organisation (STRO, The Netherlands). The other members of the consortium were: AGERATEC (Sweden), Dajolka (Denmark), FACT Foundation (The Netherlands), Humanistic Institute for Development Cooperation (HIVOS, The Netherlands), Institute for European Environmental Policy (IEEP, United Kingdom), FHIA (Honduras) and FUNDER (Honduras).

This report gives an overview of the main results, lessons learnt and conclusions of the three year project (2007-2009). More detailed information and a list of downloadable documents can be found on the project's website: http://www.gotaverde.org, both in Spanish and English.

Biofuel trial in Yoro.

2. Background

2.1. History

The Gota Verde project surges from the efforts of the Social Trade Organisation (STRO) to develop sustainable development strategies that contribute to independent, diversified and stable local economies. The relatively high price of diesel fuel in Honduras, in combination with the relatively low wage level and abundant availability of land, make the country an interesting candidate for developing a biofuel pilot experience.

After a first demonstration of STRO in 2005 with the use of Pure Plant Oil (PPO) in Honduras, sufficient enthusiasm and interest was generated among local organizations to justify the formulation of pilot project in Honduras. Various regions were identified and analyzed. The region of Yoro was in the end selected for its availability of land and labor, agro-ecological conditions and access.

In 2006 a project proposal was presented to COOPENER which forms part of the Intelligent Energy Europe program of the EC. Later that year, proposals for co-financing were presented to HIVOS and DOEN Foundation, both Dutch NGOs. After approval by the end of 2006 the Gota Verde project started in January 2007 with a Kick-off meeting in Brussels.

2.2. The Yoro region

Yoro is one of the 16 provinces (“departments”) of Honduras, located in the north of the country. The province consists of 11 municipalities, of which the project covers 8. The project’s office is located in the provincial capital, also called Yoro. Yoro province has an estimated 350.000 inhabitants, with a population growth of approx. 2,5% per year. Yoro is

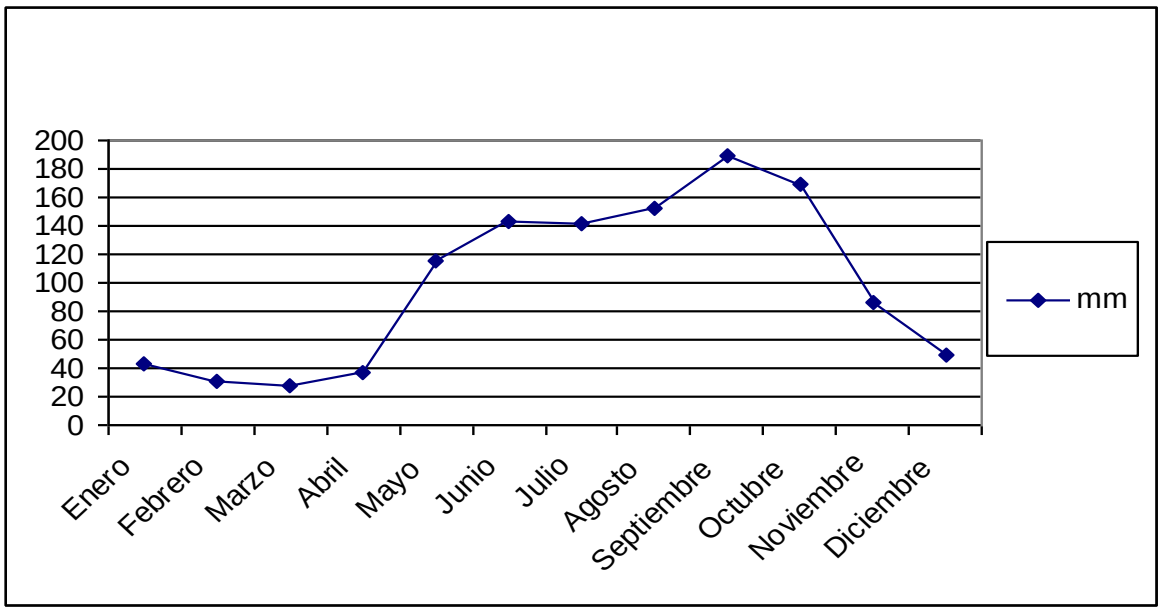
also the province with the third highest rate of emigration to the United States, a clear indicator of the lack of economic opportunities in the region. Especially the age category between 19 and 29 migrates in large quantities. 43% of the province's population lives in rural areas, although most of them in El Progreso, which is outside the intervention area. Main economic activities in the intervention area are wood exploitation (including many illegal), cattle rearing and the cultivation of basic grains (corn and beans). Remittances from family members working in the US form are an income source of growing importance.

The main socio-economic indicators of Yoro are worse than the national average, as the following table shows:

Description	National	Yoro
Human Development Index (HDI)	0,657	0,634
Malnutrition	34,0	33,2
Literacy	79,7	78,8
PIB percapita (USD)	2.321	1.822

Source: UNDP (2003)

The average rainfall in the city of Yoro is about 1200 mm per year, concentrated mainly in the months of May until November. The southern part of the department tends to be dryer and the rainy season shorter.



Source: Servicio Meteorológico Nacional de Honduras

Average temperature of intervention zone is 25º C, with maxima of around 35 degrees and minima of 15 degrees. Rainfall, temperature and altitude in most parts of the Yoro province are considered adequate for the cultivation of Jatropha.

2.3. Biofuel in Honduras

Honduras imports 100% of its fossil fuel imports. In 2008, 18,7 million barrels of fuel were imported, of which almost 70% concerned diesel and bunker. Total value of fuel imports was almost 1900 million USD, equivalent to 67% of Honduras' export earnings. This percentage has increased steadily from 49% in 2005 and 56% in 2007[2]. Fuel imports are a major drain of foreign exchange, thus reducing drastically the available purchasing power for local products. Many domestic productive sectors are severely affected by this tendency.

At the same time, Honduras has an enormous agricultural potential that is only partially exploited. Some sources estimate that only 30% of the 2,8 million hectares appropriate for agriculture are actually under cultivation[3]. In theory, Honduras could become independent from diesel and bunker imports by cultivating 70% of these un(der)utilized lands with Jatropha. Palm oil production could reach this goal with 4 times less land, but due to agroecological requirements, its cultivation is limited to a relatively small fringe along the north coast. Although in practice there may be many factors that make this impossible or even undesirable, it gives an impression of the biofuel potential of the country.

In this context, the Honduras government has adopted a law that has to make investments in the biofuel sector attractive by issuing several fiscal advantages. At the same time, however, fuel prices are a politically sensitive topic. Governments (and almost the entire population) tend to see fuel rather as a cost item than as an income and employment generating opportunity. This translates into a policy of fuel tax cuts or even fuel price subsidies in times of high oil prices. Although this is perfectly logical from the electoral point of view, it can undermine long term investment in the sector and thus the creation of income and employment opportunities for thousands of rural farmers and entrepreneurs, in spite of the favorable law.

[2] Source: http://www.bch.hn/exportaciones.php and http://www.bch.hn/importaciones.php
[3] Source: "Honduras ante la crisis mundial de alimentos", Hablemos Claro Financiero, Mayo 2008, p. 15.

3. Project description

3.1. Objectives

The general objective of the Gota Verde project was to demonstrate the economic and technical feasibility of small-scale biofuel production for local use. Specifically, the project aimed at removing the technical and organizational barriers that impeded the biofuel production chain from taking off in the Yoro region. These barriers can be found in the lack of technical know-how (at the level of farmer, processing enterprise, end-user), lack of an organizational structure, lack of markets and lack of access to an appropriate credit scheme. The project also aimed to maximize the impact on the local economy by implementing an innovative local currency scheme.

3.2. Strategy

The strategy in terms of target group, feedstock and scale sources has changed during the implementation period for the project, adapting to the changing circumstances.

Target group:

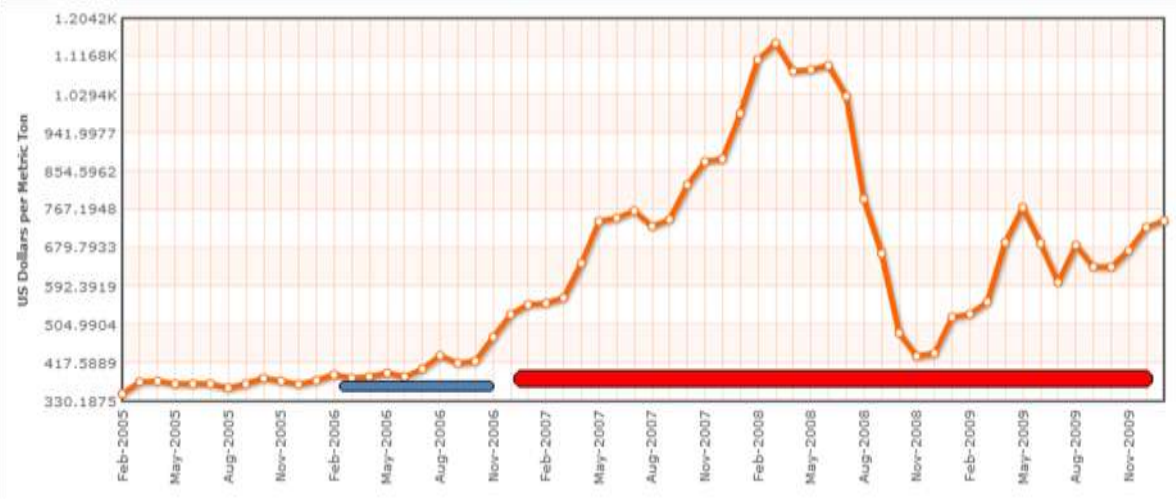
It was initially foreseen to work mainly with medium sized farmers, because it was small farmers were expected to show little and capacity to invest in a new, unknown cash crop (Jatropha). In practice, many small farmers did show a great deal of interest, especially if the crop was presented as an intercrop with other, edible crops. Although this shift to smaller producers implicated additional costs, the impact of the project increased and the experience has become richer: different types of farmers require different approaches.

