Jatropha Production in Semi-Arid Areas of Tanzania

Is the growing and processing of Jatropha in the semi-arid Central Corridor of Tanzania a way to improve the income of rural households and thereby enhance their livelihood?

A Feasibility Study

Mathias Kempf, Rural Livelihood Development Company
Dodoma, June 2007

Summary

The biodiesel markets in Europe and the US are booming. And they are waiting for Jatropha. During the past years they have built up enormous capacities to produce biodiesel from plant oil. And counting. In 2007, the US is tripling its capacity for the second consecutive year and Germany – already producing more than 50% of the world's biodiesel – keeps rising its capacity. Yet, the limits of the agricultural capacity to produce the necessary feedstock like rapeseed and soya are in tangible reach. What's more, these traditional biodiesel plants are facing more and more criticism from environmental and ethical perspectives (negative ecological lifecycle assessment; fuel vs. food). Alternatives like palm or soya oil from the tropics have been dismissed for similar reasons (rainforest clear felling).

The oil from Jatropha seeds seems to be the ideal feedstock to fill the opening gap and meet the new fuel needs of today's world that has developed awareness on climate change and scarcity of fossil fuel. Jatropha grows on marginal soils and hence doesn't compete with food crops – at the same time offering new income opportunities to the people in these often also economically marginal areas.

However, there is still a long way to go for Jatropha. Surprisingly, even though development projects have been experimenting with Jatropha for the last 20–30 years, there is a general lack of consequent documentation of projects and scientific knowledge on fundamental properties. Also, many of the projects in the past were focussing on small-scale community development. Jatropha was never explored as a real large-scale plantation crop. This is why even newly established plantations of large-scale have to be regarded as experiments. The oldest of such plantations have been planted 1–2 years ago. Considering the time for the plant to mature, the first meaningful amounts of Jatropha oil will be available to the market only in about 2–3 years. In spite of the high hopes that are being put in Jatropha it is worrying to see how little is secured about Jatropha, starting from the biological properties of the plant over the management in plantations up to the development of the biodiesel market in the next few years.

On the other hand, the enormous potential of this crop cannot be denied. It is not possible to avoid the risks completely because the broad success of Jatropha for rural producers is largely dependent on the development of a yet very limited market. But the risks can be mitigated by establishing responsible projects. When growing Jatropha, 3–4 years without yield have to be endured. During this time – and further on to reduce risks in general – Jatropha should not be planted as a single crop but in combination with annual crops. Most importantly, the expectations should be held low and realistic. If Jatropha is introduced as a side-profit generating complementary crop rather than an all-curing miracle tree the Jatropha experiment can work for the rural poor.

RLDC is the implementing body of the Rural Livelihood Development Program, which is funded by the Swiss Government Agency for Development and Cooperation (SDC). RLDC supports partnership projects that link small producers in rural areas with buyers through a value chain and private sector approach. Contact: info@rldc.co.tz.

Mathias Kempf has studied forest sciences at the Swiss Federal Institute of Technology. He worked as a consultant for RLDC specializing on biomass energy issues such as sustainable charcoal production and Jatropha. Feedback concerning this study are welcome. Please contact the author directly: mathias.kempf@gmail.com.

Front-page illustration: Jatropha – a promising developing sector with a long way to go. Seedlings germinating at Donesta's nursery, Dodoma Region

Acronyms

BSH	Bosch und Siemens Hausgeräte
GFU	Global Facilitation Unit for Underutilized Species
GTZ	Gemeinschaft für Technische Zusammenarbeit (German Technical Cooperation)
Acre & ha	1 acre = 0.4 hectare (ha); 1 ha = 2.5 acres
JCL	Jatropha curcas Linnaeus/Linné
M	Million, mega (1,000,000)
MFP	Multifunctional Platform
RLDC	Rural Livelihood Development Company
SVO	Straight Vegetable Oil
€	Euro, € 1 = TZS 1700 = $ 1.35
$	US Dollar, $ 1 = TZS 1300 = € 0.75
TZS	Tanzanian Schilling, TZS 1 = $ 0.0008 = € 0.0006

References

Sources are not quoted in the text where the information in general literature concurs. Nevertheless, all literature used is listed in the bibliography (Sources). Information that differs significantly or is thought to be especially important is quoted. Information given by actors in the field of Jatropha that were met personally is quoted with their last name in brackets; please refer to the list of actors under Sources.

Where possible web-links were inserted to facilitate further enquiry or to download the quoted documents. These links are active if the document is viewed with *Adobe Acrobat Reader* (pdf version) or *MS Word* (doc version); the links were not active using Apple's *Preview*.

Content

Tables and Illustrations

1 Introduction

1.1 Purpose of this Study

Jatropha, also known as physic nut, has lately become very popular in development circles, mainly in those specializing in sustainable biomass energy. Jatropha seems to grow in many dry areas where only few crops perform well and its uses are very diverse. The bioenergy sector puts high hopes in the production of biodiesel from the oil of this plant. In this context, Jatropha is often referred to as the "biodiesel tree" or even the "magic tree", implying not only a means against the dependence on fossil oil but also significant improvements of rural livelihoods through the cultivation and processing of Jatropha.

Jatropha is being promoted as an ideal plant for semiarid areas where it is said to benefit the rural poor as a cash crop, especially supporting women who do the harvesting and e.g. soap production from the oil of the Jatropha seeds.

There are several projects dealing with Jatropha in Tanzania and also RLDC has received proposals going into Jatropha production and processing, all with the aim of producing oil or biodiesel. But, even though this plant is widely spread and known in Tanzania (as *mmbono kaburi* or *nyonyo kaburi*) for its use in hedges, live fences and to mark graves, the seed and oil production doesn't seem to be developed at all because the traditional uses overlook the fruits, as they are toxic to humans and animals.

Because the market for Jatropha seeds or oil is still very small at the moment and biodiesel produced from Jatropha seeds on a larger scale is still a dream of the future, an important question is *if* and in which timeframe the investment in Jatropha production can become economically viable, specially in regard to the common project timeframes of RLDC. Apart from the economical start-up period for the production of Jatropha oil and biodiesel it is as important to consider the agricultural start-up time to establish plantations producing a meaningful yield.

RLDC carried out this study in order to assess the possibilities of sustainably improving rural livelihoods through Jatropha projects and base a "Jatropha strategy" upon its results.

The study gives a general round up on Jatropha growing and processing and focuses especially on the requirements for cultivation, the yields, the possible benefits and the necessary inputs.

This study seeks to provide a short knowledge basis on Jatropha including important findings from and for practice and assesses whether projects in Jatropha growing and processing can improve the income of rural households and thereby their livelihood. The main focus lies on the cultivation of Jatropha for the production of oil for the use as fuel. Therefore, an important part of this study was conducted on the existing biodiesel markets taking the largest and most developed in Germany as an example.

1.2 Methodology and Acknowledgment

The part of this report on the general plant biology, growth requirements, uses etc. relies for an important part on literature, as a number of papers on these issues is available. Good sources are papers from GTZ (German Technical Cooperation) who has gathered broad experience with Jatropha during the last 20 years. Firm scientific knowledge though is limited.

These findings from literature were complemented with first hand information from the field (actors in Tanzanian Jatropha business). This was particularly important when it came to yield figures, especially under marginal conditions (little rain, poor soil) as they are found in Dodoma and Singida Regions of Tanzania.

The investigations made in the Tanzanian field of Jatropha activities also aimed at drafting the current "Jatropha-scene" in the country: Projects and approaches, producers, buyers, processors and the market, as far as a market exists.

As a potential future market the existing biodiesel market in Europe was assessed and the development of biofuels in brief in order to estimate if and how Jatropha could fit into this market.

With the mentioned information as a broad basis, Jatropha growing was assessed, focussing on both, the biological and the economical feasibility, especially considering possible benefits for small-scale farmers in Singida and Dodoma Region.

Very special thanks are dedicated to Peter Burland, Malcolm Doherty, Janske van Eijck, Lars Kåre Grimsby, Salim Kanji and Ramadan Kidunda for their valuable first hand information, their inputs and the insight in their work they allowed me to have.

2 About Jatropha

2.1 Species and Names

Jatropha belongs to the family of Euphorbiaceae. In the genus Jatropha there are approximately 170 known species native to different parts of the world, all of which are tropic but rather dry. The species of interest – *Jatropha curcas L.* (referred to in the further as Jatropha or JCL) – originates from Central America but is today cultivated in almost all tropic and sub-tropic countries in Latin America, Africa and Asia as protection hedges around homesteads, gardens and fields, since it is not browsed by animals.

