CHIBAS

Potential of *Jatropha curcas* for the economic development of Haiti

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Contents

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Summary

Edible *Jatropha curcas* (non-toxic varieties) is a multi-purpose crop (animal feed, and energy) that can contribute to the environmental rehabilitation (reforestation and soil conservation) and the extension of agriculture toward deforested marginal lands in a country such as Haiti. It would produce locally, and thus replace imports, products for which there is strong demand in Haiti: (1) briquettes from the residues (fruit shell and seed teguments), (2) high protein meal/feed, (3) and biofuels for power plants, stoves, lamps and vehicles.

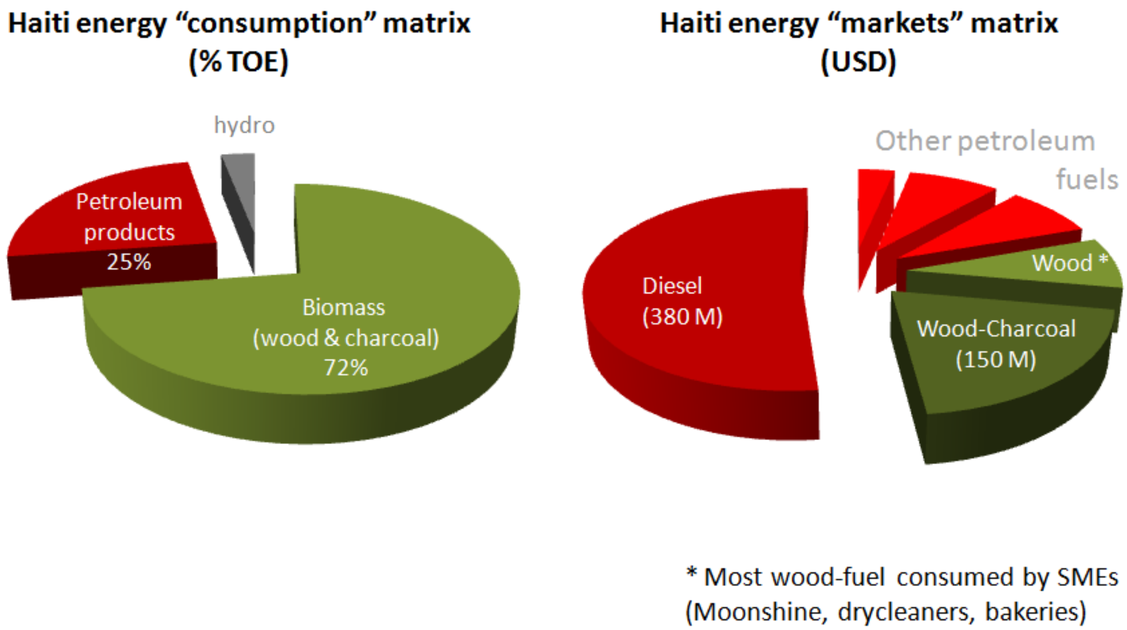
Jatropha is a plant with a set of unique properties. It is a drought-resistant shrub that helps alleviate soil degradation and prevents wind and water soil erosion, allowing reforestation and restoration of degraded land. Additionally, Jatropha sheds its leaves during the dry season, allowing for soil enrichment and long-term improved soil fertility. It is often used as a leaving hedge or fence by farmers in the developing world. Jatropha can grow in most regions around the equator. It has few requirements with respect to its environment. Jatropha can grow in areas that are unsuitable for other plants, because they are too dry or too arid, or because they have been left by humans because of soil depletion. Jatropha can also be used for reforestation because it is a perennial crop that can provide income to farmers, its trunk cannot be used to make charcoal and it is not grazed by goats or other herders (Jatropha is traditionally used for making leaving hedges and keep goats away from traditional crops); hence Jatropha plantations can easily coexist with free range goat and cattle herding.

I. Context

An Energy crisis

Petroleum and food products account for two thirds of Haiti's imports (over one third for fuels alone); imports which are continually growing. This increases the deficit in the balance of payments (the value of imports is almost four times higher than exports). This growing dependence to the imported products weakens the Haitian economy.

The second largest commodity market in the country is the diesel market (just after the rice). Poverty-stricken Haiti is totally deprived of natural resources. Because of the lack of foreign currency to buy imported fuel, Haiti faces acute energy shortages. Haiti imports hundreds of millions of dollars worth of fuel each year; over half of it is diesel; some 35 to 50 percent of Haiti's hard currency is required to cover the cost of petroleum imports. In Haiti, fuel is one of the largest commodity markets; it represents about one third of the country's total imports. These figures are ones of a country plagued by energy shortages; current diesel imports are far from covering the country's electrical needs. (Most of the electricity is produced from diesel fuel and last year the country covered less than 25% of its needs). In Haiti, half of the vehicles are powered by diesel, especially trucks and public transportation; moreover, 75% of electricity production is also produced from diesel. Close to 120 million gallons of diesel are consumed each year while the country is experiencing a severe energy shortage due to lack of hard currency to purchase equipment and petroleum products.



The largest energy markets in Haiti are wood and diesel
(Two local and captive markets)

It is worth mentioning that the absence of a nationwide electricity grid is not without affecting the development of local industries and services (cold storage and ice making plants to promote fisheries, metalwork, grain mills, dairies, etc ...)

Haiti is also the poorest country in the Western hemisphere; more than half its inhabitants survive on less than $1 per day. Haiti needs new crops that will provide revenues to its poorest farmers and be friendly to the environment. It also needs new crops that will stimulate a local agro-industry and job creation outside of the major urban centers.

Another challenge in Haiti, which is not unrelated to the previous, is the need to curb the environmental disaster caused by deforestation. The rampant cutting of trees not only jeopardizes the safety of lives and property from repeated floods, but it also contributes to the reduction of agricultural production by the loss of arable land.

The cost of imported animal feed is one of the limiting factors to animal production

Many animal products such as meat, fish, eggs and dairy products are imported in Haiti. High protein Jatropha meal from edible varieties could help revive this crucial sector of Haiti's agriculture. Increased production and quality of eggs, tilapia farming, and dairy products could significantly reduce malnutrition in Haiti.

Can we address simultaneously in Haiti the challenges of environmental degradation, food security and energy security?

A new crop to shape Haiti's future

As mentioned earlier, Jatropha provides solutions to many of these challenges. Jatropha plantations and the biodiesel agro-industry could help improve the livelihood of poor people in local communities and could contribute to Haiti reforestation and reclaim land as well as improve soil quality (currently less than 1.5% of Haiti's surface is covered by forest) and finally help ease the burden on oil imports on the country's finance and economy.

Jatropha curcas is a perennial, shrub, whose oil has the quality required for the production of bio-fuels (straight vegetable oil or biodiesel). In this paper we analyze the environmental, economic and food security issues for the promotion of edible Jatropha cultivation in Haiti.

II. *Jatropha curcas*

2.1. Jatropha curcas

Jatropha curcas is a native drought resistant shrub able to grow on marginal land unsuitable for traditional annual crops. This crop is ideal for a sustainable, and socially responsible, bio-energy production by tropical countries. The main characteristics of *Jatropha curcas* are such that it can play an important role in controlling erosion and also to obtain a high quality straight vegetable oil (SVO). *Jatropha curcas* is a perennial crop, which, losing its leaves during the dry season, improves soil fertility over the long term.

Jatropha curcas also has few demands regarding its environment enabling it to grow in soils that are too dry or too arid for other crops, or lands that have been abandoned by humans because of soil depletion. It has the potential to turn marginal areas into income and wealth generating land. *Jatropha curcas* grows on sandy or marginal land unsuitable for agriculture (large areas of Haiti's North West which are not cultivated could be cultivated growing *Jatropha curcas*). *Jatropha curcas* would therefore enhance reforestation of land which is not currently used for subsistence farming. Oil from *Jatropha curcas* could also be an important source of income for the poorest farmers in Haiti's most marginalized areas while reducing fuel imports. By improving the energy-independence of Haiti, *Jatropha curcas* will have a positive impact on the national economy and improve the balance of payments.

Job creation in rural areas is also the main social benefit attributed to the production of *Jatropha curcas* by sustainable and socially responsible production systems while the reforestation of marginal land and bio-energy are the main environmental benefits. The production of biofuels from *Jatropha curcas* generates income locally and provides affordable energy to the local/rural economy while promoting energy independence. Some African countries may be taken as examples of how the cultivation of *Jatropha curcas* may engage remote areas in energy production and wealth creation.