Feedstock for biofuel production:

At the moment of conceiving the project, palm oil was still a competitive feedstock for biodiesel production. In fact, the first trials by STRO in 2005 took place with refined palm oil. However, during the implementation of the project, palm oil prices soared (together with fossil fuel prices) and alternative sources of feedstock had to be found. The only competitive feedstock left was waste vegetable oil, whose availability was obviously much smaller than the originally

planned palm oil. For the same reason it was also decided to invest more in short-cycle oil crops.

The following graph shows the development of the Crude Palm Oil (CPO) worldmarket price dring the project's formulation phase (blue horizontal line) and implementation phase (red line).



Source: http://www.indexmundi.com/commodities/?commodity=palm-oil&months=120

Scale of biofuel production:

The project planned to start with a 1000 to 2000 liter per day automated biofuel processor. However, due to the limited feedstock available, the investment could not be justified. Instead, a low-tech and low-cost processor was built locally.

Number of farmers and area:

In the original project plan it was foreseen to include 200 farmers with a total area of 159 hectares. Already during the kick-off meeting it was decided to increase these targets 700 ha with 250 farmers in order to achieve sufficient scale for a viable biofuel processing enterprise. This was possible thanks to a larger contribution of HIVOS to the investment fund available for farmers. Also the number of agricultural advisors had to be increased.

Intervention area:

Although initially interventions were only foreseen in the municipalities of Yoro, Sulaco and Morazán, the project received many requests from farmers from neighboring municipalities. In order to increase the dissemination impact of the project and diversify the experience of the Project, it was decided to include these municipalities in the intervention area.

3.3. Components

The building of a biofuel chain requires technical capacities in multiple areas. Since biofuel is a completely new concept to the Yoro region, these capacities had to be built from zero in many cases. The main components in which the project intervened were:

Agricultural component

The agricultural component was subdivided in (a) agricultural investigation and (b) promotion, training and advisory among farmers. For the first component the Honduran Foundation for Agricultural Investigation (FHIA) was subcontracted. Part of the investigation was also carried out by students of collaborating universities, supervised by the coordination team. The second sub-component was carried out by FUNDER, the Honduran Foundation for Rural Enterprise Development. Investigations[4] clearly show that the quality of the plantations is strongly related with the intensity of the technical assistance and the quality of the plantation.

Enterprise development component

[4] See a.o. http://www.gotaverde.org/userfiles/file/D53n - Adopcion de Jatropha en Yoro_Chango-09%20(Zamorano)_ES.pdf

The processing enterprise is the beating heart of the biofuel chain. Except for the legal establishment of the enterprise (BYSA), this component also included the promotion of shareholdership among farmers, organization of the enterprise, elaboration of business plans, cost calculations for different crops and transformed end-products and training of management. FUNDER holds 51% of the shares and farmers 49%. Once the enterprise has reached selfsufficiency, FUNDER will gradually sell its shares to local farmers. Statues prohibit that one farmer holds more than 5% of the total share value of the enterprise. This avoids that the financially strongest farmers dominate the decision making process of the company. The creation of the local, farmer-owned biofuel processing and enterprise (BYSA) is therefore of the utmost importance. The continuity of the initiative on the long run depends largely on the profitability of this enterprise.

Images of the Constitutive Assembly and swearing in of the first Board of BYSA (Aug. 9th, 2008)

Financial component

The financial component consists of two areas that partially overlap: (a) the creation of an appropriate credit scheme and (b) the creating of a local currency scheme. The credit scheme is administered by FUNDER and has been an essential element in achieving the agricultural targets of the project. Depending on the degree of experimentation of the crop, farmers entered in a loan or a co-investment arrangement with FUNDER (or a mixture of both).

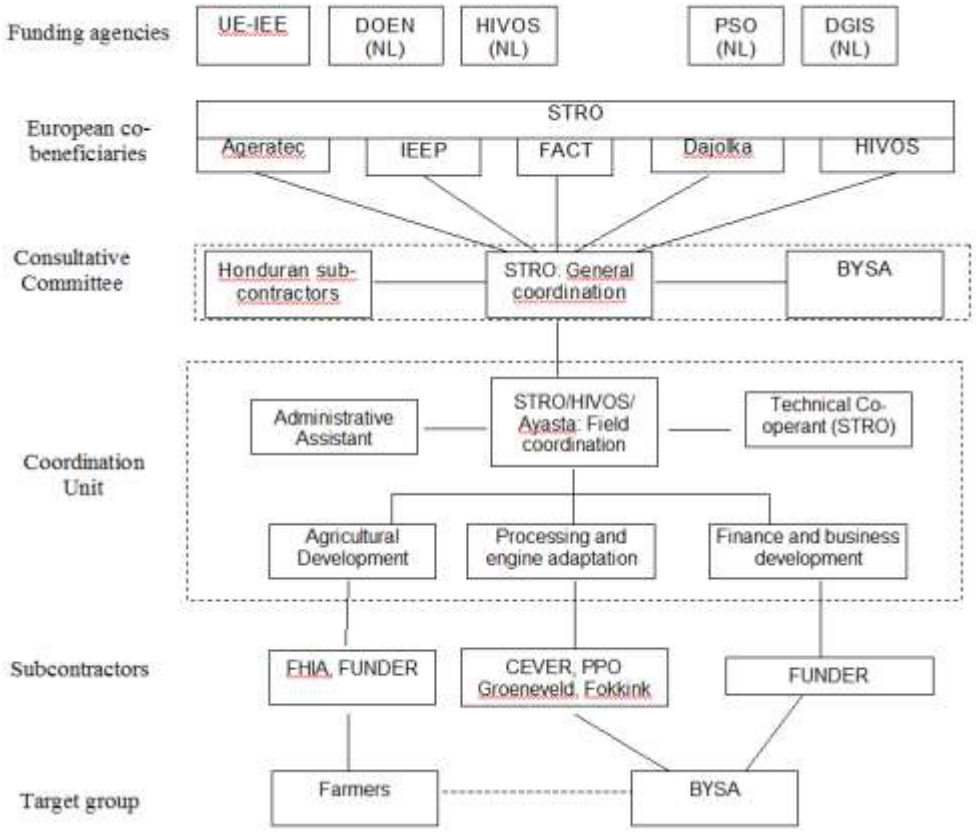
The local currency scheme aims to increase the impact of the “new oil wealth” on the local economy by stimulating that the purchasing power is spent locally. The scheme is administered by BYSA.

Engine adaptation component

The pure plant oil (PPO) technology was identified as being especially appropriate for the development of small-scale biofuel initiatives. From the point of view of the production process, it reduces considerably the cost and complexity of the biofuel production. However, from the point of view of the end-user, the use of PPO in diesel engines requires an engine adaptation. This initial investment can be compensated by lower fuel costs. Transferring the skills needed to adapt the engines was the objective of this component.

3.4. Organization

With six European organizations, 2 European subcontractors, 2 Honduran subcontractors, several regional temporary experts and a multitude of local actors, it was clear from the very start of the project that the coordination would become a true challenge. Time, language and cultural barriers had to be overcome by both local and European actors. The following scheme gives an impression of the organizational complexity.



The Consultative Committee played an essential role in formulation a coherent, field-based strategy proposals that backed by the very organizations that are

responsible for their implementation. The Consultative Committee is an open structure that meets every 6 months and consists of representatives of all local organizations (including farmers) involved and European organizations that have presence in Central America. The Committee makes recommendations to the European consortium that is responsible for the execution of the project. STRO, as a Coordinator, passes these recommendations on to one or more of the European partners, depending on its relevance. The European consortium met 3 times during the duration of the project.

(Left) Image of the third Consultative Committee, held in April 2008. (Right) Project office in Yoro.