There are 3 varieties of JCL. The Cape Verde variety is the one that is spread all over the world. A JCL variety in Nicaragua has fewer, but larger fruits (according to literature, the yield per ha is equivalent to the Cape Verde variety). A non-toxic variety, which is used for human consumption after roasting, exists in Mexico. In Tanzania, JCL is called *mmbono kaburi or nyonyo kaburi* (kaburi, the Swahili word for *grave* or *cemetery* indicates the traditional use of the plant to mark graves). The English names are *physic nut* or *purging nut*. Apart from JCL, there is the species *J. mahafalensis,* which is endemic in Madagascar and predicted to have comparable energetic promise.

Illustration 1: Unripe Jatropha fruits, Kikuletwa Farm, Moshi. The fruits are harvested when the hulls are dark and dry; Seeds from "wild" Jatropha tree in Chalinze, Dodoma Region

2.2 Biology

Growth and Development

Jatropha curcas L. is a perennial small tree or large shrub, which can reach a height of up to 5 m. JCL is an ever green drought-resistant species that sheds its leaves during very dry periods. It is adapted to arid and semi-arid conditions. The current distribution of Jatropha shows that introduction has been most successful in drier regions of the tropics with an average annual rainfall between 300 and 1000 mm. Generally, all literature cites an amount of 550 to 600 mm of annual rainfall as a minimum requirement for JCL to grow. Under exceptional conditions the plant also performs well with much less precipitation and can even withstand years without any rain at all: On Cape Verde the annual rainfall can get as low as 250 mm – but the atmospheric humidity is very high.

JCL grows on poor well-drained soils with good aeration and is well adapted to marginal soils with low nutrient content. In heavy soils, root formation is reduced. JCL is a highly adaptable species, but its strength as a crop comes from its ability to grow on poor, dry sites.

Jatropha withstands slight frost but is sensitive to wind and to fire. It is not sensitive to day length.

On marginal sites, JCL is not a weed; it is not self-propagating and has to be planted.

Jatropha plants reach an age of 40 to 50 years.

Illustration 2: Jatropha trials at Kikuletwa Farm, Moshi. 8 months after planting (heights: 1.2 m); 5 years old trees (heights: 3.5 m)

With good rainfall conditions, nursery plants bear (few) fruits after the first rainy season, directly sown plants grow fruits for the first time after the second rainy season. With vegetative propagation (cuttings), the first seed yields are considerably higher than from nursery plants. In permanently humid equatorial regions, flowering occurs throughout the year. Fruit development needs 90 days from flowering until seeds mature. Further development corresponds to rainy seasons: vegetative growth during the rainy season and little increment during the dry season. In areas with one rainy season JCL can be harvested once a year, with two rainy seasons twice and with additional irrigation trice. The plant needs 4 to 5 years to mature. Only few seeds are produced before maturity.

Cultivation

In dry areas it is important to plant seedlings or seeds directly. Plants from cuttings perform lesser depth development of the roots (no proper tap root) and do therefore not withstand droughts. It is important to completely clear the land for plantations (Doherty, cf. also below: Pests and Diseases).

Burland, Doherty and van Eijck are convinced that intercropping is the only way to go. The plants need the light that comes through to the bottom. At the same time, space for additional annual food or cash crops is created that can be harvested before JCL is mature. Intercropping raises activities on the farm and reduces the costs because the necessary JCL weeding can be combined with planting or harvesting of other crops. The experience in Tanzania shows that spacing of 2–3 m works well, resulting in 1000–1600 plants per hectare.

Regular pruning is very important to encourage growth but also to keep the seeds in reachable height for harvesting. The cuttings should be left on the farm and ploughed under the soil to recycle the nutrients. (Doherty.)

Pollination occurs through insects and especially bees. The lack of pollinators reduces seed yield respectively produces fruits without kernel. Beekeeping could therefore be favourable to improve yields (Kannan 2002).

The main harvest time is about 1.5 months after the rains. This means that Jatropha cultivating does not interfere with major farm activities. However, the fruits on JCL plants are often found in different stages at the same time. The black dry fruits are easy to peel by hand while the green or yellow ones are tough and have a milky sap (like the whole plant) that leaves permanent stains on clothing.

<u>Pests and Diseases</u>

Heller (1996) names 13 pests and diseases that have been observed on JCL. Principally, the JCL plant is known for its resilience to inhospitable environments and circumstances. But Doherty stresses that the young Jatropha plant (including direct sown seeds) is vulnerable like many other plants. Therefore he recommends radical clearing of fields before establishing a JCL plantation. Stumps should also be removed and deep ploughing undertaken if there were formerly many trees in order to avoid JCL to be choked by old roots. According to Heller, seedlings are susceptible to competition from weeds during their early development. Therefore weed control, either mechanical or with herbicides, is required during the establishment phase. Heller specifically mentions that millipedes can cause total loss of young seedlings and in Arusha it could be witnessed during this study how termites “felled” several JCL seedlings that were about 6 months old.

Illustration 3: Termite attack on Jatropha saplings, Arusha, February 2007

But there are risks for mature plants: Burland has to protect his small JCL plantation near Moshi against red beetles (eating the flowers) and fungus with chemicals. He uses “sulfit”, “karate” and “selgroin”. This is also what makes Burland sceptical about large scale plantations. He believes that large area spraying could become a major cost factor. Another considerable risk to a large surface of JCL is fire, especially because fire clearing is widely used in Tanzania. These are more reasons that speak for intercropping to achieve biological diversification. Looking at Burland’s experience it has to be considered, that Moshi (955 mm annual rain, 2 rainy seasons) is not directly comparable to semi-arid Dodoma or Singida Regions. It is possible that JCL is more delicate in moister climates.

It should be pointed out that Jatropha is a host for cassava viruses that can be transmitted. Jatropha should therefore never be planted with Cassava or be used to fence in cassava fields.

2.3 Uses of Jatropha

<u>Traditionally: Hedges and Medicine</u>

JCL is widely cultivated as a living fence around settlements and fields. Cattle does not browse the plant and it can easily be propagated by cuttings (densely planted for this purpose). In Mali, there are several thousand kilometres of Jatropha hedges.

Leaves and seeds of JCL contain curcin, a toxic protein, and diterpine esters (also called phorbol esters), therefore the plant only plays a marginal role as food or fodder.[1] Nevertheless, many parts of the plant are used in traditional medicine. The oil has a strong purgative action and is also used to treat skin diseases and to soothe pain such as that caused by rheumatism. A decoction of leaves is used against cough and as an antiseptic after birth.

Oil: Soap, SVO and Biodiesel

The most interesting uses depart from the JCL oil: In several village-scale projects (see chapter 4.1 "The Jatropha System") the seeds are pressed and the oil is used to produce medicinal soap for local and countrywide markets.

However, it is in the use of JCL oil as a fuel, where many people see an extraordinary potential. First, because of the limitation of the world's fossil oil recourses and secondly, because the use of JCL biodiesel is CO_2-neutral[2] and therefore does not enhance global warming like fossil diesel.

For the use of JCL oil in rural households lamps have been developed (ProBEC, Kakute) and a promising cooking stove is almost ready to be introduced on a large scale (ProBEC/BSH).

The big potential market is in fuel for combustion engines. JCL oil can be used in diesel engines if its high viscosity is reduced. This can be done in three ways: Preheating, mixing with other fuels and conversion to biodiesel. In diesel engines like the Lister-type[3] the purified oil can be used directly and in diesel-fuelled cars with only minor modifications[4]. This is called the Straight Vegetable Oil (SVO) use. Engines like the Lister-type drive milling machines, electricity generators, pumps and seed presses on village-level. If several of the named units come together around such an engine, we speak of a multi-purpose-platform, MPF.

The conversion of the oil to biodiesel[5] is a bit more complex but JCL biodiesel can be then used in any diesel engine like fossil diesel (without any modification).

Illustration 4: Jatropha oil filter-tube, Kakute, Arusha. Multifunctional Platform, TaTEDO, Dar es Salaam

[1] The consumption of only 4–5 seeds can be lethal for humans. Only a Mexican species can be eaten after special treatment.