2.2. Products of Jatropha curcas

Straight vegetable oil (SVO) is an indirect substitute for bio-diesel, petro-diesel and a direct substitute for fuel oil. Jatropha SVO is the least capital intensive Jatropha fuel supply chain that enables small-scale farmers and producer cooperatives to maximize value added to the end product in the local economy. Jatropha SVO can be consumed in diesel engines that have been converted to run on SVO fuel. Examples of Jatropha SVO ready engines are most fuel oil engines and low-speed, gravity fed Lister type engines running under 1200 RPM. These types of engines have strong competitive advantages in the production of local electricity, grinding mills, seed crushing operations, water pumps, irrigation, and small industry due to lower fuel costs associated with SVO fuel relative to bio-diesel, petro-diesel and fuel oil. Approximately 75% of Haiti's electricity is produced in large, fixed-speed diesel engines creating a large potential demand for Jatropha SVO fuel. SVO engine and conversion system technologies have been around for nearly a century and have been proven with Jatropha SVO in Africa and Asia.

Bio-diesel is a direct substitute for petro-diesel fuel that is equally efficient and has the potential to burn cleaner than petro-diesel if quality standards are met. Bio-diesel can be used purely in diesel engines as B100 or blended with diesel (at any percentage) creating flexible and low-switching cost consumption. The majority of Haitian liquid fuel consumption is in the form of petro-diesel and fuel oil, both of which use compression ignition engines and are ideal for use of Jatropha bio-diesel. In addition to substituting petro-diesel, Jatropha bio-diesel is a less-toxic substitute for kerosene fuel used in Lamps and stoves. Bio-diesel applications in lamps and stoves will have the largest impact on rural villages for lighting and cooking.

Briquettes are an ideal by-product from Jatropha fruit shells and hulls which can be used as a substitute to charcoal. Charcoal is the primary fuel used for cooking in Haiti and is largely responsible for the rapid rates of deforestation in recent decades as a result of hardwood used as the primary input for charcoal production.

High-protein animal feed is a potential high-value product derived from nontoxic Jatropha varieties (phorbol ester free varieties). Jatropha seeds have high-levels of protein creating an opportunity for Jatropha to produce energy, food and animal feed in larger quantities than soy beans would. Haiti currently imports animal feed that is too expensive for small-scale rural farmers, effectively creating a large barrier of entry for animal husbandry, such as chicken, tilapia, pig and dairy farming. Unlike soybean, Jatropha can be grown on land that is not currently utilized for traditional food crops making Jatropha a very attractive crop for Haiti.

Honey, produced from Jatropha flowers is a high-value Jatropha product that adds value at the local village level. Jatropha is pollinated by insects, primarily honey bees, creating ideal conditions for honey bee propagation in conjunction with Jatropha farming. By producing honey with Jatropha pollen, bees enhance Jatropha fruit production which equates into higher oil yields per tree and hectare.

Products and byproducts of the industry

III. *Jatropha curcas* and sustainable management of Haiti's watersheds

In Haiti, 60% of the country land has an inclination greater than 20%. Most of these slopes are left barren by past clearing for timber and charcoal production combined with years of unsustainable slash and burn agriculture practices. These practices and intensive tropical erosion are associated with loss of soil fertility and generally followed by farmers abandoning any forms of exploitation on theses eroded and depleted soils. Today, 72% of the energy consumed in Haiti is in the form of wood or charcoal and is directly related to this unsustainable exploitation of resources[1]. The demographic and economic pressures are such that so far, the numerous reforestation and watershed management projects have had little impact at the national level. Also, the lack of work on the economics and the absence of a value chain approach associated with these watershed management projects largely explain their lack of success[2]. The recent flooding in Haiti following the 2008 hurricane season, illustrates the need to promote sustainable technical solutions to reforest Haiti's watersheds while simultaneously addressing and increasing farmers' economic security.

It is therefore essential to promote income generating solutions for soil conservation[2]. *Jatropha curcas* can provide an economically viable solution for the restoration of soils affected by erosion while contributing to the income of small landholders. *Jatropha curcas*, being a perennial tree, it can contribute to the reforestation of Haiti. *Jatropha curcas* would address energy security, while providing income to farmers; also the fruit shell and seed teguments can be used for making briquettes, the kernel (almond) is rich in oil that can be used for making biodiesel or used directly as a biofuel for lamps, stoves or operating generators, and finally the meal from edible variety can be turned into high protein animal feed.

Jatropha curcas can meet Haiti's fuel needs and be a substitute to charcoal which is a factor in the state of environmental degradation of the country. *Jatropha curcas* is also potentially a great tool for the reforestation of the country since it is a tree which could provide income for farmers; it is an economically useful plant and the tree is not grazed by animals (*Jatropha curcas* is traditionally used for making hedges rows and protect crops from goats). *Jatropha curcas* could contribute to the fight against erosion and deforestation and thereby allow the rehabilitation of lands left bare by deforestation and previously lost to agriculture. Finally we can add vegetation and biomass where there were none and trap a significant amount of carbon dioxide (CO2) therefore contributing to the fight against global warming.

However, due to high population pressure and chronic food shortages in Haiti, it is essential that *Jatropha curcas*' cultivation does not endanger food security. In this

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[1] BME, Bilan énergétique Haïtien, 2009

[2] Michel Jean Chariot, 2009. Le développement de filières de cultures pérennes et semi-pérennes & la Gestion Durable des Terres (GEF/MDE/PNUD). 1[ere] Conférence des acteurs et parties prenantes de la filière *Gwo Medsiyen*

regard, the development of edible varieties offers the opportunity to encourage production for both food and biofuels; not to mention that *Jatropha curcas* potentially grows on currently uncultivated marginal soils. We must therefore establish land use maps and zoning to minimize the impact of *Jatropha curcas* cultivation on the production of traditional annual food crops.

IV. Land use and Food Security

Because of the acute food production shortages facing the country, it is essential that the cultivation of *Jatropha curcas* does not affect the already limited food production and more broadly food security. The issue of land availability and the minimization of socio-economic and environmental risks are essential to the establishment of a national strategy to develop the cultivation of *Jatropha curcas*.

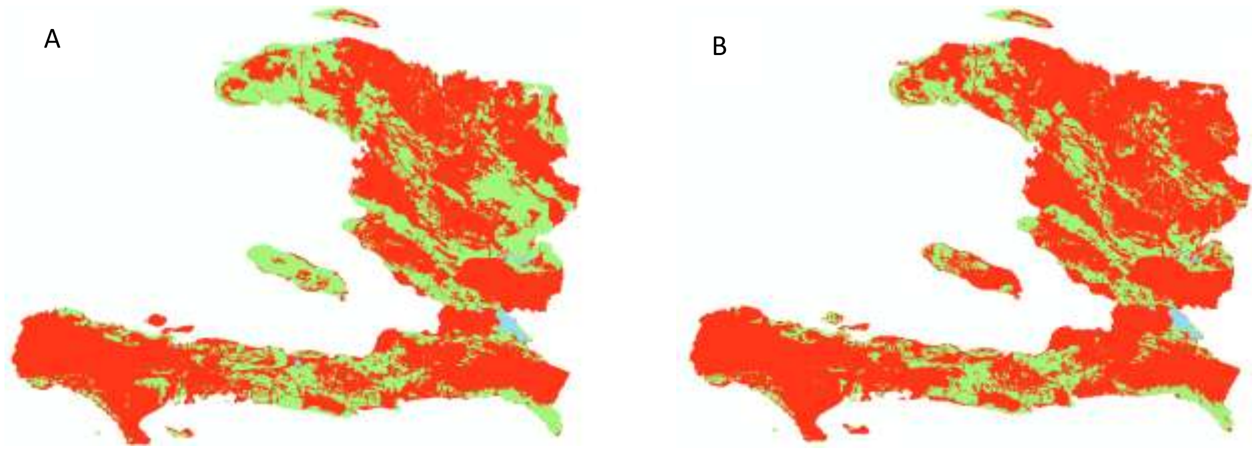
A significant proportion of soils are not cultivated in Haiti as shown in Figure 1 made from the land use map available from the Haitian Geographic and Geospatial Institute (CNIGS).

Figure 1 : Land use map (Pressoir, 2009; adapted using data from CNIGS)

In red: cultivated areas

To estimate the amount of land available for the cultivation of *Jatropha curcas* while minimizing the socio-economic risks, we excluded the wet hills (suitable to growing fruits), areas above 1000 m (unsuitable for Jatropha), the slopes inclinations greater than 40%, land with high potential for agriculture cultivated or not, and all cultivated areas (Figure 1). In Figure 2A we limited the exclusion to these factors and in Figure 2B we have additionally ruled out the plains, valleys, plateaus with slopes less inclined than 12% (cultivated or not, and regardless of aridity) and also all areas with high population density.