4. Main results

4.1. Oil crop area planted: 599 ha

The original target of the project was to establish of only 159 ha in 3 years. This target was increased to 700 ha in order to create an economically interesting scale for the processing enterprise. Main obstacle in achieving this target was the limited availability of loan funds and the higher than expected amount per ha needed[5]. In spite of these limitations, 85% of this increased target was accomplished (599 ha). The established area consisted mainly of Jatropha (70%), castor bean (17%) and sesame (12%), next to small, trial areas of soy bean, sunflower, peanut and canola. In total, 416 farmers planted oil crops, surpassing the project's goal of 200.

Year	Crop	Area (in ha) established	Area lost	Existing area
2006	Jatropha	18	11	7
2007	Jatropha	55	16	39
2008	Jatropha	258	44	214
	Castor	107	47	0*
	Soy	3	2	0*
	Sesame	10	8	0*
	Canola	1	0	0*
2009	Jatropha	115	2	113
	Peanut	1	0	0*
	Sunflower	2	0	0*
	Sesame	28	0	0*
Total		**599**	**130**	**373**

* Areas with short-cycle crops that have been harvested

It can be observed that the relative area of Jatropha lost each year (as percentage of the area planted) decreased each year since 2006, reflecting refined criteria for both site and farmer selection, as well as improvements in the land preparation methods.

[5] See 5.6.


(Left) Peanut – Jatropha intercropping.

(Right) Image of the first commercial-scale sunflower trial in MorazYoro.

4.2. Testing agricultural practices of Jatropha

The Although Jatropha is indigenous to Central America, it has never been treated as a cash crop[6]. Farmers use the plant traditionally as a living fence (cattle does not eat the leaves), for soap making and as a natural medicine. Also literature did not offer much validated information about cultivation practices. The experiences over the past 3 years have offered many interesting lessons in the agricultural field. Thanks to these lessons, the quality of the plantations established in 2009 is significantly better than those of the previous years. The main lessons are:

- It is important to establish the Jatropha planta plantations early in the rainy season (May-July) to ensure that the plants develop well before entering the dry season (January-June).
- Leaving 4 to 6 meter between rows allows the establishment of an intercrop during the first years, when the Jatropha plantations are still little productive.


Jatropha intercropped with corn (left) and improved grasses for cattle fodder (right)

[6] Except for a Pilot Project in Nicaragua during the 1990s and a few recent commercial initiatives.

- If the land has been prepared, the soil is sufficiently humid (the rainy season has started) and the seeds are fresh, direct sowing is the best and cheapest way to establish plantations.
- Avoid sites that are badly drained (e.g. heavy clay soils) or are to near to river beds. Jatropha is extremely susceptible to root rot.
- Land preparation is generally necessary to ensure good root development. Roots that do not develop results in small plants and a higher vulnerability to drought.

(Left) correct Jatropha root development in well prepared soil
(Right) Distorted root system in heavy soil without soil preparation

Comparison of Jatropha plant development in good (left) and heavy, unprepared soil (right) .

- Up till now, there is no clear relation between the source of the Jatropha seeds and the performance of the plantations. Management practices play a much more important role.
- Fertilization and irrigation accelerate the growth of the plant. More investigation is necessary to determine how this translates into a higher productivity once the

plants have matured and to which extent this higher production justifies the additional investments in fertilization and irrigation.

- The timing and way of pruning is essential for the branch development, which is expected to increase production in later years.

(Left)Fertilization trial in Sulaco, Yoro. (Right) Pruning field training, performed by staff of FUNDER.

- The production during the first three years (0 – 400 kg per ha) is often too small (too dispersed over time and space) for a farmer to bother recollecting it.
- Jatropha planted on steep hills as an anti-erosion measure develop equally or better than Jatropha planted on flat lands.

Approximately 17 ha of Jatropha has been planted in the hilly area of Chancaya, Yoro

- The commercial sowing of Jatropha in living fences seems to be feasible in areas that are frequently visited by the farmers (e.g. milking areas for cows, near houses). Jatropha planted in fences in less frequented areas tend to be

neglected. The maintenance (and in the future: harvest) of these trees is often considered too time-consuming by the farmer.

Many of the conclusions have been incorporated into the Gota Verde Jatropha manual and the recently published FACT Jatropha manual (see website).

4.3. Loans valued at 112 500 Euro issued to 416 farmers

In total almost 3 million Honduran Lempiras (approx. 112.000 EUR) was allocated to 416 farmers during the 3-year project period. Most of the loan amount (78%) was for Jatropha and was therefore long-term. The remainder was for short-cycle intercrops. 13% of the credit was issued to women. The loans are administered by FUNDER.

The promotion of a new, unknown cash crop among small farmers is difficult. More so, if it takes 4 to 5 years to produce interesting yields. An appropriate financing scheme is therefore essential for any successful promotion effort. Gota Verde has chosen for a risk sharing arrangement in which 30% of the farmer's harvest is retained for payment of loans. The repayment period is not fixed. This way, FUNDER and the farmer share the risks of the experimental character of the crop.

4.4. FUNDER establishes the regional Biofuel Centre "Gota Verde"

During the past 2 years, FUNDER – the main local counterpart in the project - has clearly manifested its conviction that biofuels represent an enormous business opportunity for rural Central America in general and for small farmers in particular. In various occasions FUNDER has promoted the project in the press, in workshops and conferences and among its donors. The interest of FUNDER to take the lessons of the project to a higher level, fits well with one of the project's objectives, to create a permanent platform for the promotion of small-scale biofuel initiatives in Central America. The broad network and good reputation of FUNDER are highly valuable assets in this effort.

The Centre will promote small-scale renewable energy projects in rural areas, with an emphasis on biofuels. It aims to reduce the main obstacles that biofuel project promoters experience: lack of technical know-how, lack of access to finance and lack of capacity in the formulation of sustainable small-scale biofuel

initiatives. The Centre intends to systematize small-scale biofuel experiences in the region, train and advise staff of interested organizations, participate in investigations (agriculture, processing, appropriate socio-economic promotion models), promote the concept among financing agencies and engage actively in dissemination. The experience, reputation and network of the Gota Verde project is the main asset of the Centre, which explains the name chosen by FUNDER: *Centro Gota Verde*. FUNDER received a grant for two years from the Dutch NGO Cordaid, to build the basis for the Centre. The Centre has an open character: new organizations are invited to join the effort.

4.5. Low-tech biofuel processing equipments designed, built and tested

The initial idea was to install a professional biodiesel processing equipment, fed initially by Crude Palm Oil and later by Jatropha oil. For reasons explained in 5.2, neither of these feedstocks was available in sufficient quantity to justify the investment in such an equipment. Alternatively, it was decided to use waste vegetable oil and build a locally a low-tech biodiesel processor for experimental and training purposes. With technical assistance from Nicaragua and later from the USA, the equipment was gradually built and improved. The main elements of the biodiesel processing equipment are a mixing tank, a washing equipment, filters and a methanol recuperation device. The quality of the biodiesel was tested in Costa Rica and complies with the main quality standards.

Biodiesel and storage facilities of BYSA (December 2009)

Apart from the biodiesel equipment, the following equipments have also been built locally: an oil press (10-15 kg/h capacity), oil filter, Jatropha seed dehuller and a seed selection device. The processor has a capacity of about 750 liter per week,

although due to the limited availability of feedstock this capacity is used only partially.

Advantages of the low-tech processing approach is the relatively low cost, the training aspect (operators acquire a thorough understanding of the different steps of the biodiesel process) and the fact that equipments can be repaired and improved locally. This reduces technological dependency. On the other hand, the disadvantages are that the operation requires well-instructed personnel (initial need for external experts) and that the quality control is not as strict as in standardized automated processors.

A possible future scenario is that the low-tech plant is replaced by a high-tech one, once the (Jatropha oil) production volume justifies such an investment (possibly after 2012). The low-tech plant can then be relocated to another, starting biofuel project that has not yet reached sufficient production volume.

4.6. Creation of the local, farmer-owned biofuel company BYSA

On August 9, 2008, the biofuel processing and marketing enterprise BYSA[7] was established during its Constitutive General Assembly in Yoro. Formal registration took place on November 25, 2008, with 62 founding members. By the end of 2009, the enterprise had grown to 197 shareholders: 196 local Jatropha farmers (13% female) and FUNDER[8]. Total capital, contributed by shareholders is 195 967 HNL (almost 7500 EUR). FUNDER holds 51% of the shares, while the farmers hold the remainder. FUNDER's share will be sold back to farmers once BYSA has become a self-sustainable enterprise (expected after 2012).

(Left:) Shareholder composition of BYSA.

(Right:) Logo of BYSA

[7] Biocombustibles Yoro Sociedad Anónima.

[8] Foundation for Rural Entreprise Development, main implementing local partner of the Project.

In the second half of 2009, BYSA bought a 4 ha site to build its own office and processing installations. The site borders on one side the main paved road from Yoro to El Progreso, and on the other side with a permanent creek that can provide water year round. The latter is important given the plans to expand the operations with a biogas digester. The site is also sufficiently large to reserve an important area for (long term) agricultural trials.