[2] The use of any biofuel (=fuel of plant origin) theoretically has an even CO_2-balance because the amount of CO_2 that is released in the combustion has been absorbed from the atmosphere and was bound by the used plants only few years earlier. In contrary, the use of fossil diesel discharges CO_2 that was bound thousands of years ago and therefore ads up to the current level of atmospheric CO_2. However, the overall lifecycle assessment will not be all that favourable as for production, transport etc. of the biofuel there is always energy input from conventional sources producing CO_2 (cf. also 7.3 Agricultural and Ecological Downside of Biofuels).

[3] Other such engines types are: Deutz, Hatz, IFA, Elsbett, DMS, Farymann.

[4] Preheating to about 110°C, mixing with fossil fuel or two-tank system.

[5] By transesterification: methanol or ethanol is added to the oil; the reaction produces biodiesel and glycerine. The glycerine is separated from the diesel and can also be used further.

Press Cake: Organic Fertilizer and Combustible

Contrary to some sources, the JCL is not a nitrogen-fixing plant. The press cake however, is saturated with nitrogen-fixing compounds thus making it a good organic fertilizer. The press cake has a nitrogen content similar to chicken manure and richer than cow dung. A GTZ case study (quoted in: Heller 1996) with pearl millet in Mali showed that it is more rentable to use press cake than mineral fertilizer: The yield was slightly higher and the costs considerably lower.

Literature suggests that the use of seedcake as fertilizer is very easy but does not specify how the seedcake has to be used. Van Eijck stresses that the seedcake should not be used as a fertilizer without composting it first, a process in which the toxic substances of the oil-rich press cake decompose. Henning (Henning/GTZ 2000) states that the toxic oil residue in the press cake acts as an insecticide and reduces the amount of the nematodes in the soil.

Composting however means additional work – which can bring about additional benefits. In the ideal case, composting is done in a simple reactor, producing biogas at the same time. Kakute has set up such a reactor in their compound in Arusha. With the 8 x 1 m plastic reaction tube (using 2 kg seedcake + 2 kg cow dung + 20 l of water) one stove can be fed (“light meals only”).

Illustration 5: Simple biogas reactor tube (below, left) and balloon tank. Kakute, Arusha

Because of the considerable amount of remaining oil in the press cake (with current technology ~15% of seed weight) it can be used for firing bricks, although only for industrial use as its combustion needs high temperatures and produces a lot of (toxic) smoke. Diligent produces such firing bricks and is also developing a charcoal briquette for household use from carbonized press cake. The latter product is not yet being sold because it is not sure if the smoke is toxic – Diligent has sent samples to a South African lab for fume testing; the charcoal briquettes are light and crumble easily.The press cake cannot be used in animal feed because of its toxic properties.

Other Uses

Because of its drought resistance JCL can play a role in combating desertification and for soil erosion control as it is being propagated recently in Cape Verde. In Madagascar and also in a few places in western Tanzania and Uganda, it is used as a support plant for vanilla. JCL wood can be used as a burning material but is of poor quality for that purpose as it is very light (density below 0.35 t/m^3). Fruit hulls, seed shells and press cake can be used as a burning material.

Other potential uses e.g. as plant protectants could hold more possibilities but are still being studied.

Seed Yields in Theory and Practice

In the consulted literature the figures for JCL seed yields largely range between 4 and 8 tons per hectare and year (for mature plants after 4 to 6 years). Some sources though go as high as 12.5 t and few indicate yields less than 1 t per hectare.

The reports of yields in literature vary greatly and in addition they are difficult to interpret due to the following factors: yields are reported in weight per ha in some cases, in others per plant; no indication of variance in germplasm (provenience); unstipulated spacing between plants (plants/hectare); no specific data on soils (ranging from marginal to fertile, and if fertilizer was applied); no information on rainfall and other climatic conditions, and if plants were irrigated. When irrigated, Jatropha trees are said to produce seeds throughout the entire year. For plantation yield reports (often projected yields), it is not mentioned if they were established by vegetative propagation (cuttings) or by direct seeding. Often, the age of the plants is not mentioned. JCL is said to begin producing a measurable amount of nuts at approx. 18 months (after 1 rainy season for cuttings and seedlings, after 2 rainy seasons for direct seeding), but is not expected to reach maturity and optimal yields until after 4 to 6 years. Also, yield variations between years are missing.

What's more, in some literature clearly dedicated to promote Jatropha, the figures used as a basis for feasibility calculations should be consumed with great care. It seems that often, these relatively high figures are not based on a specified source but are probably more likely desired yields or such achievable under "optimal conditions".

To better assess the figures found in literature, yield figures from existing projects and estimations of actors in the field in Tanzania were consulted. Van Eijck (Diligent, Arusha) and Burland (Kikuletwa Farm, Moshi) have years of experience and they concur in their information on yield: In a semi-arid area with one rainy season, no artificial irrigation and no fertilizing not more than 2–3 kg of seeds can be expected from an mature JCL plant as an average. Burland, who has been keeping record on the development of his plants for the past 5 years states that his best trees yield up to 5 kg. It must be noticed however, that Moshi gets around 1000 mm of rain per year – almost double of what Dodoma gets.

Departing from 2–3 kg of seeds per plant, planted at a 2.5 x 2.5 m spacing to allow enough room for the trees and for intercropping 1600 plants will be found on one ha (or 640 on one acre) producing 3200–4800 kg of seeds per hectare and year. At an extraction rate of 25% 800–1200 kg of oil could be produced per ha and year. In a region with two rainy seasons (or if irrigation is applied) it can be expected that this yield would almost double (usually the 2nd season brings less rain).

Apart from precipitation and irrigation, which seem to be the major factors, the yield is influenced by the following factors:

- Care: trimming, protection against insects and pests
- Provenience[6]: adaptation to planting area
- Method of propagation: seedlings or cuttings (cuttings produce earlier)
- Selection of seeds and cuttings
- Planting density (spacing)
- Natural soil condition and fertilization

[6] Lately there have been reports on high yielding varieties from Indonesia and Brazil (www.jatropha.de → news) and D1 oils plc is selecting elite seeds for for increased oil yield (D1 oils plc 2006/b).

Oil Content

The oil content of JCL seeds is less contradictory. It varies between 31% and 39% of the seed weight (most figures around 35%).

For comparison the oil contents of some other plants: oil palm fruit 55%; oil palm kernel 45–55%, coconut (dry) 65–70, groundnuts 40–50%, sesame 35–50%, sunflower 25–40%, cotton seeds 15–25%, castor 35–55%, soybean 15–20%, safflower 35–45%, rapeseed 40–45%.

The amount of oil that can effectively be won from the seeds is mainly dependent on the used machinery. The entire 35% oil content in the JCL seed can only be extracted by chemical means. This is complicated and expensive.

Currently, in Jatropha projects in Tanzania one of the following two presses are used[7]:

Sayari or *Sundhara Expeller*[8]. This expeller is a German development but is produced and sold locally by Vyahumu Trust, Morogoro (TZS 3.2 M) who also provides training. It is an engine driven screw press (diesel or electric). In the lab Diligent managed to recover maximally 73% of 38% measured oil content in the seed (recovery = 27% oil/seed weight). In practice the recovery rate lays between 15 and 20% (oil/seed weight); that's 5–6 kg of seeds for 1 l of oil. The Sayari Expeller can be used for small-scale industrial use. The capacity reaches 20 l/hour.

Ram-press[9]**.** The ram-press is a small hand operated one-man press. In Tanzania it was developed in 1986 by Appropriate Technology International (ATI). It is also known as *Bielenberg ram-press* named after the developer. In lab tests up to 20% oil (by seed weight) could be extracted using the ram-press. However, in practice the recovery rate usually lies around 10% (10 kg of seeds for 1 l of oil). This press is used in smaller, village-based projects with little seed volumes to press. Kakute sells such locally made ram-presses (TZS 200,000). The capacity is about 1.5 l/hour.

Illustration 6: Ram-press (Kakute) and Sayari Expeller (Diligent). Photos: J. van Eijck

3 Earlier Experience with Jatropha

GTZ has a long history of JCL projects in Mali, Cape Verde and Central America. Most of these projects followed the "Jatropha System" approach for community development (cf. chapter 4.1). GTZ evaluated the small-scale "Jatropha System" approach in 1997 for a project in Mali and 2003 for another one on Cape Verde Islands (GTZ/Wiesenhütter 2003). GTZ concluded in both cases that they

[7] For foreign expellers (incl. technical details and prices) refer to Energy Africa/Grimsby (2007).