Figure 2 – The two models minimize the impact on food security model 2B additionally excludes areas of high population density and areas with with slopes < 12%. In red: areas excluded in order to minimize environmental risks, impact on food security and any adverse agro-ecological consequences. Green zones: suitable for growing *Jatropha curcas*. 2A: 934.803 hectares of land available for cultivation *Jatropha curcas*; 2B: 642.573 hectares available.



These preliminary results[3] suggest that between 600,000 and 900.000 hectares of sub-humid and semi-arid areas are suitable for the cultivation of *Jatropha curcas* without affecting food security, and without using land now under cultivation. Even the most conservative model (which restricts areas with high population density and all the uncultivated flat areas) leaves a significant amount of land available for the cultivation of *Jatropha curcas*. Only 350.000 hectares would be needed to meet the entire current Haitian consumption of diesel[4]. So there is enough land in Haiti to produce the biodiesel needed for our domestic consumption while minimizing the risk of impact on food security, on the environment, and without affecting the availability of land to increase food production on the island.

Land emerging from the two models (Figures 2A and 2B) correspond to what is known in Haiti as the "hot & warm Lands". Most of this land lies in areas that the National Coordination for Food Security (CNSA), defines as "the dry agro-pastoral areas" and "dry lands with limited farming and fishing". In these areas, growing *Jatropha curcas* would only marginally affect food availability and food security[5]. It was however noted by the spokesperson of the CNSA that the demographic parameter (reflected in Figure 2B) and estimating the proportion of the population that would benefit from an increase in income in a given area must be accounted for along with the importance of

[3] Pressoir et al, 2009; a more detailed study should begin soon

[4] IDB and USAID / DEED, Biodiesel Value Chain Feasibility Study for Haiti, 2009

[5] Mathieu G, 2009. Insécurité Alimentaire en Haiti - État des Lieux et propositions de solutions (CNSA).

minimizing the diversion of plots contributing to food availability. It is clear that biofuels will not solve food insecurity but may play a role in increasing revenues and thus the ability to acquire food in areas already heavily dependent on markets for access to food.

Figure 3 – Food security zoning (CNSA 2005)

V. Edible varieties of *Jatropha curcas*

Edible *Jatropha curcas* is consumed by many indigenous peoples in Mexico and Guatemala[6]. In Mexico we observed that not only it was cultivated by humans in order to prepare over 40 different culinary preparations (kernels are roasted or cooked in gravies), but it is also consumed by rodents and birds.

The protein concentration of the *Jatropha curcas* meal/cake is greater than 50% with a satisfactory amino acids composition to prepare animal feed[7]. The edible varieties show low or no phorbol ester ([7,8] which causes *Jatropha curcas*' toxicity. To be incorporated into animal feed, the meal or kernels must be boiled or roasted and [7] phytase should be added to improve phosphorous uptake. A comparison of the amino acid content between *Jatropha curcas* and soybeans shows a similar composition for all essential amino acids except for a lower lysine and higher and cysteine and methionine content for *Jatropha curcas* [9]. Lysine is available at low cost and can be added to achieve a balanced meal (Lysine is also commonly added to soybean meal). The richness in methionine and cysteine, two essential amino acids, is desirable because they are very

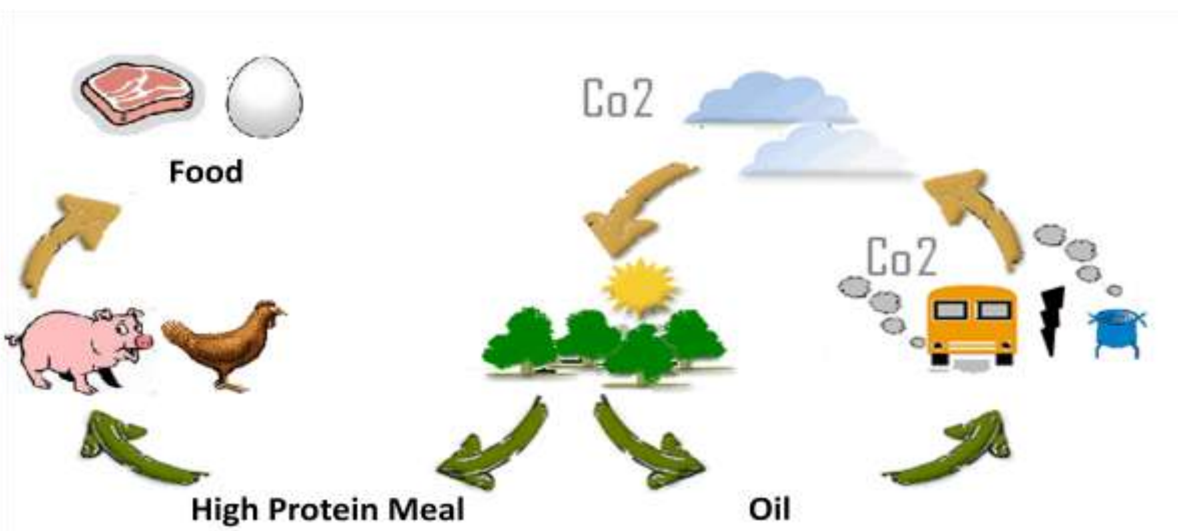
[6] Personal observations
[7] Makkar HPS, Aderibigbe AO et Becker K 1998, Comparative evaluation of non-toxic and toxic varieties of Gwo Medsiyen for chemical composition, digestibility, protein degradability and toxic factors, Food Chem. 62 (1998) 207–215.
[8] Martinez-Herrera J, Siddhuraju P, Francis G, Davile Ortiz G et Becker K 2006, Chemical composition, toxic/antimetabolite constituents, and effect of different treatments on their levels, in four provenances of Gwo Medsiyen L. from Mexico, Food Chem. 96 (2006) 80–89.
[9] Vasconcelos IM, Siebra EA, Maia AAB, Moreira RA, Neto AF, Carnpelo GJA et Oliveira. JTA 1997. Composition. toxic and antinutritional factors of newly developed cultivars of Brazilian soybean (Glycine mar). Journal of the Science of Food and Agriculture. 75: 419-426.

costly as supplements and makes *Jatropha curcas* meal an excellent source for high protein meal.

Edible *Jatropha curcas* meal can therefore be used to feed monogastrics such as chickens, pigs and Tilapias (one of the main problems for the production of poultry in Haiti is the prohibitive cost of imported food, essentially soymeal).

In a speech at the first *Jatropha curcas* stakeholders conference in Port-au-Prince held in 2009, the Secretary of State for Animal Production, Dr. Michel Chancy, stressed Haiti's dependence vis-à-vis either the importation of meat or eggs, or else soymeal. This situation affects particularly monogastric livestock farms (pigs, poultry and tilapia). Cultivation of edible *Jatropha curcas* could help develop monogastric animal husbandry by creating a national/local high protein meal production for these animals. It is also important to note that *Jatropha curcas*' protein yield per hectare is close to that from the best soybean varieties. The cultivation of soybeans in Haiti would require the best arable land; *Jatropha curcas* is a perennial crop, shrub, allowing reforestation and can be grown on highly degraded soils.

The use of multipurpose *Jatropha curcas* (edible) varieties would increase the number of markets for *Jatropha curcas*' products. *Jatropha curcas* could divert the funds used to import fuels toward our farmers and, by using edible varieties, to simultaneously make high protein animal feed; *Jatropha curcas*' cultivation can contribute simultaneously to the food and energy security of the country.



Food and Energy Security can go hand in hand

VI. Profitability of the *Jatropha curcas* value chain

A study commissioned by the Inter-American Development Bank to Haiti analyzed the profitability of the *Jatropha curcas* value chain [10]. The findings of this study suggest that the exploitation of edible *Jatropha curcas* can be profitable (with an advantage to the edible varieties if a market for the meal and feed can be put in place).

The IDB study indicates that the cultivation of *Jatropha curcas* on 65.000 acres is profitable and would create more than 22,000 full-time agricultural jobs and between 2600 and 3250 jobs in the fruit processing centers. In all, to meet the current diesel consumption of 120 million gallons per year, the *Jatropha curcas* market chain could create more than 150,000 direct jobs and generate hundreds of millions of dollars in revenue in the country.