(Left) Draft construction plan. *(Right) First constructions on the BYSA site.*

4.7. Six diesel engines adapted

In the beginning of 2008 a first engine was adapted by ENASA, a Honduran NGO specialised in developing low-tech innovations. In October 2008, Niels Ansø of Co-beneficiary Dajolka carried out more formal diesel engine adaptation training in the main professional training centre in Yoro, CEVER. More than 15 car mechanics were trained, among which students, mechanics of Yoro, teachers of CEVER and of other professional training centers in Honduras. Five engines were adapted, of which 4 vehicles and one irrigation pump. Four of the kits were bought from Elsbett in Germany. The fifth (the pump) was adapted using a 2-tank system, improvising on-site.

By the end of 2009, 3 of the 6 engines still used PPO on a regular basis; one vehicle is under repair, one is no longer functioning (for non-fuel related reasons) and a sixth belongs to a farmer that withdraw from the experiment due to lack of confidence. Until December 2009, the 3 remaining adapted engines functioned well and reported no uncommon repair or maintenance.

Students and teachers of the local technical school CEVER working on an engine adaptation, under the guidance of Niels Ansø of Dajolka.

4.8. Local currency system operational

One innovative feature of the project is the introduction of a local currency by the processing enterprise BYSA. The new currency reduces financial costs and increases sales for BYSA, while at the same time it enhances the impact of the biofuel chain on the local economy as a whole. The local exchange medium is issued by BYSA and backed by its inventory. In 2008, a participatory process took place within the Board of BYSA to determine the name and design of the vouchers. The name *Peces* ("fishes") refers to the extraordinary (and scientifically unexplained) meteorological phenomenon of small fishes falling from the sky that only takes place in the city of Yoro[9].

After a training of the BYSA administrators by STRO staff, the first Peces were brought into circulation by the end of February 2009 in the form of salary advances to employees, employees buying Peces with Lempiras and operational expenses of Project. A brochure has been designed and printed in order to facilitate the understanding of the functioning and benefits of the system and promote its use in the local business community.

By the end of January 2010, 26 businesses in Yoro accepted the currency and a total of 107.646 *Peces* was emitted between February and December 2009, of which approx. 39.000 were in circulation on December 31, 2009. Enterprises use the *Peces* to buy from each other, to buy biodiesel from BYSA, to give as change for purchases in Lempiras, to partially pay wages to their employees or to convert

[9] The currency was named after an extraordinary natural phenomenon that occurs almost yearly in Yoro: the "fish rain" (*Lluvia de Peces*). See also: http://es.wikipedia.org/wiki/Lluvia_de_peces_en_Yoro.

back into Lempiras[10]. FUCOHSO[11] converts Lempiras into Peces to purchase construction materials at a local hardware store who gives special discounts when receiving payments in *Peces*. FUCOSAO also plans to introduce *Peces* into the local loan and saving schemes (Cajas Rurales) they support. Finally, BYSA's (farmer) shareholders, receive loans from FUNDER which are converted partially into *Peces*, for purchases of agricultural inputs.

(Left) Sample of a 1 Pez voucher. *(Right) One of the 26 enterprises that accepts Peces.*

[10] Only two enterprises, both grocery stores, are allowed to convert *Peces* to Lempiras. It is expected that in the future, as biofuel production increases, more *Peces* will be redeemed into biofuel and less into Lempiras.

[11] FUCOSOH is a local non-profit organization that introduces sustainable organic farming techniques into farming communities in the region.

5. Main obstacles encountered and measures taken

5.1. Dramatic fall of oil prices during second half of 2008

The year 2008 has been one of the most turbulent years of modern economic history. The worst financial and economic crisis since the 1930s has affected the project's results in several ways. The graph below depicts crude oil (petroleum) prices between 2005 to 2009, with the green bar indicating the period of conception and design of the project and the red line the period of project implementation. World market oil price fell from an all-time high of 147 USD per barrel in July 2008 to less than 40 USD in December 2008, the lowest level in 3 years. At that moment, production costs of biodiesel became higher than pump prices. The project Gota Verde was not the only victim: virtually all biodiesel producers in Honduras stopped producing. In 2009, oil prices started climbing again.

Graph. *Crude oil (petroleum), price development 2005-2009, in USD per barrel.*

Source: http://www.indexmundi.com/commodities/?commodity=crude-oil&months=60

With the fuel prices of December 2009, BYSA's PPO and biodiesel production, based on waste vegetable oil, had turned profitable again. On the other hand, the production of PPO from jatropha seeds is still not a profitable business.

Table. *Cost price and margin per biofuel, in Honduran Lempiras (HNL) and per gallon*[12]

Product	Cost price	Diesel price	Margin (HNL)	Margin (%)
PPO from WVO	27,49 HNL	56,00 HNL	28,51 HNL	104%
Biodiesel from WVO	47,32 HNL	56,00 HNL	8,68 HNL	18%
PPO from jatropha	76,67 HNL	56,00 HNL	-20,76 HNL	- 27%
Biodiesel from jatropha	112,99 HNL	56,00 HNL	-56,99 HNL	-50%

Source: Calculations provided by BYSA

As a reference: In July/August 2008, diesel prices in Honduras surged to more than 90 HNL per gallon (approx. 0.90 EUR per liter). At this price level, all biofuels mentioned above give good margins, except for biodiesel from Jatropha oil. It is important to take into account that these calculations assume zero added value from sub-products. The table clearly shows that, creating a market for PPO gives extra margin to the small-scale biofuel producer, thus reducing its vulnerability to the volatility of the markets. It becomes also clear that, in order to render small-scale biodiesel production from Jatropha oil profitable, it is necessary to fully exploit the subproducts of the Jatropha processing, unless fuel prices surge to levels above 200 USD per barrel.

The main measures taken in order to reduce the vulnerability of BYSA to the world market price of oil:

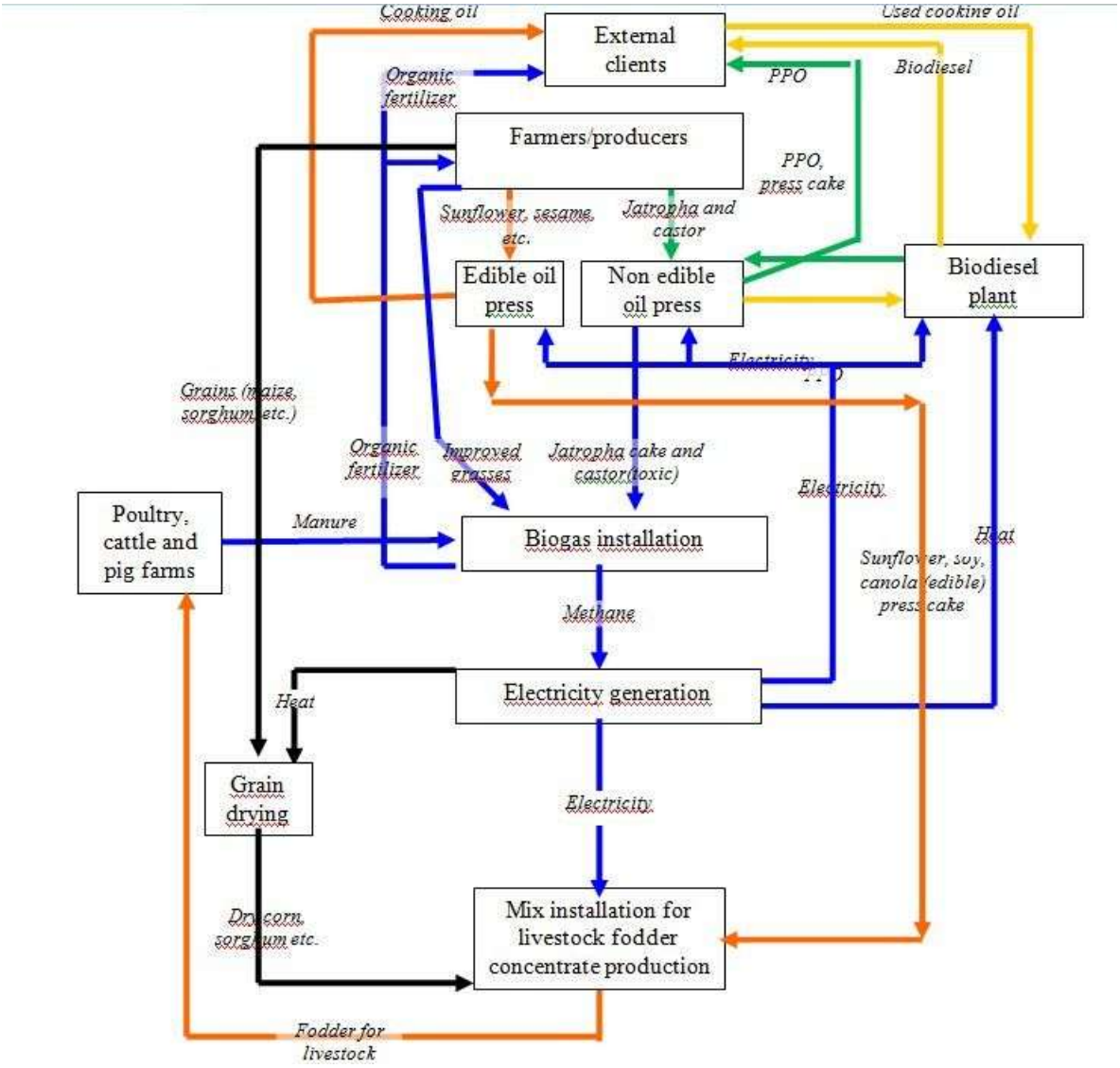
(a) Deepening of the production chain: generate as much added value as possible to the subproducts of the biofuel production chain. Future activities that are studied are: biogas (e.g. for grain drying), organic fertilizer (effluent of the biogas production), electricity generation, soap. BYSA already sold jatropha seeds for reproduction, liquid soap (made from glycerine, a biodiesel subproduct) in 2009.