[8] Details on: www.jatropha.de/tanzania/expeller.htm

[9] http://www.jatropha.de/rampresses/biel-ram.htm

were not economically viable, mainly because the produced oil was much more expensive that fossil diesel. The only places where GTZ saw the chance of viable JCL production was for remote areas where fossil fuel is expensive or not available throughout the year. However, another major problem was found in the fact that it was very unlikely that the population would embrace the idea in the long run and take over the projects. The JCL oil was finally only used for the engines running the seed presses and for the production of soap. For the soap GTZ found that the quality was lower than imported toilet soap and the production was largely dependent on necessary additives that could not be found in the country. Also, for soap production only small quantities of oil are needed. The final conclusion of GTZ was for both cases that under the found circumstances and at that time, JCL production could not benefit poverty alleviation in a sustainable way. Economic viability could only be calculated by also including secondary values like press cake manure and erosion control in the cost-benefit analysis.

An initiative of the Austrian Development in Nicaragua 1997, worked with Jatropha plantations and a central processing plant for biodiesel production. The project failed because it was economically not viable and no major oil company was interested in offering an alternative fuel at that time. (GTZ/Wiesenhütter 2003.)

Euler and Gorriz (2004) analyzed initiatives in Belize, Nicaragua and India and found that in many projects too high expectations were created, not only among the participants, the set-up of projects was based on far to high figures for seed yields. In Nicaragua monoculture plantations were established and as the projected yields were not achieved the farmers soon replaced Jatropha by food crops.

From his work in Tanzania Grimsby confirmed cases of disappointment and abandonment in projects where farmers were promised a lot and not realistically informed about time frame and risks. In such cases it is very difficult to win back the confidence of the farmers – also for the introduction of other new crops or methods.

For India, Euler and Gorriz found that for households who had an alternative option for agricultural income Jatropha could in no case compete economically with the alternative option. They conclude that the failing of all the examined initiatives (measured at their targets) is due to the neglect of the necessary production factors (establishment costs, long term investment, insecure land tenure for poor producers, basic production for market development). They underlined that the modesty of the plant only guaranties its own survival under harsh conditions – and not the yields necessary for an economically viable use.

Economical viability was not achieved in several past projects. At this point it is important to point out that the price of fossil oil is a major factor in determining the viability of alternative fuels. Because the oil price lately rose considerably such past experience should be revised under the light of higher oil prises, which could significantly change an assessment in favour of alternative fuels.

4 Jatropha Activities in Tanzania

For this study the Jatropha initiatives in Tanzania were split up according to the criteria if they influence or have the potential to influence the Jatropha market. This separation leads to three groups of actors in the field of Jatropha: Small-scale projects, usually on village level that use the produced seeds and the oil for further processing or consumption and are not directly related to a national or international market on one hand and the medium-scale projects which are market related because they buy and sell seeds and interact with each other. A third group would be projects that are clearly dedicated to large-scale production and export. A few such initiatives have been around and are still around but none of them has made substantial progress to date. For an overview please also refer to the list of the actors in the field of Jatropha in Tanzania in the appendices.

4.1 Minimal Market Links: Small-Scale on Village Level

The Jatropha System

In the 1980s and 90s Reinhard Henning and GTZ developed *The Jatropha System* (Henning, 2004)[10]. It is the concept of an integrated rural development approach. By planting Jatropha hedges to protect gardens and fields against roaming animals, the oil from the seeds can be used for soap production, for lighting and cooking and as fuel in diesel engines. In this way the Jatropha System covers 4 main aspects of rural development:

- Promotion of women (local soap production)
- Poverty reduction (protecting crops and selling seeds, oil and soap)
- Erosion control (planting hedges)
- Energy supply for the household and stationary engines in rural areas (mills for maize, oil)

The advantage of the Jatropha System is that all the processing procedure, and thus all added values, can be kept within the rural area or even within one village. No centralised processing (like e.g. in the cotton industry) is necessary.

The central hypothesis of the Jatropha System is: the Jatropha System creates a positive reciprocity between raw material/energy production and environment/food production i.e. the more seeds/oil Jatropha hedges produce, the more food crops are protected from animals and erosion. Also additional income is created, mainly for women.

In Arusha, Kakute is roughly following the Jatropha System approach in their soap production projects with the “Alternative Resources Income for Monduli Women” (ARI Monduli) and the ARI Arumeru women groups. However, these projects are limited to soap production and the use of locally made ram-presses for oil extraction.

The system can be extended or altered to fuel production for project vehicles and village electricity generation. A combined approach with solar and plant oil generated power is being carried out in Mbinga (Ruvuma Region) with the support of different German partners.[11]

For an overview about all small scale Jatropha activities in Tanzania please refer to the list of the actors in the appendices that includes brief project aims and contacts.

4.2 Medium-Scale: Regional and National Level

In this group all actors are described. Some of these actors have the potential to target international markets. They are listed in this section for what they are now: active at a regional and national scale.

Diligent Tanzania Ltd., Arusha

Diligent Tanzania Ltd.[12] (D) is a company dedicated to the production of Jatropha oil and biodiesel but also offers consultancy cervices on Jatropha growing. At the moment, D is the only actor in Tanzania who produces oil for sale. D modifies diesel engines in cars for straight vegetable oil use (SVO; 5 to date) and they also invest in research on JCL in their own lab and test fields.

D has its basis in Holland and a branch in TZ and Columbia. D receives Holland government funding for its first phase of three years, after that they have to work profitable. The first phase ends in

[10] For more information and many links concerning the Jatropha System refer to Henning’s JCL site: www.jatropha.de

[11] Mbinga: www.sonne-ueber-mbinga.de/en

[12] Diligent TZ Ltd.: www.diligent-tanzania.com

December 2007. Diligent TZ is managed by Janske van Eijck who wrote her master thesis "Transition towards Jatropha Biofuels in Tanzania?" (van Eijck 2006) before working for D. This work gives a detailed insight in the JCL scene in Tanzania in the year 2005, including economical calculations and involved actors.

As the JCL cultivation initially takes time to get established and D therefore gets less seeds at the moment than it could handle, D has also started to sell its services/advice on JCL. D has through the last years gathered a considerable amount of experience in the field of JCL in Tanzania. D believes that it is important to do research them selves. Presently D is engaged in:

- Testing of different Jatropha varieties
- Different soil analysis and plant reaction
- Lab tests with the oil (on storing, moisture content, de-gumming/refining etc.)

For the scientific part D hosts interns from European universities.

van Eijck states that there is very little JCL knowledge present in TZ. D receives many proposals but in many cases the people have very high hopes but actually no knowledge at all. D wants to spread realistic expectations and provide thorough training; van Eijck sees the need even just for planting/cultivation.

D has produced 10,000 l of filtered JCL oil last year. Van Eijck believes that the market is no problem. D gets many requests for oil and biodiesel from big companies (e.g. Mitsubishi). Even if the demand in Tanzania would be smaller than the offer D could sell the oil via Holland. At the moment the production of D is not even big enough to meet the demand of themselves and their partners: D sells oil to Kakute who is involved in several JCL initiatives and BSH (Bosh und Siemens Hausgeräte) who is doing large scale testing of a vegetable oil stove in the area of Arusha. Therefore, D does not even fuel its own modified car with JCL oil.

D is about to establish a big surface JCL plantation in Handeni or Tanga. Up to now, D bought the JCL seeds from farmers around Arusha (TSH 120/kg at factory gate or TSH 100/kg when collected). D is now extending the outgrower concept to Singida Region where they are planning to set up collection centres. D offers outgrowers 10-year contracts.

D is also experimenting with biodiesel. D has ordered a 300 l reactor and will start producing biodiesel soon. In the long run however, D wants to focus on the production of refined oil for SVO – not on mass production of biodiesel.

D is linked to the Dutch founded FACT foundation[13].

Kakute Ltd., Arusha

Kakute Ltd. (Kampuni ya Kusambaza Teknolojia)[14] is a private company, which was established and registered in 1995 with a social justice agenda to reduce poverty through real business opportunities. Kakute Ltd. is working for the promotion of Jatropha and related technology transfer. Kakute trains farmers in Jatropha planting, oil pressing and soap producing, and implements the ARI-Monduli project (Alternative Resources Income project for Monduli women), where several women groups are producing Jatropha soap at village level.[15] Kakute is sponsored by the British McKnight foundation. Another project implemented by Kakute is Kiumma Hospital (Matemanga, Tunduru), where a JCL plantation was established with the aim to run the hospital's generator on JCL oil. These projects typically fall under „The Jatropha System" – Kakute is listed here because they are a major actor in

[13] Fuels from Agriculture in Communal Technology: www.fact-fuels.org

[14] Kakute Ltd.: www.Jatropha.de/tanzania/Kakute/kakute.htm

[15] ARI-Monduli: www.Jatropha.de/tanzania/Kakute/ari-monduli/ari-m-project.htm

Tanzania's Jatropha business, involved somehow in a lot of projects and initiatives and they do buy and sell seeds, seedlings, oil and equipment.