If this sector can be profitable for our farmers, it also represents a tremendous opportunity to create economic development in the rural areas. To extract the oil from *Jatropha curcas*, to turn it into biodiesel, we could establish the small industry that is lacking in the remote areas of the country. The considerable advantage of a crop not intended for export, is that we're not only creating agricultural jobs, but also the jobs needed for the processing of these products. The other benefit of bio-fuels is that we have a captive market worth several hundred million dollars. The bio-fuels industry is therefore not reliant on any strategic choice made in and by any other country. The whole economic sector (value chain) would find its place in the heart of our provinces and will generate revenue (with money that otherwise goes to Petroleum Exporting Countries). If we substitute domestic production to our fuel imports, this industry will create hundreds of thousands of jobs and become the largest employer in the country.

A recent study by CHIBAS[11] indicates that oil, meal and briquette processing from edible Jatropha is more profitable than oil and briquette processing from toxic varieties. The Net Present Value (NPV) is the highest for the processing of the oil, the manufacture of briquettes from the fruit shell and seed teguments, and the valorization of the high protein meal as animal feed (Figures 4 and 5, next page). In this study we consider an inclusive model, company or coop, which guarantees the minimum wage to producers (through a subsidy the first years) and also covers the initial costs in establishing the plantations; in our model farmers and producers also have a minimum of 30% of the fruit processing company as for the Lèt Agogo dairy coops[12]. With this model (very advantageous to smallholders) toxic Jatropha is not profitable if one only processes the oil and only marginally profitable in valuing oil and briquettes; edible Jatropha allows internal rate of return that are higher than 30% despite the advantages offered to small producers.

[10] IDB and USAID / DEED, Feasibility Study of Biodiesel industry, 2009
[11] Truong and Pressoir, 2010, unpublished
[12] Let a Go Go is a milk transformation cooperative which makes dairy products

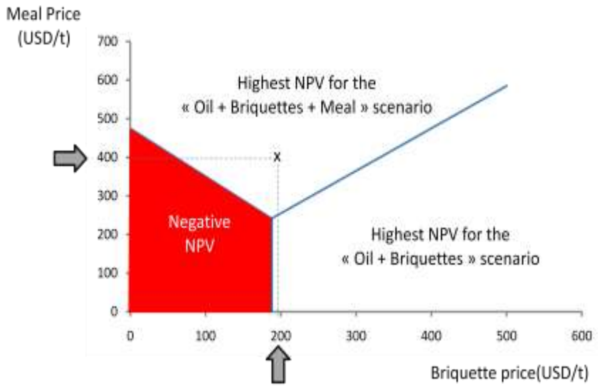


Figure 4 – Net Present Value (NPV calculated over 10 years, 10% discount rate) based on the price of firewood and meal for animal feed (calculated over 10 years). The edible Jatropha offers better prospects in views of current firewood and high protein meal prices in Haiti.

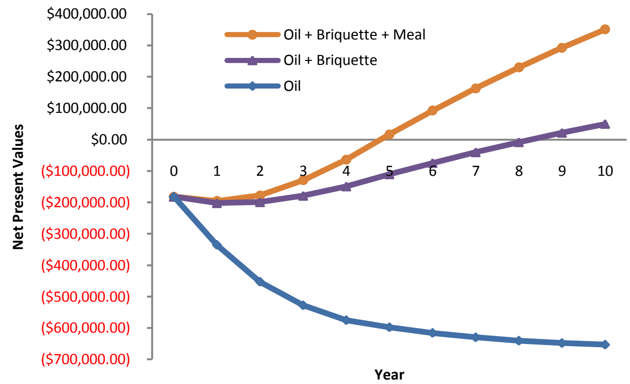


Figure 5 - Comparison of NPVs for the three scenarios considered (NPV in USD, 10% discount rate). The net present values are calculated for 1, 2, 3, ... 10 years.

This profitability can be greatly enhanced by the use of edible varieties for which there is a market as shown in Figures 5 and Table 1. NPV is over twice as high with the edible varieties (Figure 5).

Table 1 - Market in Haiti for the Jatropha products (US$)

Coproducts	**Market**
Oil *	$ 280,000,000 [1,2,*]
High Protein Meal	$ 100,000,000 [2]
Solid Biomass (firewood or briquettes for SMEs)	$ 60,000,000 [1]

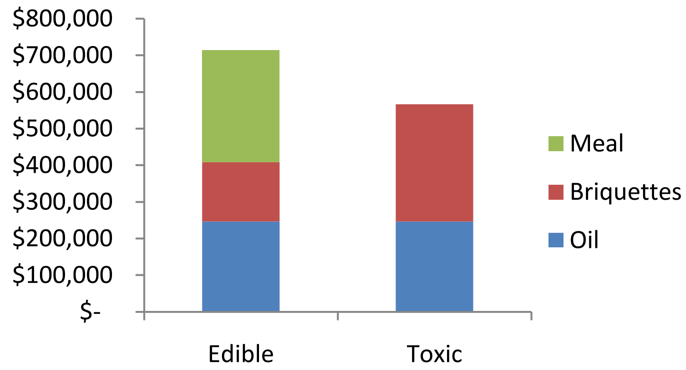
[1] Source : Energy and Mining Office, BME
[2] Source: IDB et USAID/DEED, Biodiesel Value Chain Feasibility Study for Haiti, 2009
* $US 380 Millions for diesel

Table 2. Revenues and sales from the fruit/oil processing centers (in $ US)

	area (ha)	Full time jobs	Cash inflow (producers) $ / ha	Average daily cash inflow (producers)	NPV (10 year) Fruit processing centers	Cumulated profits (10 years)	Sales (yearly)
Edible *J curcas*	350	135	$ 1,020.00	$ 8.19	$ 337,590.00	$ 771,567.00	$ 707,858.00
(oil + briquettes + meal)	65000	25000	$ 1,020.00	$ 8.19	$ 62,695,289.00	$ 143,291,074.00	$ 131,459,275.00
	300000	115000	$ 1,020.00	$ 8.19	$ 289,362,873.00	$ 661,343,419.00	$ 606,735,115.00
Toxic *J curcas*	350	135	$ 945.00	$ 7.65	$ 36,220.00	$ 350,097.00	$ 560,595.00
(oil + briquettes)	65000	25000	$ 945.00	$ 7.65	$ 6,726,607.00	$ 65,017,952.00	$ 104,110,575.00
	300000	115000	$ 945.00	$ 7.65	$ 31,045,879.00	$ 300,082,857.00	$ 480,510,344.00

It is important to stress that revenue and profits are much higher for the "Oil + Briquettes + Meal" scenario both for the producers and the fruit processing centers (Table 2). The internal rate of return for an investor exceeds 30% for edible Jatropha; over a 10 year period the investor can multiply its initial capital three times. For the “Oil + Briquettes” scenario (toxic Jatropha) the IRR falls to 13%. It is important to stress that the Net Present Value is positive from the 5th year onward for the “Oil + Briquettes + Meal" scenario (edible Jatropha) and only from the 9th year onward with the “Oil + Briquettes” scenario or toxic *Jatropha curcas*.

Figure 6 – shares from the different products in the fruit processing center revenues (350 ha)



The improved profitability of the "Briquette + oil + meal" model is primarily attributable to improved net income (Figure 6). It should be noted that the largest share of revenues comes from the sales of the meal, and not from oil sales.

The cultivation of edible *Jatropha curcas* should logically be preferred because it offers more flexibility (choice between the "Oil + Briquette" or "Briquette + Oil + cake" scenarios) not to mention that the "Oil + cake + Briquette” scenario is the most profitable given current market prices and for the foreseeable future.

But the main advantage of the model developed by CHIBAS is the income that farmers can gain from growing edible *Jatropha curcas*; this industry would generate above minimum wage revenue for the producers (most farmers’ revenues in rural areas do not currently meet the minimum wage) and multiply by more than 5 their income per hectare (in the sub-humid or semi-arid areas). Additionally, cultivation of *Jatropha curcas* can easily be combined with livestocks husbandry (goats, poultry, pigs) in agreement with the land use plan recommended for the semi-arid and sub-humid mountainous areas by the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR).