(b) Diversification of the income sources of BYSA. Main diversification strategy is the development of an edible oils production line. Edible oils follow a less extreme price development than fossil oil. E.g. in the same period July-December 2008, when fossil oil prices fell more than 70%, soy bean and canola oil fell by about 50%[13]. BYSA started to sell experimental quantities of cooking oil in 2009. The seed cake of the edible oil is also an excellent input for the fabrication of animal feed, a line studied by BYSA in 2009, giving income additional stability to the company.

[12] 1 gallon equals 3,78 ltr

[13] Based on quotes from http://futures.tradingcharts.com/

The scheme below gives an impression of possible future extensions of the jatropha biofuel production chain and its integration with other production chains, in order to increase the added value throughout the production chain. Preparations have advanced to add a biogas and cattle fodder component in 2010. A biogas-fed grain drying installation may follow in 2011.

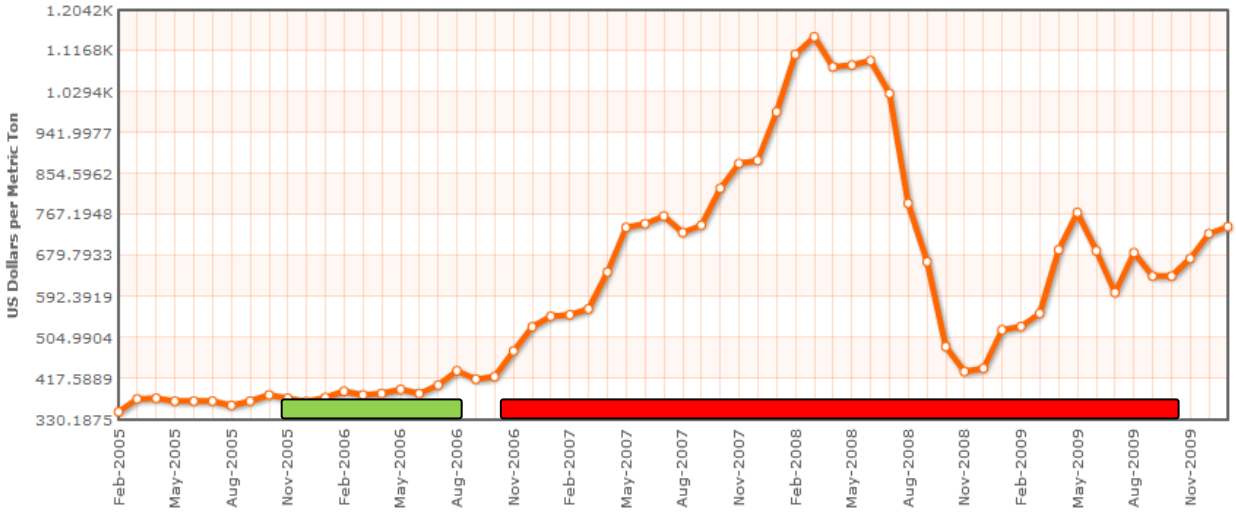


Note: The graph gives an overview of the different possibilities to extend the jatropha biofuel chain. The easiest way to read the figure to start with the basic jatropha biofuel chain (in **green**), followed by an expansion with a biodiesel processor (in **yellow**), an expansion with edible oil crops and cattle fodder (in **orange**), the expansion with a biogas installation (in **blue**), and finally the addition of a grain drying installation (in **black**). Obviously, the expansion process can follow another order and can only include a few of the expansions mentioned here.

5.2. Strong increase of Crude Palm Oil prices

Crude Palm Oil (CPO) was identified during the preparation stage of the Project as a viable alternative to start biodiesel production. Since Honduras is largest palm oil exporter of Central America, sufficient supply was expected to be found locally. Graph 4. depicts the CPO price development from 2005 to 2009, with the green and red bar indicating again the planning phase and the implementation phase of the Project. CPO prices rarely rose above 500 USD/MT during the past 25 years. However, driven by fossil fuel prices, the booming biofuel market and speculation, CPO prices almost tripled in 2007-2008. In the second half of 2008, in response to the worldwide recession outbreak, prices fell back again. In 2009, prices started climbing again to historically very high levels.

Graph: *Crude palm Oil (CPO) price development 2005-2009, in USD per MT*



Source: *http://www.indexmundi.com/commodities/?commodity=palm-oil&months=60*

The consequence of this development for the Project was that that no feed stock was available to make possible commercial scale biodiesel production during the starting phase. This meant that the planned investment in a professional biodiesel processor could not be justified. Alternatively, a low-tech equipment was built locally and waste vegetable oil was used as a feedstock. The quantities found, however, were insufficient to comply with the targets set at the beginning of the Project.

5.3. Low Jatropha yields

During the design of the project, the Jatropha yields during the first years were expected to be several hundreds of kg of dry seed during per hectare during the first two years and more than 1 MT per ha in year 3. In practice one can observe great differences in yields of plantations with the same age, but even the highest yield (400 kg/ha in year 3) is not near the original expectations.

Table . *Jatropha production and yields per ha (in kg of dry seeds) in 2009*

NOMBRE DEL PRODUCTOR	AREA DE FINCA en has	PROCEDENCIA	Año de Siembra	VARIEDAD	PRODUCCION 2009 CANTIDAD KILOS	RENDIMIENTO kilos /ha DEL 2009
FHIA	0.50	Comayagua	2007	Cabo Verde	199.00	398.00
FHIA	1.00	Guaruma	2007	Cabo Verde	98.18	98.18
Miguel Angel Flores	1.20	Finca Flor Azul	2006	India Salvadoreña	217.73	181.44
Jimy Rafael Calix Minero	0.70	Finca Sarahi	2006	India Salvadoreña	172.27	246.10
Dionicio Mejia	0.60	El Rosario Locomapa	2008	India Salvadoreña	16.59	27.65
Grupo Pastoral	0.70	Roque Oloman	2008	India Salvadoreña	99.09	141.56
Isidro Machado	0.70	Victoria	2008	India Salvadoreña	30.91	44.16
Albino Amaya	0.5	Cuyamapa, Yoro	2008	India Salvadoreña	97.73	195.46
Juan Silverio Lopes	0.7	Chancaya, Yoro	2008	India Salvadoreña	32.72	46.74
Ramon Medina Garay	2.62	El Negrito	2008	India Salvadoreña	128.63	49.10
Jose Santos Hernandez	0.5	El Negrito	2008	India Salvadoreña	23.63	47.26

Source: *Own data Gota Verde.*

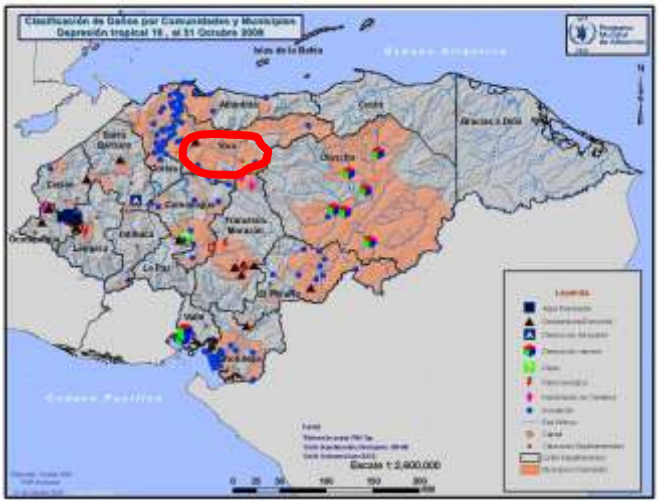
It has to be observed that 2009 was an exceptionally dry year due to the “El Niño” phenomenon. This clearly affected the yields: several plantations had even lower yields in 2009 than in 2008. Nonetheless, yields are disappointing. Gota Verde is not unique in experiencing low yields. Worldwide the Jatropha has lost its “wonder plant” image and investors are increasingly cautious. The hypothesis that Jatropha can be cultivated commercially on marginal lands (that are not apt for agriculture) has not been validated in any part of the world so far. It becomes more and more clear that commercially interesting yields can only be obtained by providing the plant with an optimal combination of nutrients and water. This requires higher investments than assumed until now. Seed improvement programs are needed to increase yields and investigation in cultivation practices to determine optimum investment packages for farmers. Comparative studies with other biofuel crops under the same circumstances are also important. In the meanwhile BYSA will have to diversify its income sources to reduce risks.