Kakute buys and sells JCL seeds and also grows their own seeds. Kakute sells equipment such as locally made ram-presses (recovery rate ~10% oil/seed weight, TZS 200,000 ($ 160), oil lamps TZS 2000 TZS ($ 1.6). Kakute Ltd. is also developing a JCL cooking stove in cooperation with the University of Dar es Salaam, but so far without success.

Kakute experiments with biogas production from JCL press cakes. The small reaction tube (8 x 1 m; mixture of seed cake, cow dung and water) at their compound in Arusha can feed one stove ("light meals only").

MVIWATA: Private-Smallholder Farmer Association Partnership

This initiative is based on a cooperation between a private company and MVIWATA (Mtandao wa Vikundi vya Wakulima Tanzania), a strong Tanzanian farmer's organization. The initiative aims at involving 10,000 small-scale farmers, initially in Morogoro Region, to plant Jatropha in hedges. A processing plant will be established in Morogoro for oil processing. The actors behind this initiative estimate that the demand for JCL oil is so much higher that the offer that the storage time will be less that 4 months. Therefore the oil will be filtered only. There will be no production of biodiesel. The target market for the oil is the domestic energy market (lightening, cooking, engines and transportation).

The farmers will be offered a 5-year contract with a guaranteed minimum price of $ 0.1 per kg of dry seeds. The initiative is in the early stages of implementation, just about 2000 Farmers are involved so far. The target per farmer/household are 1000 JCL plants. Conservative yield estimates are used with 1 kg/plant in the third and 2 kg/plant from the fourth year on. This would mean an additional net profit over the five-year period of at least TZS 250,000 for each participating household. Once the plants are mature the same amount could be achieved yearly.

In terms of production the capacity once the target is met would be 20 million kg of seeds (10,000 households * 1000 plants * 2 kg) or 4 million litres of oil (at a recovery rate of 20% of seed weight).

Other Actors

Kikuletwa Farm of Peter Burland

Burlands main business is Aloe vera. Earlier, he believed in big financial potential of Jatropha and wanted to plant large surfaces of JCL. He started planting JCL in 2002 so the oldest plants on his farm are almost 5 years old now. He apparently changed his mind and focussed on Aloe; but was contracted in 2005 to plant 20 acres (8 ha) of JCL. The contractor lost interest and Burland continued to manage the JCL on his own, in a research way, planting JCL from different proveniences, comparing performance of seedlings and cuttings etc.

At the moment, Burland has 6000 kg seeds harvested in 2006 but he is not keen on selling them to e.g. Diligence at a price of TZS 100–120; he believes that he will be able to sell at a higher price. Burland does not produce or process oil. In the short run he just wants to continue the research on JCL but he hopes to find someone who will take over the JCL plantation in the long run. Burland provides seeds for planting. Responsible for the JCL research is Ramadan Kidunda.

JPTL

JPTL (Jatropha Products Tanzania Limited) is a Jatropha umbrella organisation of which Kakute is also a member. This organization has been around for some time; it recently (February, 2007) had a meeting to discuss its future. What kind of activities they are really planning is unclear.

TaTEDO

TaTEDO (Tanzanian Traditional Energy Development and Environment Organization)[16] is a Tanzanian NGO working with rural alternative energy sources. It is running two Multi Functional Platforms (MFP), one outside Dar es Salaam, one in Monduli (Arusha). TaTEDO is experimenting with biodiesel production from JCL and has been involved in studies on biofuels with GTZ for the national biofuels taskforce. TaTEDO buys JCL seeds and oil.

BSH, ProBEC and GTZ

The German domestic appliances producer BSH (Bosch und Siemens Hausgeräte GmbH) has developed the "protos" plant oil stove that had vast success in the Philippines about 10 years ago. Together with ProBEC BSH is now testing this stove thouroughly after it has been adapted to JCL oil in Arusha. The tests are coming along well but there are still some issues to solve and it is not clear yet when the stove can be introduced and promoted on a large scale. ProBEC (Programme for Biomass Energy Conservation in Southern Africa)[17] is a SADC (Southern African Development Community) programme, which is implemented by GTZ[18]. The group testing the stove is closely collaborating with Diligent from whom it gets the JCL oil.

Illustration 7: Plant oil stove "Protos": burner (front), oil tank and pressure pump (rear), BSH/ProBEC, Arusha

4.3 Large-Scale: Targeting International Markets

Large-scale projects have been announced in Tanzania more than once. The UK-based global producer of Biodiesel D1 oils plc[19] announced a large-scale plantation in Dodoma Region years ago but it never took off. D1 however, is a major player in the emerging field of biofuels (cf. chapter 5.2).

Even though currently, no large-scale project is yet producing in Tanzania there are two initiatives that might become significant over the next years.

[16] TaTEDO: www.tatedo.org

[17] ProBEC: www.probec.org/goto.php/index.htm

[18] GTZ Tanzania: www.gtz.de/en/weltweit/afrika/tansania/599.htm

[19] D1 oils plc: www.d1plc.com and www.d1africa.com

Sun Biofuels Ltd.

In 2004 Sun Biofuel Ltd.[20] started the initiative for a large-scale plantation in Kisarawe District. Malcolm Doherty has the mandate to set up this project that shall start with 9,000 ha and expand to 18,000 ha. The project budget is £ 10.4 million. The requested land survey, demarcation and village meetings were carried out, all the villages have agreed to the project that promises to create employment for 4,000 people. Nevertheless, Doherty has constantly been meeting new challenges: He has still not obtained all the necessary permits from the government. Almost a year ago, expecting to be able to eventually start establishing the plantation, a South African project manager was hired who has since then not been able to start his work. The investors are according to Doherty getting impatient and are considering dropping the project and instead going to Uganda where the government offers land and licences "without lots of bureaucracy".

During finalization of this study, Doherty announced that the project is now a go and that he is looking forward to start planting early next year.

Donesta Ltd. and Savannah Biofuels Ltd.

Donesta Ltd. (Dodoma Nursery and Estates) is a Tanzanian company new to the Jatropha field. Donesta is planning to establish JCL estate farms in different places in Dodoma Region. A nursery has been established with 100,000 seedlings to date to be planted out with the next rains. For the time being, Donesta has acquired 2000 ha and has started this January with planting 200 ha of sunflowers – allowing to cover the farm clearing costs. Donesta wants to continue this 2-crops-strategy and intercrop sunflower with JCL at least until year 3 when they expect to start harvesting JCL seeds. In this way Donesta hopes to cover directly some of its investment. Donesta is foresees to install an oil mill with the efficiency of 25% before the end of this year. The plan is to encourage as many outgrowers as possible in the area to follow their own example and plant JCL and sunflowers intercropped – with the offer to buy first sunflower and then JCL seeds from the farmers.

Donesta is aiming at exporting crude Jatropha oil to the expanding European biofuel market. They do not know yet if they will produce biodiesel for the national Tanzanian market.

5 Jatropha Activities Elsewhere

5.1 East Africa, India, Australia

There have been and there are many Jatropha projects and initiatives around the world. However, to the author's knowledge, there is at present no large-scale JCL project that is already producing JCL seeds and oil in large amounts in any country. This is also the reason why to date, no international market for JCL oil or biodiesel has been established. The feedstock is simply not there yet.

Nevertheless, there are medium- and large-scale projects, most of which started planting JCL 1–2 years ago, that will start harvesting major quantities of JCL seeds in about 2 years from now.

In the region of East Africa, Tanzania seems to be ahead with most small- and medium-scale JCL activities. However, there are several JCL projects emerging in Uganda (e.g. Consumer goods producer Mukwano Industries[21] in Liria and the NGO VEDCO[22] in Mukono area) and in Kenya (e.g. Energy Africa Ltd. in the Shimba Hills[23]).