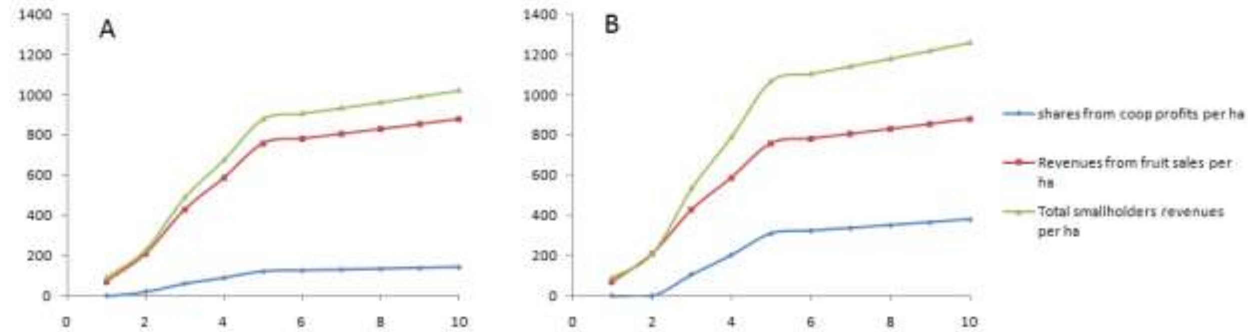


Figure 7 – Average farmers' income per hectare ($U.S.).
7A: Farmers owns 30% of the coop - scenario with investors.
7B: Farmers owns 100% of the cooperative scenario – scenario with loan (interest rate of 12% per year).

The economic model and the corresponding business plan should be published shortly by the CHIBAS.

This market value chain could eventually account for nearly half a billion $US in the country for a captive market (production and consumption, Table 1 & 2)

VII. *Jatropha curcas* and local development

The study commissioned by the Inter-American Development Bank as well as CHIBAS' own study both suggest the profitability of the sector for both edible and non-edible Jatropha. While targeting the national market (large cities), this industry can also be based on the village economy, communal section or even locality. A concrete example is the project carried out by the GAFE on the communal section of Belle Fontaine in the town of Kenscoff[13]; *Jatropha curcas* can provide oil for the operation of lamps and stoves within the community. The necessary equipment (small hydraulic press, lamp oil, stove oil) are relatively simple to manufacture and many can be made by local artisans. GAFE has recently trained local ironworkers into manufacturing locally made presses, lamps and stoves. Straight Vegetable Oil lamps and stoves have proven to be equally effective as the versions that run on kerosene. In a second step, we can also set up generators based on Lister-type engines to electrify a rural area as part of a local development project[14]. The same type of Lister engine can operate irrigation pumps, mills or other machinery for processing of local agro-products. There is precedent in Mali and Niger with this type of approach at the village level; local development has

[13] Hurtaud A et Tilus D, 2009. Projet Gwo Medsiyen sur la commune de Kenscoff (GAFE). 1ere Conférence des acteurs et parties prenantes de la filière *Gwo Medsiyen*
[14] Echols S et Pressoir G, 2009. Génération d'électricité à partir d'huile de Gwo Medsiyen. 1ere Conférence des acteurs et parties prenantes de la filière *Gwo Medsiyen*

resulted in significant improvements in living standards of the people concerned by the project[15].

Another possible aspect of rural development is the possibility of establishing *Jatropha curcas* fruit processing centers in these rural areas. Two advantages to this approach are the jobs and value added in the rural communities; local actors can be fully integrated in the ownership and operation of these centers in order to increase the creation of wealth in these communities. A possible example of a proven business model is given by the Lèt Agogo dairies where producers are shareholders. CHIBAS' study shows that a coop or inclusive business model may double the income that producers will gain from the exploitation *Jatropha curcas* (see Table 2). Indeed, the study shows that income can be doubled if the operator is also part owner of the fruit processing center. *Jatropha curcas* fruit processing centers could be a component of rural development by creating jobs and wealth in these regions.

Both approaches presented here can also be combined. Indeed, the oil produced by the fruit processing centers *Jatropha curcas* can power engines running on SVO (Photo 1) that would produce electricity at a much smaller cost than that produced from diesel and allow the electrification of our provinces. About 75% of electricity in Haiti is already produced by diesel or heavy fuels creating a large potential demand for *Jatropha curcas* Strait Vegetable Oil. This oil may also be sold locally to operate the lamps, stoves (photo 2), pumps and mills previously mentioned. In the provinces or rural areas, diesel is often sold at a more expensive cost than in Port-au-Prince; the local production of fuels (including biodiesel) would significantly reduce transportation costs and thus further reduce the cost of transporting goods (including food).

[15] Tilus D, 2009. Dynamique de développement local au Niger autour de la valorisation du Gwo Medsiyen (GAFE). 1ere Conférence des acteurs et parties prenantes de la filière *Gwo Medsiyen*

Photo 1. –3-15 kW Electric generator
Lister Engine.

Fuel = Strait Vegetable Oil

Photo 2.- PROTOS Stove by Siemens.

Fuel = Strait Vegetable Oil

www.siemens.com/sustainability/en/sustainable/protos.htm

Annex 1 - Jatropha Fruit Processing Center

Economic Analysis
(Additional data)

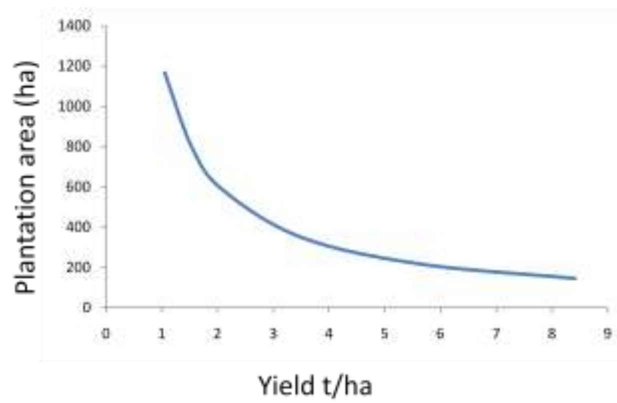
1. An inclusive and integrated business model

We study here an inclusive and fully integrated business model between the Fruit Processing Center (FPC) and the Jatropha growers (smallholders).

The growers are shareholders of the FPC even if they do not bring any of the initial capital. They own 30% or 100% of the company. If an investor (or many investors) brings the capital, they then own 70% of the FPC. We also developed a purely cooperative model (farmers own 100% of the shares) with a 10 year loan (the rate used here is 12%).

Figure 1. Plantation size (ha) given Jatropha yield

The size of the FPC is the size of the plant needed to process the fruits of 350 ha of plantations with a yield of 3.5 tons / ha at maturity. The area required for plantations varies given Jatropha yields (Figure 1).



The higher the yields, the smaller the plantations needed for an FPC.

Here we consider six scenarios

- **a.** FPC producing oil. Energy produced from solid waste;
- **b.** FPC producing oil. Energy produced from oil;
- **c.** FPC producing oil and briquettes. Energy produced from solid waste;
- **d.** FPC producing oil and briquettes. Energy produced from oil;
- **e.** FPC produces oil, briquettes and high protein meal. Energy produced from solid waste;
- **f.** FPC produces oil, briquettes and high protein meal. Energy produced from oil.

In many cases, we will only consider the scenarios c (then called “oil + briquette”) and e (then called “oil + briquettes + meal”).

1.1. Farm

In this study, we consider an inclusive model. The FPC guarantees the mimimum wage to the growers through a subsidy the firs years (when production is low) and also fully subsidizes the plantation cost. In our model, farmers and producers also have a minimum share of 30% of the fruit processing company following a similar model to the Lèt Agogo dairies.
The farmer manages his fields (minimum of 2 ha). Though related to the FPC, he exploits his land for his own profit.
We estimated the number of working hours and cost of agriculture inputs per hectare for establishing the plantations and maintaining and harvesting the fields during the first ten years. We consider a minimum wage of 4.5 USD per day (180 Gourdes). The purchase price and the subsidy then guarantee the minimum wage per working day. In addition to the sales and the initial subsidy, the farmers also take 30% of the company's profits.