5.4. Adverse weather conditions

In October 2008, the north and east of Honduras was hit by Tropical Storm #16. Although the phenomenon never reached the strength of hurricane, it was by many farmers considered as the worst natural disaster since Hurricane Mitch struck Honduras in 1998. More than 600 mm of rain fell over a period of 12 days causing

flooding of rivers, landslides and turning many agricultural lands in impenetrable swamps for almost two weeks. Statistics indicate that more than 40.000 people were displaced and more than 72.000 ha of agricultural land (almost 10% of all land under cultivation in Honduras) was affected. Total losses are valued at 154 mln USD. Almost the entire intervention area of Gota Verde (in the red circle) was affected.

Graph. *Areas affected by Tropical Storm #16*



Graph source: UN World Food Programme (WFP), affected areas in pink, red circle indicates project area.

(Left): inaccessible road after heavy rainfall.

The project lost 25 ha of oil crops (about 7% of the total area planted with Gota Verde support): 12 ha of jatropha, 5 ha of castor bean and 8 ha of sesame. The investments lost in these 25 ha amount to approximately 9 250 USD, of which three-quarters were contributed by the Gota Verde Investment Fund (which will absorb these losses) and the rest by farmers. Given the dimension of the phenomenon, the 7% loss is relatively small in comparison with the average loss of crops in the region.

An analysis of the causes of the losses has led to more strict selection criteria for both the location of the plantations and for the period of establishing the plantations (per crop).

5.5. Difficulties in the cultivation and processing of castor bean

In order to increase the amount of oil available for processing in the short run, in the beginning of 2008 it was decided to substitute part of the jatropha investment

plans for castor bean. Its fast growth (4-5 months until harvest) and its wide use as a biodiesel feedstock in Brazil were considered the main benefits of this crop. The first trials with oil extraction gave good results. This would become the first commercial castor bean effort registered in Honduras.

The castor bean trial has produced mixed results: farmers that cultivated the crop in the valley had disappointing yields. The time of sowing proved to be poorly chosen: in the beginning rather than in the second half of the rainy season. Of the 107 ha of castor planted in 2008, 47 ha was lost due to the “Tropical storm #16” (see 5.4), a long drought spell in August and river floodings in November of the same year. Moreover, the quality of the seeds purchased appeared to be poor, resulting in low germination percentages. Thanks to a training organized in September 2008 by experts from El Salvador, the capacity of the project and of BYSA in the area of castor bean cultivation was improved. However, for many plantations this was too late: in total only 4 MT of seed was collected in 2008. Farmers had become disappointed by the crop and most of them eliminated the crop after the 2008 trial (although it can produce for a second year).

On the other hand, coffee farmers that planted castor bean as a shadow plant generally showed satisfaction with the crop, although at the moment of harvest, only a minor part of the production was actually recollected due to organisational problems. IHCAFE, the Honduran coffee institute, supervised the trials of 100 ha of new coffee plantations with castor as a shadow plant and has shown interest to expand the experience in the coming years, paying more attention to the recollection process.

(Left) Salvadorean expert César Urbina in a castor bean training session in Yoro.

(Right) Use of castor bean as a shadow plant among coffee farmers.

Also the processing of castor beans proved to be more difficult than expected: the extraction result is highly dependent on the temperature of the seeds at the

moment of extraction. Also the separation of the thick castor oil from the sediments proved to be a major challenge. In the course of 2009, the castor oil pressing process was improved[14] and several successful extraction press trials were carried out. Also a successful trial was carried out using castor oil as a lubricant in a two-stroke engine (a grass-cutter). More and longer tests are necessary, but this application looks promising for small-scale, local use.

(Left) testing grass cutter powered by a two-stroke engine, using castor oil as a lubricant.

(Right) Castor oil extraction trial in Ocotepeque.

Castor remains on the Project's agenda due to its important industrial potential, its adaptability to different micro climates and because it fits well in the biofuel chain. However, in 2009 castor was maintained only as an experimental crop. No commercial upscaling is planned until good yields, full domination of the extraction process and successful local applications have been achieved.

5.6. Investment Fund for farmers exhausted in 2008

When the project was designed, it was anticipated that the yields of the existing (2006) jatropha plantations would be sufficient to revolve part of the investments from 2008 onwards. This revolved part of the investment fund, together with a growing willingness of financial institutions to invest in the crop, was expected to be sufficient to plant 250 ha in 2009. However, jatropha harvests in 2008 were minimal: only sufficient for certain extraction experiments. Moreover, the low oil prices in combination with the financial crisis made that financial institutions were (and still are) very reluctant to invest in crops that do not have a proven track-record.

[14] Mainly by preheating the castor beans and the press before starting castor oil extraction.

Given this situation, it was decided to suspend further establishment of Jatropha plantations in 2009, unless fresh funds would be raised or third organisations would be willing to invest in new crop areas. The little funds that remain in the investment fund would be used exclusively to maintain the areas established in previous years, especially those areas that are in good or regular conditions.

Fortunately, in 2009 the strategy of involving third organisations bore fruits: two institutions showed serious interest in the project's objectives: TechnoServe and Fundación Cosecha Sostenible (FUCOHSO). With the support of TechnoServe and 91 ha of jatropha and intercrops was established in 2009. FUCOSOH financed intercrops and gave technical assistance to 23 ha (33 small farmers). BYSA took care of the processing and marketing of a large part of the products.

Finally, FUNDER was successful in its negotiation with the Ministry of Agriculture to obtain of finance for corn and beans (as a Jatropha intercrop) for small farmers.

5.7. Underperformance of small farmers

The introduction of a new crop requires fine-tuned promotion strategies. More so, if it takes several years before the plants become productive and the final target group consists of small farmers. Farmers that participate in the Gota verde project cover all socio-economic pyramid: from large, well-off cattle farmers to small subsistence farmers that still live largely outside the money economy. The weight of the participating farmers is on the lower end of this pyramid. A study carried out by the University of Zamorano15 shows that the smallest (often subsistence) farmers tend to have the worst jatropha plantations. Various factors explain this tendency:

- the quality of their lands
- their short-term needs make that they tend to neglect long-term investments ("short horizon")[16]

[15] Samuel Oblitas: "Factores socio económicos que influyen en los productores de piñón al momento de desarrollar el cultivo de jatropha" (Zamorano, 2009). See: http://www.gotaverde.org/userfiles/file/D53I - Estudio Samuel Oblitas ES.pdf

[16] Gota Verde (as many other Jatropha projects with so-called "outgrowers") has experienced that farmers tend to neglect their Jatropha plantations soon after they are established, because it takes 3 years before the plantations generate their first significant harvest and 5 years to reach full production. Given the

- their lack of resources to maintain the plantations without external support[17]
- their need for intensive technical assistance to keep motivated

Especially this last factor appears to be important. Subsistence farmers that have received additional attention performed actually much better than medium and larger farmers that received the same amount of attention. However, since the technical advisors have to attend up to 80 farmers, additional attention for small farmers is difficult to realise: technical advisors have targets formulated both in number of ha to be established and number of farmers to be attended. Possible solutions to improve the performance of small farmers are:

- Contract para-technicians (good performing farmers that are compensated for assisting other farmers in their area);
- Offer the sowing of intercrops between the jatropha rows;
- Reduce the targets for technical advisors in terms of area and increase target in terms of number of small farmers, so technical advisors can give more attention to small farmers;
- Increase coordination with other institutions that give technical assistance or credit to the same farmers;
- Offer a complete support package (agricultural inputs, mechanisations, credit if necessary) from the establishment of the plantation until it reaches maturity;
- Organize exchanges between farmers;
- Stimulate the sense of ownership of farmers of their processing enterprise, by organizing meetings, visits to the processing plant, etc.

All of these measures have been applied in the Gota Verde project, especially during the last year (2009), with a clear improvement in the results. It is clear that these measures increase the costs of a Jatropha promotion project, but at the same time they increase the project's impact on poverty alleviation.

immediate needs of most small farmers, they give prefer to attend their short-cycle crops (mainly corn and beans) and neglect the jatropha plantations, especially the weeding. This negatively affects the development of the Jatropha plants that have to compete for sun and nutrients with the weeds.

[17] Many medium and larger farmers can use resources that are already available for other crops, in the jatropha cultivation, e.g. irrigation pumps, tractor, transport, contracted labour.

Jatropha intercropping with corn and tomato

In March 2009 a survey was held by the project's agronomists to determine the quality of the plantations still existing at that moment. Main objective of the exercise was to define a strategy on how to distribute the technical assistance efforts to the different areas. The results show that an important proportion of the area (more than a quarter) is in a (fairly) bad shape. The attention was focused on the regular and recoverable bad plantations, to upgrade them to a higher category. The exercise will be repeated each year in April to determine the progress.