---

[20] Sun Biofuels: www.sunbiofuels.com

[21] Mukwano Industries Ltd.: www.mukwano.com

[22] Volunteer Efforts for Development Concerns: www.vedcouganda.org

[23] Energy Africa Ltd.: www.energy-africa.com/company_profile.html

Beyond Africa, in India the government shows much interest in becoming less oil-dependent through Jatropha and promises to engage in extensive plantations and supporting tax reductions.

Also in India, the oil-major BP, in cooperation with The Energy and Resources Institute (TERI) started an undertaking in Andhra Pradesh that claims to be “India's biggest biofuel production project”. The project[24+25] with a budget of $ 9.4 million started in 2006 and plans to cultivate 8,000 ha of JCL aiming at the production of 9 million litres of biodiesel per year. This project is part of BP’s commitment to invest $ 500 million for biofuel related research over a period of 10 years (2006–2015). Moreover, they already do purchase a considerable amount of biodiesel today (266 million litres in 2005), mostly for blending with conventional diesel.[26]

It must be noted that Jatropha does not play a role in today’s biodiesel production. In Australia for example, BP has announced that they will provide 200 million litres of biofuel per annum by 2008. Almost half of this amount will be ethanol made from wheat and the rest will be biodiesel made from tallow (rendered animal fat).[27] The main feedstock for today’s biodiesel production in Europe is rapeseed.

5.2 D1 oils plc: Around the World

D1oils plc[28] has the vision “to be the worlds leading biodiesel business”. Between 2005 and March 2007, the UK based company has planted 145,000 ha of JCL in Southern Africa, India and South East Asia. This of course means that for the time being, there is still no feedstock to produce oil and biodiesel. Nevertheless, D1 has established biofuel refinery capacity in the UK for 32,000 t per annum that is already operational. Here, D1 has successfully managed to produced biodiesel from JCL seeds fulfilling the European standard EN14214. D1 is establishing a second refining plant and will have a total capacity of 132,000 t by the end of 2007 and is targeting 320,000 t by the end of 2008. D1 plans to start delivering Jatropha oil and Jatropha biodiesel to the UK market in 2008.

D1 is in the process of developing an improved JCL “elite” seed called “E1” that is supposed to yield almost double the oil production compared to the seeds used today.[29]

In 2006 D1 had net expenses of £ 46.2 million and wrote a loss of £ 12.6 million. D1’s total equity shareholders’ funds are £ 80.5 million. (D1 oils plc 2006a+b).

[24] BP: www.bp.com/genericarticle.do?categoryId=2012968&contentId=7014607

[25] The Energy and Resources Institute: www.teriin.org/press_inside.php?id=17110

[26] BP: www.bp.com/genericarticle.do?categoryId=2012968&contentId=7018719

[27] BP: www.bp.com/genericarticle.do?categoryId=2012968&contentId=7016898

[28] D1 oils plc: www.d1plc.com and www.d1africa.com

[29] D1 expects an oil yield of 1.7 t/ha with “wild” seeds and at least 2.7 t/ha with “E1” seeds. These seeds shall be planted from 2008.

6 Biological Feasibility: Precipitation and Soil

Jatropha grows on marginal soils like they exist throughout Dodoma and Singida Region. Crucial however is the level of precipitation. Literature coincides that a minimum of 550–600 mm annual precipitation is necessary for JCL to grow. The table below gives a selection of rainfall levels in Places in Dodoma and Singida Regions and a few other places to compare.

Dodoma (DOM)	550 mm	Shinyanga (SHI)	781 mm
Kondoa (DOM)	604 mm	Kahama (SHI)	1022 mm
Kongwa (DOM)	512 mm	Tabora (TAB)	863 mm
Mpwapwa (DOM)	721 mm	Morogroro (MOR)	913 mm
Manyoni (SIN)	652 mm	Arusha (ARU)	1191 mm
Singida (SIN)	670 mm	Monduli (ARU)	840 mm
		Moshi (KIL)	955 mm

***Table 1: Annual rainfall in the Central Corridor (and other places to compare)*[30]**

The regional average precipitations are slightly higher in all cases: Dodoma 666, Morogoro 1079, Singida 789, Shinyanga 1065 and Tabora 894 mm per year (Heinimann et al. 2004). According to these figures – no matter if it gets slightly more or less than 600 mm of annual rainfall – Dodoma is on the limit. However, the fact that examples of JCL can be found growing in several places in Dodoma Region (near Chalinze and Mvumi) and many farmers have been using JCL hedges for a long time in Singida Region (where Diligent TZ Ltd. is setting up collection centres for JCL seeds) proves that principally JCL does grow in these regions. As there is no monitored project in these regions not much can be predicted about the exact performance of the plant.

It must also be noted that a drought year can disrupt a continuous yield: The plants in a documented GTZ project in India suffered severe moisture stress in a year of only 470 mm rainfall (annual mean 630–870 mm). They didn't yield any seeds in the drought year and in the following year the yield was lower than usually (GTZ, Sustainet/Gaul 2005).

The sandy soils with low nutrition of the semi-arid Central Corridor generally seem to be suitable for JCL. However, the reaction of JCL to two soil characteristics could not be answered conclusively: salt content and water logging (water saturation of soil surface area). Doherty indicates that JCL is slightly salt-tolerant but is frail to water logging (the latter was strongly confirmed by van Eijck). This should be kept in mind thinking of the plains around Dodoma that can be flooded during months in years of strong rain (2006/2007) and that in some places have salt concentrations, which are so high that the salt can be harvested.

[30] Long-time average from the early 20th century until the 1980s; data derived from The Global Historical Climatology Network: www.worldclimate.com

7 Economical Aspects

7.1 Production

This chapter outlines the important cost factors without going into a full cost breakdown.

Establishment of Seed Production

First of all, the establishment of a JCL plantation is an investment with late return: JCL produces first fruits after 2 rainy seasons, then the yield gradually increases until the plant is mature after 4–5 years. No meaningful yield can be expected for at least three years from planting. Therefore, any investor has to be able to afford this "waiting period" or develop a strategy to fill this time without return, e.g. by intercropping. Kanji says that with the growing of sunflowers in the first year he can cover the land preparation costs (clearing, spraying). For an investor in a large-scale plantation this is perhaps less crucial then for a poor outgrower. Subsistence farmers will not be inspired easily by a concept where there is no short-term benefit. Intercropping with food or cash crops or the planting of JCL as protection hedges that provide other benefits seem to be viable options while awaiting the first yields of Jatropha seeds.

For the establishment of a plantation the land should be cleared completely to reduce the risk of pests and insects to the vulnerable young plants to a minimum. JCL can be planted as seeds directly or as seedlings. Seedlings are the more secure option but add costs for nursery material, care, transport, and planting. The planting of faster yielding cuttings is only advisable in more humid areas because the roots develop more shallowly.

The establishment investment was not calculated for this study as it depends largely on the kind of plantation (size, environment) and the methods used (direct sowing, seedlings from nursery, cuttings; irrigation; necessary treatment of surface). A GTZ study however, calculated 460 €/ha for the establishment of a JCL plantation with 1300 plants per hectare (GTZ, EUEI/Gaul 2006).

Seeds for planting are available in Tanzania from 1500–3000 TZS/kg.[31] The Tanzanian Tree Seed Agancy (TTSA) sells JCL seeds from Utengule (Iringa) highly overpriced at 11,000 TZS/kg. TTSA also offers seedlings for 500 TZS/piece.

Running Costs

Weeding the plantation and pruning of the trees is the minimum maintenance; and at least from time to time some treatment with pest or insect killer will be needed (Burland).

On Kikuletwa farm a worker picks about 30 kg of dry seeds per day, that is about 4 kg/h. Henning (2004) gives a picking rate of only 2 kg of dry seeds per hour. Even calculating with the higher picking rate of 4 kg/h, the annual picking costs for a hectare (1000 plants, 2 kg of dry seeds each) are still high: TZS 133,000. Regarding the value of the seeds of TZS 200,000 (2000 x TZS 100) the picking costs are critical. Because of this huge labour cost for picking, which hardly can be mechanised, an economy of scale will have only a minor effect on the realised profits. At the assumed rates for running costs (only direct costs, see below) the seed production with a plantation would financially not be more interesting than buying the seeds at the currently paid price of TZS 100 per kg.

Heller (1996) reports that the best pickers in Nicaragua harvest up to 18 kg of seeds per hour. This picking rate would significantly change the picture. As there is at the moment no plantation in Tanzania that is operating commercially it is not possible to obtain secure facts on picking rates.