Figure 2 – Breakdown of the growers Incomes (in USD) per hectare. Numbers given for edible Jatropha (2.5 tons per hectare from the fifth year of production - conservative figure for the yield)

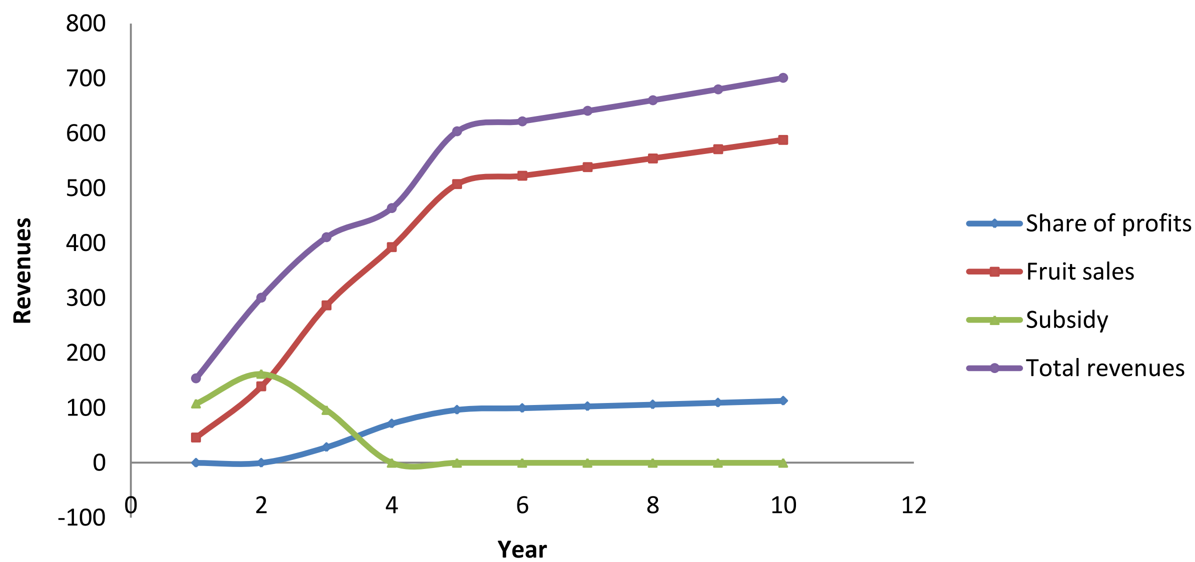
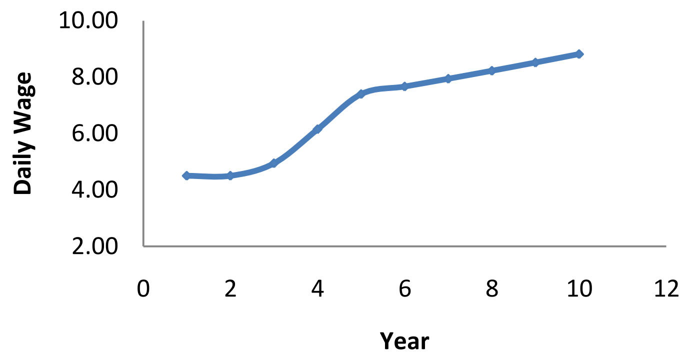
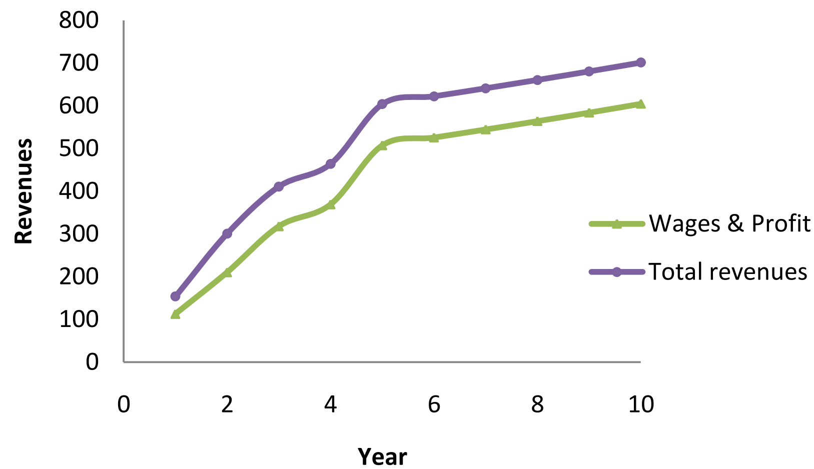


Figure 3. – Average Daily Revenue (in USD) for the producer of edible Jatropha (2.5 tons per hectare variety).



As shown in Figures 2 and 3, this model allows the producer earn the minimum wage for the first two years (no profits being made by FPC or farmers); the following years, the salary increases rapidly. The rise is mainly driven by increased yield, growing shares of the FPC profits and the adjustment in prices being paid for the harvest (indexed to inflation). The average daily wage for Jatropha growers in our business model quickly exceeds the minimum wage in force in Haiti.

Figure 4. – Share of profits + wages in grower's total income..

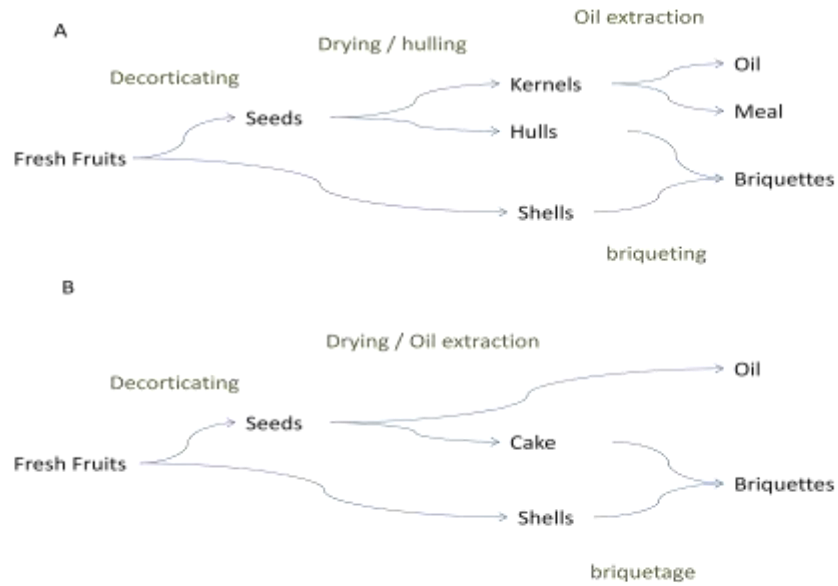


After removing farm expenses (mainly the cost of inputs: fertilizer & pest control), we can see that sales & profits made in a marginal area (soils unsuitable for agriculture of annual crops) are comparable to those of Sugar Cane on fertile arable land. Jatropha is a very profitable crop for Haiti's growers.

1.2. The Fruit Processing Center (FPC)

The FPC buys the fresh fruits from the growers. It has the necessary machinery for processing the fruits and the valorization of one, two or three byproducts ("Oil", "Oil + Briquette" or "Oil + Briquette + Meal") (Figure 5).

Figure 5.
A : “Oil + Briquette + Meal”
B : “Oil + Briquette”



1.2.1. Choosing an energy source for operating the FPC’s machines

For the production of energy (to run the machinery), the FPC may use the oil (with Lister type low rpm engines) or the residues are burned in a steam boiler, steam is then used to power the engines.

Except in the event of a lack of availability of water for the steam boilers, it appears that the scenarios using the steam boilers are more profitable than the scenarios using oil as an energy source (Table 1). In all cases, the choice of the boiler results in a clear improvement of the profits.

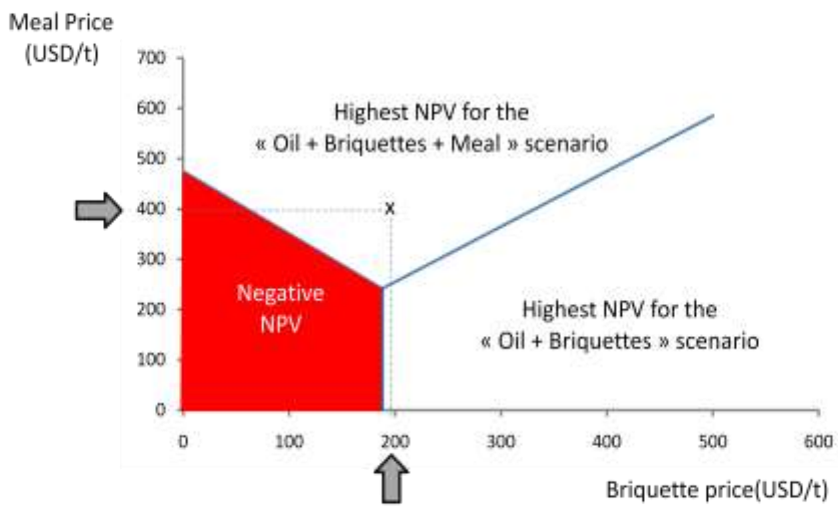
Table 1. Net Present Value (NPV) and Internal Rate of Return (IRR) based on the different scenarios (for a 3.5 t / ha and 35% oil content variety)

Scenario / Energy source	NPV (USD)	IRR (%)
a. "Oil" / "Oil powered Lister"	$ -971,167	negative
b. "Oil" / "Steam Boiler"	$ -765,431	negative
c. "Oil + Briquette" / "Oil powered Lister"	$ 13,834	11%
d. "Oil + Briquette" / "Steam Boiler"	$ 98,089	17%
e. "Oil + Briquette + Meal" / "Oil powered Lister"	$ 288,015	27%
f. "Oil + Briquette + Meal" / "Steam Boiler"	$ 372,270	31%

1.2.2. Choosing a business model

The net present values or Internal rates of return of the two models that only produce oil are always negative. They can only be profitable with abnormally high oil prices and excellent extraction rates (a gallon of oil must then be sold for more than 3.7 USD, or much more than the current retail price of diesel on the Haitian market).