Table. *State of Jatropha plantations, per geographical sector, in ha, March 2009, Gota Verde*

Sector	Good	Fairly good	Regular	Fairly bad	Bad	Total
1	29	20	28	30	18	124
2	20		33		14	67
3	26	12	23	4	4	69
Total	**75**	**32**	**84**	**34**	**36**	**261**

Source: *Own data Gota Verde.*

Farmers that did receive support for intercrops perform significantly better than farmers that did not. An important lesson to be drawn from this experience is that when planning a jatropha project with small farmers, it is important to budget not only the establishment of the jatropha plantations, but also the intercrops and the maintenance of the plantations during at least the first 4 years. A challenge will be to select farmers that are really interested in jatropha and not merely in the credit for the intercrop.

5.8. Political instability in Honduras

On June 28, 2009, Honduras' President Zelaya was sent into exile by the military after several months of confrontation between the President, Parliament and the Supreme Court about the constitutionality of holding a referendum on a change in the constitution. This action caused worldwide indignation, international

political isolation of the Honduran government and civil unrest in many parts of the country. In an effort to control the unrest, the interim government installed curfews at night and initially even during the day. Demonstrations of both supporters and opponents of the ousted president blocked roads, causing severe travel limitations during various months. Government also closed several times the international airports, limiting international travel options. Many countries advised their citizens to avoid traveling to Honduras. Some of the activities involving European participants, had to be cancelled for this reason.

The operational work within in Yoro did not suffer greatly, because the turmoil became more and more concentrated in the capital Tegucigalpa and the curfews were not applied strictly in the rural area of Yoro.

6. Lessons learnt

The Gota Verde project has been one of the most comprehensive experiences worldwide in testing and analyzing what works and what does not, when promoting biofuel crops (and especially jatropha) among small farmers. In this section, the main insights of the past 4 years will be summarized.

In addition to these general lessons, the Project has produced a wealth of knowledge in the technical area (agricultural, biofuel processing, engine adaptation). This knowledge has been integrated in the various manuals that can be found on the website[18].

6.1. Jatropha projects require long term commitment

The main lesson of the Project is that the creation of a fully sustainable biofuel chain, based (mainly) on Jatropha, takes at least 5 to 6 years. Main reason is the low productivity of Jatropha during its first years. Other reasons are the time needed to train local technicians (agronomists, car mechanics, processing personnel) and to convince potential clients of the safety of the biofuels. It is possible that in the future, when improved Jatropha cultivars are developed and biofuels become more mainstream, this time span can be shortened. Organizations that promote Jatropha projects should be aware of this long term commitment.

6.2. Small farmers need short term incentives

It is not realistic to expect that small farmers maintain their plantations without further support. The long time required until the plantations are productive (4-5 years), the uncertainty about future yields, in combination with the often urgent immediate needs at the household level, make that farmers prefer focusing their attention to short-cycle crops, like corn, beans or vegetables. Farmers need additional, short-term incentives to maintain their plantations. Providing support for the establishment of short-cycle intercrops (preferably oil crops) has proven to be a good strategy: farmers maintain and fertilize the areas between the Jatropha rows that are used for intercrops.

[18] See http://www.gotaverde.org/new_portal/node/10.

6.3. Visits from technical advisors are major motivation factor for small farmers

Regular visits by technical advisors to farmers are not only important to ensure proper plantation management, but also to maintain the confidence of the farmer in the Project and the processing enterprise. This is especially true for small farmers. Investigations of Zamorano University confirm that small farmers that receive regular attention from technical advisors perform better than larger farmers that receive the same amount of attention. However, small farmers that receive little attention tend to have worse plantations than larger farmers that receive the same amount of (little) attention.

Group training events played an important role in capacity building as well as maintaining motivation.

6.4. Jatropha promotion projects need substantial investment funds

Projects promoting Jatropha as a new cash crop among small farmers should include sufficient own investment funds for farmers to establish plantations **and** maintain them during the first 4 to 5 years. Only financing the establishment of plantations is not likely to have a durable result. In the ideal case the Project disposes also of a revolving fund for short-cycle intercrops on the Jatropha plantations. One has to expect that the conventional financial sector will not step in until commercial viability has been proven (possibly after year 5).

6.5. Local building of equipment requires a pre-existing technical capacity

In the processing component, the project learnt that – within a proper technological context – many existing processing technologies (e.g. for corn and coffee processing) can be adapted to the Jatropha production chain. The

advantage is that equipments can be fabricated and repaired locally, which increases the sustainability of the production process, while at the same time creating additional local income and employment opportunities. The viability and sustainability of these adaptations, however, depend on the presence of a technical capacity in the intervention region, such as a technical school. A provincial capital city generally fulfills this condition. This should be an important selection criteria when identifying region and choosing a headquarters of a Jatropha promotion project.

CEVER, the local technical school in Yoro

Manual Jatropha dehuller, adapted by the Full Belly Project from a peanut dehuller and built in Yoro

Traditional corn degrainer

Mechanical jatropha dehuller, fabricated by a technical school in Nicaragua

The building of more complex equipments, like biodiesel processors and oil presses requires an even more sophisticated technological context and pre-existing technical capacities. These capacities can be further developed in larger cities, possibly in collaboration with higher level technical schools or universities. Capacity building investments in this area should follow an expected future demand, e.g. because of the establishment of several hundreds of ha of jatropha

(or other oil crops) in a certain region. Until that moment, complex equipments are better imported, or built locally with the help of external experts.

6.6. Small-scale biofuel enterprises need to prepare for price volatility

Small-scale biofuel processing enterprises (as well as large ones) face a highly volatile petroleum market. Highly profitable enterprises may go bankrupt within months because of these dramatic changes in international fuel prices[19]. Small enterprises are more vulnerable to this market instability, due to the fact that they generate less economies of scale.

Small-scale biofuel producers and small-scale ones can perfectly co-exist because the price of the product is not determined by the most efficient producers, but by the worldmarket price for petroleum. However, if efficiency differences become to large, less efficient (small) producers may be bought out of the market. Small producers should therefore perme\anentoy work on efficiencu improvement.

In this context, small-scale biofuel producers should implement strategies that reduce their vulnerability and increase their efficiency, such as:

a. Reduce distribution and promotion costs by:
    i. focusing on the local market, preferably the demand of the very farmers that produce the oil seeds.
    ii. focusing on a few large consumers (e.g. agroindustries with stationary equipment that use large amounts of diesel), rather than many smaller ones.
b. Use the oil for higher value uses, e.g. Jatropha oil for soap making or as a biopesticide. These markets are limited, but because of their higher margins, they can contribute significantly to the profitability and stability of the enterprise.
c. Diversify into edible oil production. This can be perfectly combined with Jatropha oil production (intercrops), while making largely use of the same technology and skills needed for PPO production (extraction and filtering). The price of edible oil has proven to be less volatile than that of fuel.

[19] Prices almost tripled and then fell 70% within the project period.

d. Take full advantage of the subproducts of the transformation process. The marketing or use of some of these (transformed) subproducts requires a linkage (or even integration) with other, existing production chains in which the supplying farmers are involved: e.g. organic fertilizer production (sludge from biogas production), grain drying (biogas), milk cooling (with electricity produced from biogas), cattle fodder (from press cake of edible oil seeds) etc.

The Project has only tested some of these strategies on an experimental scale. The scope and duration of the Project was too limited to implement the strategies on a commercial scale.

6.7. Biofuel may actually improve food supply

The "Food-Fuel" debate has surged as a major issue during the duration of the Project, especially in 2008 after food prices rose dramatically at the same time when biofuel initiatives multiplied quickly. Several investigations show that the food price increases have many causes, of which the shift from food to biofuels is one[20]. Although biofuels may cause food shortages in many contexts, the project has proven that under certain conditions a local biofuel sector may actually increase food production.

Two important inputs for food production are credit and mechanized equipment. Mechanized equipment requires fuel (mostly diesel) to operate. Especially in developing countries, fuel supply to rural regions is often unreliable. In June 2008, at the beginning of the rainy season, the Yoro region suffered severe diesel scarcity, caused by a combination of ill planning by fuel importers and speculating fuel distributors. As a result, many farmers had to postpone the preparation of their lands. The Project, on the other hand, could continue its land preparation plans thanks to the access to biodiesel.

The Project also has experienced that, in a context of Yoro, the limiting factor to produce more food is not land but credit. Thanks to the intercropping scheme of the Project, many small farmers had access to credit for food crops that were sown between the Jatropha rows. This resulted both in an increase of the area established and the productivity per area. Interesting finance schemes can be

[20] See e.g. the OECD study "Rising Food Prices, Causes and Consequences" (2008): http://www.oecd.org/dataoecd/54/42/40847088.pdf

implemented once the Jatropha plantations of small farmers are mature, using the expected Jatropha production as a guarantee for a loan for an (edible) intercrop.