[31] 1 kg ≈ 2000 seeds → ~0.5 kg/ha → ~1000 TZS/ha for seeds only.

Doherty however, calculates with a picking rate of 12 kg of seeds per hour. This would make a big difference leaving the plantation an advantage in direct seed costs of 85,000 TZS/ha (cf. table below).

Doherty in his project plans to reduce the running costs by letting local farmers intercrop their own vegetables etc. in the plantation – at the condition that they do the weeding.

	Harvesting performance	
	low[32]	high[33]
Weeding (chemical, Burland)	30,000	30,000
Pest/insect treatment (own assumption, conservative)	10,000	10,000
Pruning (own assumption, conservative)	30,000	30,000
(Irrigation, fertilizing)	0	0
Harvesting	132,000	45,000
Total direct running costs TZS/ha (1000 plants, 2 kg seeds/year and plant)	≈ 200,000	≈ 115,000

Table 2: Estimate for direct running costs of Jatropha plantation per hectare

Outgrowers vs. Farm Plantation

The direct running costs of a plantation – without overhead for the plantation itself and with the low picking rate of 4 kg/h – amount to TZS 200,000 for one hectare producing 2000 kg of seeds. This is the same price that is currently paid to buy 2000 kg of JCL seeds directly from farmers (at 100 TZS/kg, cf. Market and Prices, below). This means that running a plantation – mostly due to the high harvesting costs – is not cheaper than buying directly from outgrowers.

Looking at the outgrower model there are cost adding factors that can be substantial. Collection centres have to be set up in order to accumulate reasonable amounts of seeds, transports have to be undertaken and collection activities have to be organized. This is especially costly if seeds are collected in remote areas. To illustrate the cost of transport: To run a Fuso and collect 7 t of seeds over 500 km (and back), the equivalent of 750 kg (more than 10%) of seeds will be used on the fuel for this journey.[34]

The margins in JCL oil production are very narrow. Therefore careful calculations for an outgrower model have to be made in each single case. It is advisable to set up a seed processing plant (oil mill) in an area where a big number of outgrowers can be reached at short distances and much land is available for cultivation of JCL.

The big advantage of running a farm plantation yet is that the owner has control over the production and a reliable feedstock supply.

Processing

In processing a major factor is the oil recovery. With the best current local technology about 5 kg of seeds are needed to produce one litre of crude JCL oil. It can be expected that better expelling technology could bring this ratio down to 4 kg of seeds per litre of oil. The improvement from 20% to 25% oil from seed recovery would mean a 25% increase in terms of absolute oil recovery.

[32] @4 kg/h: 1000 x 2 kg = 2000 kg / 30 kg/d = 66 man days * 2000 TZS day pay.

[33] @12 kg/h: 2000 kg / 90 kg/d = 22 man days * 2000 TZS day pay.

[34] Assuming a 7 t Fuso consuming 15 l/100 km and an oil recovery rate of 20% (of seed weight).

2000 kg seeds → [20%] → 400 kg = 440 l oil → [900 TZS/l] → 396,000 TZS/ha

2000 kg seeds → [25%] → 500 kg = 550 l oil → [900 TZS/l] → 495,000 TZS/ha

(German rape seed oil price per litre: € 0.55 = TZS 950)

Table 3: Influence of oil recovery rate on hectare value

The oil has to be at least filtered for the use in stoves or engines. If it has to be stored for more than 6 months the oil has to be degummed (refined).

Diligent Ltd. is the only actor producing a limited amount of oil for sale. There is nobody producing biodiesel in Tanzania for the time being. Therefore it was not possible to establish well-founded calculation for oil and biodiesel processing costs. It can be said though, that the margins are narrow (cf. Market and Prices, below).

The main focus of both Diligent and Donesta lies on exporting crude oil to be processed to biodiesel in Europe. Diligent plans to sell the oil also in Tanzania for SVO use and Donesta sees an option of producing biodiesel in Tanzania for the local market. It can be expected that these actors will adapt their products according to the development of a market and its prices.

Henning (2004) describes the economy of soap production by the example of the ARI Monduli women groups in Arusha and comes to the conclusion that soap production is "the most interesting and economically viable use of the Jatropha oil" because it is an appropriate technology for villages, where the entire value added benefits the village community (Henning 2000). A GTZ study on Jatropha soap production questions this at least for the examined case in Cape Verde (Wiesenhütter/GTZ 2003) comes to a much more critical result: Jatropha soap was of significantly lower quality compared to imported soap because of the lack of adequate technology on village level; except for Jatropha oil (which makes up only 20% in the recipe) all the ingredients had to be imported and the market was narrow. However, the village-level soap production was not covered in depth by this study.

7.2 Market and Prices in Tanzania

At present there is only a very small market for JCL oil and no market for biodiesel in Tanzania. Most projects pressing oil from JCL are small-scale and produce just for their own local needs. Diligent Tanzania Ltd. is the only actor theoretically producing for the market. In 2006 Diligent produced 10,000 l of oil (filtered, neutralized and degummed). This oil was mainly sold to other actors in the field of Jatropha development (BSH, Kakute). Within this development sector the demand is already so high that Diligent can't run its own modified car on JCL oil (February 2006). TaTEDO faces the same problem with the multifunctional platforms they are running: Because of lack of Jatropha oil they are currently fuelled with diesel (February 2007).

For biodiesel made from JCL oil the situation is even less advanced. Biodiesel is only being produced on experimental scale (by TaTEDO and Diligent, who is presently installing a 300 l reactor) even tough the demand from big companies (e.g. Mitsubishi) has been voiced. The reasons are the limited availability of seeds/oil in general but also the prices.

Diligent as the only major buyer has set the kg-price for seeds at TZS 120 ($ 0.09) at factory gate and TZS 100 ($ 0.08) at collections points. Diligent claims that they can not go any higher than these prices for the following reasons: Needing 5–6 kg of seeds to press 1 l of oil, Diligent makes a profit producing oil that they sell at TZS 1000 respectively 1500 ($ 0.77/1.15) to BSH for their stove development and to Kakute for resale. This price is slightly lower or comparable to other vegetable oils. On the oil no tax is paid so far.

For biodiesel the situation looks different: For biodiesel under the present legal framework the regular fossil fuel tax and VAT of roughly TZS 400 ($ 0.31) per litre would be applied. This means that with the currently used technology only the raw material cost and taxes already amount to around TZS 1000 ($ 0.77) per litre. During the past months the diesel price fluctuated between TZS 1100 and 1200 ($ 0.84 and 0.92). As biodiesel should be at least slightly cheaper than regular diesel it seems difficult to produce biodiesel profitably under the prevailing conditions.

This situation might change if there is a change in policy reducing the tax on biodiesel, with the introduction of more efficient technology in the oil extraction (currently, 15–20% of the 30–35% oil content are recovered) or with a further raise of the international oil price. A biofuel task force is working on the tax issue in the Tanzanian administration but it is difficult to find out anything about this development.

7.3 European Biofuel Market

In 2005, the EU produced 3.9 M t of biofuels. 3.2 M t of these biofuels were biodiesel and 0.7 M t bioethanol – in the US the proportion is contrary: much more bioethanol than biodiesel is produced. The EU biofuel production represents slightly less than 1% of the union's diesel and petrol consumption. Therefore, the target to replace 2% of petrol and diesel for transport by 2005 that the EU had laid down in its biofuels directive adopted in 2003, was not met. It also appears unlikely that all member states will achieve the 2010 target of 5.75% biofuels, even with substantial progress in the next years. The European Commission therefore aims at reinforcing their legislative framework and the EU leaders committed to a binding minimum target of 10% biofuels in road transport fuels by 2020 at the March 2007 European Council.[35]

The fact that the total production in 2005 increased by over 60% compared with the previous year (2.4 M t biofuels of which 1.9 M t biodiesel, 0.5 M t bioethanol) however suggests that there is an enormous development in the biofuel market and that the production of biofuels in 2006 was already considerably higher that 4 M t (European Commission 2006).

Rapeseed Biodiesel in Germany

Even though the European Union has targets on the market share of biofuels, there is no uniform policy and tax framework on biofuels in place. Several European countries have decided to support the production and use of biofuels through subsidies or tax reductions. To investigate on "the European market" Germany was chosen as a little case study. Germany is presently the largest biofuel market in Europe in which biodiesel has the major share (Germany is the worlds largest biodiesel producer). Also, Germany will most likely stay at the forefront of the development in biofuels due to its motor and car industry on one hand and its well-established biofuel industry and lobby on the other hand. Germany and Sweden are the only European countries that have met the EU target of 2% for 2005: Germany with 3.75% (mainly biodiesel) and Sweden with 2.23% (mainly bioethanol).