Figure 5 – Profitability of the different scenarios depending on the market prices.



At current market prices, the "Oil + Briquette +Meal" scenario presents the highest NPV and IRR (Figure 5).

2. Choosing a variety.

Why do we need to breed or select the best Jatropha varieties? (Why can't we just use any available ecotypes?)

Plant breeding is the most cost-effective way to achieve an increased and stable yield. While native Jatropha offers an already-substantial yield and drought tolerance, plant breeding would allow for continuous increase and release of ever more productive varieties. Trials and selection allows the identification of the best material currently available. In industrial terms, this increase will translate to, for example, oil with increased oxidative stability and other properties that will lower the cost of making biodiesel and enhance its quality. Varieties with higher oil content in percent of dry weight will also provide increased revenue per working-hour for the farmers. The development of nontoxic varieties will allow farmers to have additional markets for their product (not just biodiesel). The 'green revolution' for major cereals would not have been made possible without the release of outstanding varieties. A new green revolution will require also new outstanding energy crop varieties.

2.1. Effect of seed toxicity, oil content and yield on the profitability of the FPC

The cost of inputs per hectare is not affected when using a lower yielding variety. The lower the productivity, the higher is the share of inputs in the total cost. Therefore, lower productivity implies an increase in production costs (excluding salary).

Figure 6. – Net present values depending on oil content.

A : yield of 3.5 t/ha
B : yield of 2.5 t/ha
C : yield of 1.5 t/ha

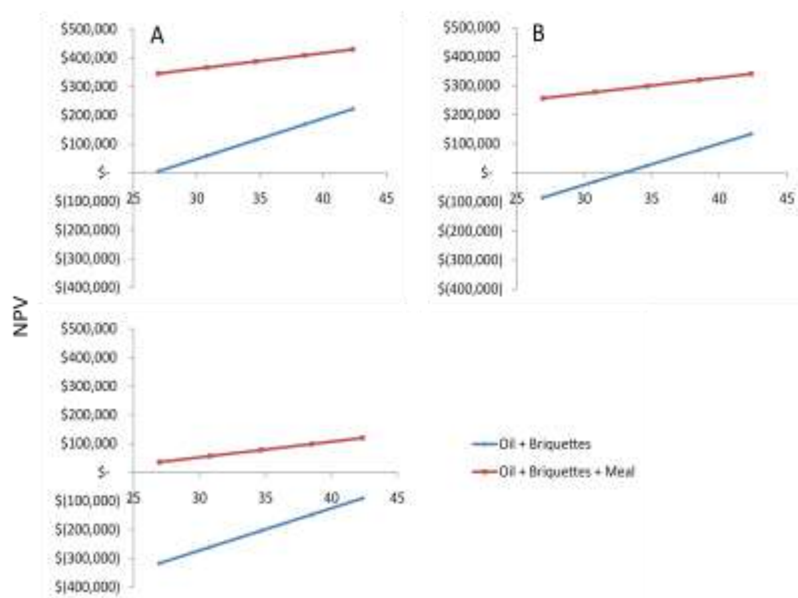
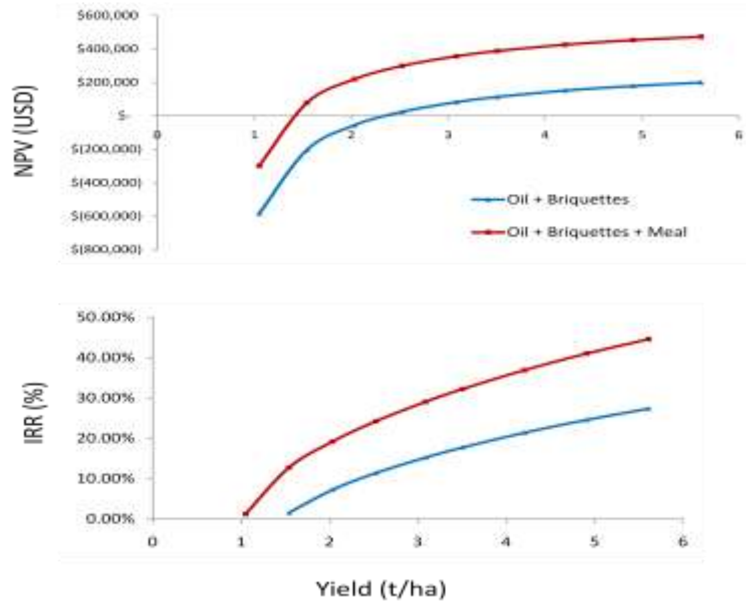


Figure 7 – Effect of Jatropha yields on the profitability of the FPC



It may seem surprising at first sight that yields affect the profitability of the FPC. This can be explained by the fact that in our model, the FPC subsidizes the growers the first years (subsidy is independent of yields) and, more importantly, the FPC finances the establishment of the plantations (overall plantation cost is affected by the number of hectares needed to run an FPC, the lower the yields, the higher the overall plantation cost). The establishment of the plantations is the largest share of the total investment and represents 35-40% of this investment.

Figure 7. – Cost of plantation establishment given the yields (same yield output as for 350 ha of a 3.5 t / ha variety)

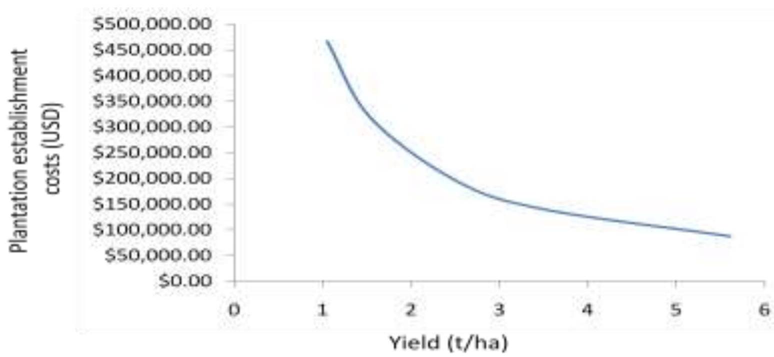
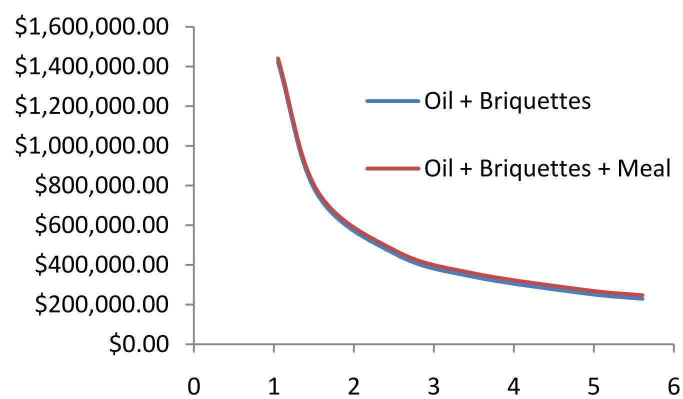


Figure 8. – Investment required (USD) to set up a FPC + Plantation (same yield output as for 350 ha of a 3.5 t / ha variety) given the yields



It appears that to reduce the costs of plantation establishment it is important to choose a high yielding variety.

2.2. Effect of fruit toxicity, oil content and yield on the grower's income

As mentioned previously, the economic model used works to the benefit of the small landholders by providing support for the plantation and subsidizing the first 2 years of production. Given the same price for the fruits there is little difference in the farmers' incomes from growing the edible or non-edible. The small difference is driven by a higher profitability and therefore a higher share of the profits from the FPC (Figures 9 and 10).