An article on the topic has been written by the Project Coordinator in 2008[21], putting the Food-Fuel discussion in the context of a land abundant region.

7. Conclusions

7.1. About the economic feasibility

In the reality of a dynamic world, the same product and production process may be profitable at one moment in time (when fuel prices are high), while losing money at another moment. Also, the profitability will differ from country to country or even between regions within the same country, depending on prevailing wage levels, the government's fuel policy, land availability and quality, infrastructure, efficiency of existing fuel distribution systems etc. It is therefore very difficult to make general statements about the economic feasibility of the approach of small-scale biofuel production for the local market.

In general terms, however, one can say the economic feasibility of small-scale biofuel production improves if several of the following conditions apply:

- Competing fuel prices are relatively high (e.g. because the location is isolated);
- One or a few large diesel consumers are locally present, that are willing to shift to biofuels (preferably PPO);
- There is a local market for certain (transformated) subproducts, e.g. the presence of certified organic coffee farmers that are willing to pay for a premium for organic fertilizer;
- Low-cost feedstock can be obtained (e.g. waste vegetable oil);
- Availability of cheap labour;
- Availability of un(der)used, arable land;
- Access to credit for long term crops;

[21] See: http://www.nextbillion.net/blog/2008/10/01/guest-post-exploring-the-food-fuel-relationship-in-rural-develop.

- Government pursues an active policy to stabilize the biofuel sector and encourage the involvement of small farmers in the production of its feedstock.

Although it is impossible to make general statements about the feasibility of small-scale biofuel initiatives in developing countries, it is clear is that the context will improve in the coming decade, with increasing fuel shortages and oil prices. Capacity building in this area may therefore proof to be highly visionary in the years to come, even if the activity is only marginally profitable under today's economic conditions.

7.2. About the technical feasibility

Independent if PPO or biodiesel is produced, factors that contribute in general to the technical feasibility of small-scale biofuel production, especially based on Jatropha, are:

- Local presence of formally trained car mechanics;
- Local presence of a technical school that has sufficient capacity to design, build and repair common agricultural implements and equipments;
- Experience in the region with commercial fruit tree cultivation;
- Experience in the region with oil extraction and processing;
- (In the case of biodiesel,) access to chemicals at reasonable prices (methanol and NaOH or KOH).

These conditions generally correspond with a provincial capital city of at least 25.000 inhabitants that functions as a service centre towards the surrounding rural areas.

7.3. About the feasibility of local marketing

Selling biodiesel to the national market generally means that the biodiesel should first be transported to the central fuel mixing facility, than transported the regular distribution network of established fuel stations. This is not likely to be an interesting start-up strategy for small-scale biofuel producers, because a large part of the margin is lost in transport and distribution costs, outside of the production region. It is important for small-scale biofuel producers that legislation permits the sale of 100% biofuels (whether PPO or biodiesel). In Honduras the law allowing

100% biofuels was passed, in spite of the resistance of established fuel distributors, mainly thanks to the lobby of the palm oil sector.

Fuel prices in Honduras are determined by the Government-led Oil Administration Commission (CAP). This commission determines weekly the various components of the fuel price. The following table gives the price structure of diesel fuel per gallon (3,78 liters) of the week from April 28 to May 3, 2008, in the capital city Tegucigalpa.

	Price component	**Value**
(a)	CIF import price	61.46 HNL
(b)	+ Margin for importer	1.23 HNL
(c)	+ Taxes	11.54 HNL
(d)	+ Margin distribution companies	1.49 HNL
(e)	+ Transport over land	0.81 HNL
(f)	+ Margin fuel station	3.29 HNL
(g)	-/- Government fuel subsidy	- 12.76 HNL
	Consumer price	**67.07 HNL**

Source: Comisión Administradora de Petróleo (CAP) of Honduras. http://www.cap.gob.hn

All components, except for the import price, are fixed by the CAP and can only be adjusted by a governmental decision. Local biofuel marketing can eliminate various margins (d+e+f), thus improving the competitiveness of the product, reduce vulnerability to downward price shocks and avoid that purchasing power leaves the local economy. Biofuels are exempt from the tax component (c). The government subsidy (g) was abolished in the second half of 2008 due to its unsustainable nature.

Although the project, as a result of the limited supply of feedstock, has only been able to gain little experience in the field of biofuel marketing, it is clear that the lack of confidence in the new fuel among users is a major problem to overcome. The Project has experienced resistance from consumers both in case of biodiesel and PPO. The sample was too small to draw any significant conclusions. It is expected that in the coming years, as the oil availability improves, more conclusions can be drawn about the feasibility of local biofuel marketing.

Interesting is the role of the complementary currency system in promoting biofuel consumption. Since the *Peces* cannot be exchanged into national currency by most of the enterprises that accept them, they are forced to look for products offered by BYSA. This has led to various new curious clients for BYSA.

7.4. Pure Plant oil (PPO) versus biodiesel

The technical as well as economic feasibility of small-scale biofuel production depends largely on the question if PPO or biodiesel is produced. The technical experience of engines using PPO and biodiesel in the Project was generally positive, in spite of the limited local know-how on the repair and maintenance of the engines using these fuels.

Investment costs for biodiesel production are considerable. This requires a certain minimal scale in order to become viable. As the table in 5.1 showed, PPO production is considerable less costly than biodiesel production, especially in a small-scale context. Also, the small-scale biodiesel production with low-tech equipment requires a well-trained staff to ensure safe working procedures and good fuel quality. Moreover the biodiesel process requires certain external inputs (methanol, KOH or NaOH), that may not be easily accessible for small-scale initiatives. The sale of methanol is e.g. regulated in many countries. The energy content of PPO is slightly higher than that of biodiesel, resulting in a higher fuel efficiency. The limited processing requirements of PPO also leads to less energy input, as compared to biodiesel, to produce the same amount of energy. On the other hand, the introduction of biodiesel is less difficult because it does not require any significant investments in engine adaptation. Biodiesel is also considered less experimental, which contributes to a faster market acceptation.

The following table gives an overview of the main factors that determine the appropriateness of each technology in the case of small-scale biofuel production.

Table. *Comparison of appropriateness of PPO and biodiesel technology in a small-scale context.*

Factor	PPO	Biodiesel
Required investment cost in processing equipment	+	-
Required technical capacity of personnel and service providers	+	-
Production cost	+	-
Dependence on external inputs	+	-
Energy content of the fuel	+	-
Energy balance	+	-
Psychological barriers to market introduction	-	+
Required investment in engine adaptation	-	+

+ = favorable; - = unfavorable for small-scale biofuel initiatives.

In summary, from the technical and economic point of view, the PPO technology seems to be more appropriate than biodiesel for smaller biofuel initiatives. All these advantages may compensate the scale disadvantages of small

biofuel initiatives. On the other hand, from the marketing point of view, biodiesel seems to be preferable.

An important condition for the take-off of the PPO technology is that a strong in-country technical capacity exists in diesel engine adaptation. Specially trained experts can adapt engines, design and compose local adaptation kits, train local users and resolve problems when necessary, thus generating confidence among users and employment among technicians. However, this capacity will only develop if sufficient PPO is available in constant supply and quality and at competitive prices. A possible development scenario for small-scale, vegetable oil-based biofuel development is therefore:

i. Pilot phase with a few small PPO initiatives. Distrust in the PPO technology among private owners of diesel powered vehicles and car mechanics is still high. The small PPO initiatives focus on large, local consumers, such as agroindustries. As oil production increases also non-local industrial PPO users can be served.

ii. Once the PPO production has achieved a significant and steadily growing volume nationwide, a PPO training program for different levels of diesel engine experts has to be organized: integration of the topic in the curriculum of mechanical engineers, train teachers of the institute for professional training (INFOP), train teachers of local technical schools and train mechanics. The training efforts should be concentrated in regions with an immediate PPO potential. The use of locally produced biodiesel is a clear indicator of this potential. The experience in Yoro may proof of great importance in these PPO training programs.

iii. Shift growth from industrial PPO users to large users in the transport sector. This may be stimulated in programs promoted by local or national government, e.g. the use in urban public transport in order to reduce pollution. Access to reliable technical support is essential at this stage, in which the technology enters its commercial stage. Gradually more and more specialized PPO service providers will appear.

iv. Massive, market-based promotion of small-scale PPO initiatives, driven by the profit potential of the technology, a public awareness campaign and possibly fiscal incentives.

8. Epilogue

The report has made clear that in order to draw conclusive lessons from the Gota Verde experience, more time is needed. This report has presented the results of the first phase of the project from January 2007 until December 2009. Thanks to the support of various donors, the Project will continue to play its path-breaking work in developing and testing appropriate technology and organization models for small-scale biofuel production until December 2012. It is expected that in this period the plantations established in 2007 and 2008 will become mature, which provides BYSA with sufficient feedstock to become a self-sustainable biofuel processing and marketing enterprise. Moreover, various production lines that make use of subproducts of the biofuel process, will be developed.

For updated information on the project, please visit our website: http://www.gotaverde.org.