Figure 9. – Wages & (given the same fresh fruit price)

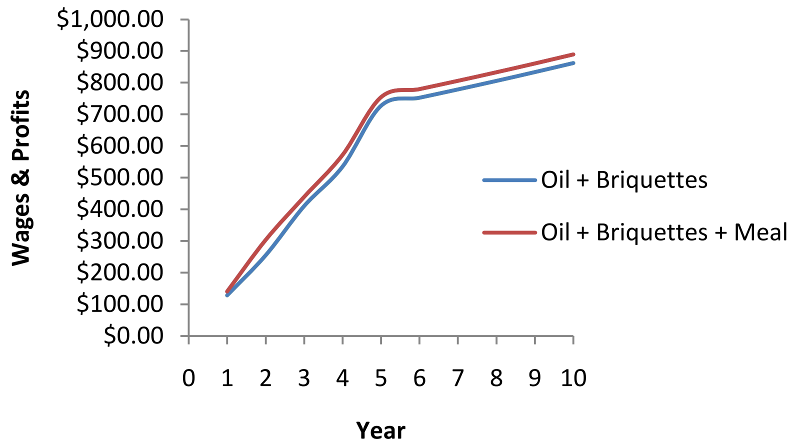
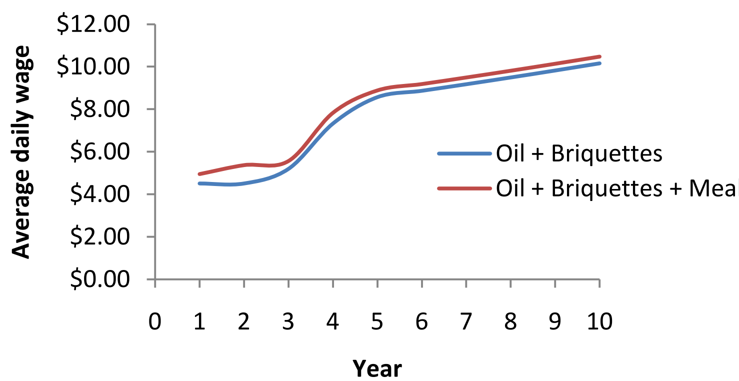


Figure 10. – Average daily wage (given the same fresh fruit price)



We can see that the wage is only marginally affected by the model. This is because most of the wage and profit come from the selling of the fruits (which is by far the largest budget item of the FPC). The only way to have a significant impact on wages and / or profit is to provide a better fruit purchasing price or with a better yield.

Figure 11. – Wages and profit per hectare (10th year) depending on the yield (scenario "Oil + Briquettes + Meal")

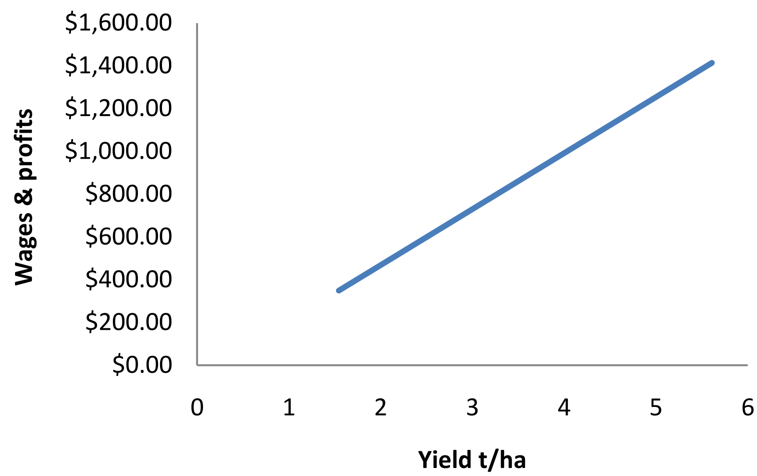
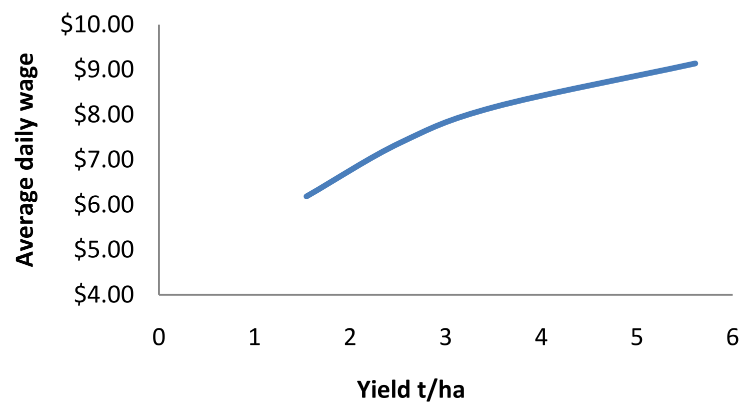


Figure 12. – Average daily earnings (10 years) based on the yield (scenario "Oil + Briquettes + Meal")



Figures 11 and 12 show that not only the daily wage increases but the total income is also increasing with increasing yields.

Figure 13. Net Present Value (10 years, 10% discount rate) based on the price paid per kilo of dried fruit.

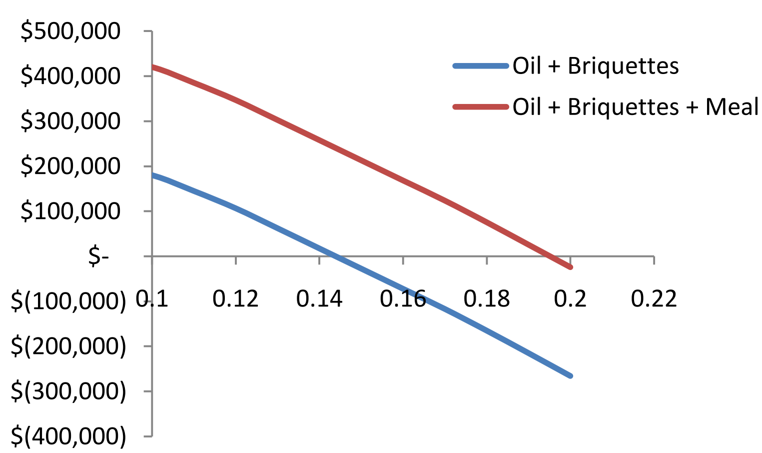
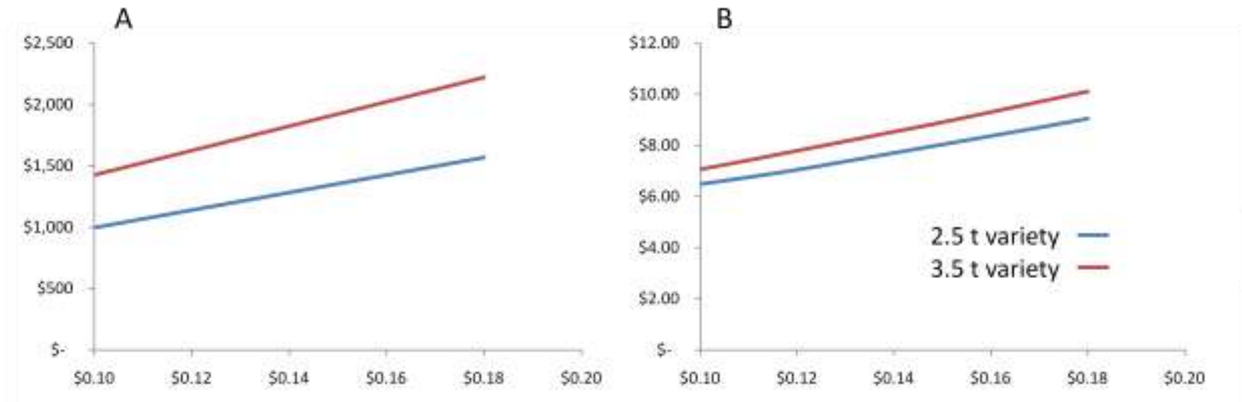


Figure 13 shows that the cultivation of edible Jatropha is profitable for an investor even a price of 0.19 USD per kilo of dried fruits. Toxic Jatropha is no longer profitable above 0.14 USD per kg. Edible Jatropha allows for a better fruit purchasing price to the farmers (and therefore improved earnings).

Figure 14. – Scenario " Oil + Briquettes + Meal”. A: Salary and profit per hectare depending on the price of a kilo of dried fruit (for a 2.5 or 3.5 t / ha variety) B: Average daily wage (average over 10 years) according to the price of a kilo of dried fruit (for a 2.5 or 3.5 t / ha variety)



So clearly (Figure 14) farmers income is dependent on both yield and he price paid per kilo of dried fruit by the FPC. Only edible Jatropha allows greater freedom in the price of dried fruit (Figure 13).