Situation

In 2006, Germany has taken serious steps going beyond the EU targets: In the law on biofuel quota the fuel producers were committed to provide 4.4% (1.5 M t yearly) of the diesel disposal in biodiesel from January 1st 2007. With 1.2% the bioethanol target at the moment is still low. The general biofuel quota has to reach 6.25% by 2009 rising to 8% by 2015.

Not only has Germany set targets beyond those of the EU, Germany has already surpassed its own targets for 2007 last year. In 2006 2.8 M t of biodiesel were consumed in Germany, of which 2.4 M t

[35] EU press release: http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/07/5

were produced in the country (VBD 2007). The biggest consumers are the transport industry and mineral oil companies that use biodiesel for blending (1.25 and 1 M t respectively; the rest is used in private and agricultural vehicles).[36]

Even though Germany has a production capacity (transesterification of plant oil to biodiesel) of more than 4.4 M t of biodiesel at present and will reach 5 M t by the end of 2007, the feedstock is not enough. Apart from its biodiesel import necessary to meet the demand Germany is importing rapeseed and also rapeseed oil to meet the demand of its own refineries. Once the German production is running on full capacity (5 M t) the country will be able to substitute more than 15% of its diesel consumption (energy-corrected figure: the energy value of biodiesel is 5–10% lower than for fossil diesel). (Zeddies 2006.)

Unlike in many other countries, where biodiesel is mainly blended with regular diesel (e.g. "B5": 5% biodiesel and 95% diesel) in Germany, more than 60% of the biodiesel is consumed as "B100" i.e. pure rapeseed biodiesel. The users are mainly the transport companies that fuel their trucks but Germany also offers a network of 1900 biodiesel stations for private consumers.[37]

Prices

The following price indications are for wholesale prices in Germany, May 2007 (UFOP 2007/a)[38]. It is with the range of these prices that an importer has to compete on the German market today.

Rapeseed, non food (240 €/t)	0.24 €/kg
Crude rapeseed oil, from mill (~610 €/t)	0.55 €/l[39]
Rapeseed biodiesel (without tax)	0.63 €/l[40]

Table 4: Relevant wholesale prices on German biodiesel market

The cost for transesterification (the refining of oil to biodiesel) is 0.07–0.1 €/l. For the last years, the biodiesel price at the petrol station was always about 0.1 € below the diesel price.

Subsidies and Taxes

Germany has adapted a new energy tax system that will gradually rise the taxes on biodiesel from the present 8.86 €cts/l to 45.07 €cts/l in 2015. The latter level almost corresponds to the current diesel tax of 47.4 €cts/l, which already applies to blended fuels like B5 (fossil diesel with 5% biodiesel).

General surface subsidies for farmers also influence the price of biofuel, which is still high, compared to fossil diesel and could not compete if it would underlie the energy tax for regular fuel. In the prospect of the slowly rising taxes on biofuel in Germany there is already a strong lobby calling for the complete tax exception of biofuel in order to keep German biofuel production viable. More so, as heavily subsidized biodiesel is entering the German market from the US. Thanks to a tax credit of 1 $/gallon (0.26 €/l) US biodiesel can be sold on the German market for 53.25 €, less than the wholesale price of crude rapeseed oil in Germany. In addition to the US tax credit, the US exporters avoid the EU external tariff on biofuels (6.5%) by declaring "Organic Chemicals" (0%). The German biodiesel producers are therefore calling for punitive tariff duties on such imports (UFOP 2007/a).

[36] Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e.V.: www.agqm-biodiesel.de/_1____95.html

[37] VDB: www.biokraftstoffverband.de/vdb/biodiesel/marktdaten.html

[38] UFOP provides a monthly newsletter on the German biodiesel market: www.ufop.de/publikationen_marktinformationen.php

[39] Density =ca. 900 kg/m^3; 1 t = 1111 l.

[40] 72 €/100 l incl. energy tax (8.86 €cts/l, not including 19% VAT); without energy tax: 63 €/100 l.

Limitation

Germany is currently producing rapeseed on a surface of 1.4 M ha; the limit is estimated to 2 M ha (Zeddies 2006). But the surfaces for the production of biofuels are not only limited for the EU's biggest biodiesel producer but for the whole of the EU. The European Commission calculates that the achievement of the target of 5.75% for biofuels set by the EU for 2010 represents the allocation of 18 M ha to their production – out of a total cultivable area of about 100 M ha in the 25 member states.[41] This certainly bears the risk of competition with the agro-foodstuffs industry and could result in a price explosion for certain agricultural products.

According to Zeddies (2006), the limits for rapeseed will be reached soon and the EU will have to focus on bioethanol, which is more surface efficient, to reach the set targets. His estimations predict, for agricultural reasons, that the EU-25 will not be able to substitute more than 3% of its diesel demand but up to 40% of the petrol demand with bioethanol (from cereals and sugar beet) by the year 2020. But to achieve this, significant investments in the bioethanol sector will have to be made.

Bockey (2006) comes to a similar conclusion and predicts that the EU's imports of oilseeds, oil or biodiesel will rise gradually if the EU member states are serious about reaching their targets.

Rapeseed yield: average seed yield 3000 kg/ha; oil content 43% → 1100–1800 l/ha
Rapeseed oil density: 0.9 t/m^3
Rapeseed biodiesel density: 0.9 t/m^3
Fossil diesel density: 0.83 t/m^3
Gallon (US liquid): 3.785 l
Biodiesel (rapeseed): 1 M t = 1.1 M m^3 = 1,100,000,000 litres

Table 5: Rapeseed oil and biodiesel: figures and conversion basis

Second-Generation Biofuels: Far Away Alternative

An alternative to the expansion of surfaces and the import of feedstock is to focus on second-generation biofuels. While first-generation biofuels are derived directly from oil or alcohol made from agricultural goods, the feedstock for second-generation biofuels are plants or fractions that are not in direct competition with plants grown for food and can be residues from agricultural or forestry activity (grass, straw, sawdust, off-cuts etc.). More generally spoken, it is possible to use the lingo-cellulosic biomass from all kinds of plants as a basis for fuel production. There are two ways to do this: The first is biochemical and involves extracting the sugar and glucose using very efficient enzymes. The other, known as "biomass to liquids" or BTL, involves first gasifying the raw material to a mixture of hydrogen and carbon monoxide and then transforming this mixture into a liquid fuel.

However promising these possibilities may seem (e.g. for the European forestry sector which is far from fully exploiting it's forests) the required techniques and processes are at this time still very expensive and at the same time inefficient. A third way to generate second-generation biofuel is to generate biogas through the fermentation of organic waste. Biogas however, needs a whole new engine technology and is therefore not directly compatible with the current systems. Sweden is the most advanced country regarding the use of Biogas.[42]

[41] European Commission, RTD Info: http://ec.europa.eu/research/rtdinfo/50/article_4231_en.html
[42] European Comission: http://ec.europa.eu/research/rtdinfo/50/article_4231_en.html

Compatibility is certainly the big advantage of biodiesel and bioethanol. Both can be used in any regular car in blends (of 5–10% biofuel) that are more and more widely sold (often without declaration; countries have started to oblige the petrol industry to generally blend a certain amount of biofuel in diesel and petrol). Biodiesel (100%, B100) can be basically used in all diesel engines; the car industry even offers solutions for the combination with modern diesel particulate filters. 100% bioethanol needs a slightly different engine, the so called "flex-fuel engine" that is widely spread in Brazil.

Agricultural and Ecological Downside of Biofuels

While literally the whole world – from political left to right, from the US to China – seems to have accepted the need and embraced the concept of biofuels, and in consequence has started taking serious measures and making major investments, there are voices getting louder, which question the blessing of today's rapid development towards more biofuels.

In Europe and the US most biofuel is produced from food crops like rapeseed, corn, soy or sugar beet. This has several consequences. In general, the available agricultural surface is limited, producing a competition between food and fuel crops respectively crops use for food versus fuel. To use food crops as a feedstock for fuel production causes more and more critique for ethical reasons, especially related to food shortages in parts of the world. The US is at the moment pushing their biofuel industry with good subsidies. Several new biofuel plants with high capacities are under construction that will produce ethanol from corn. At the same time, the US are are the world' and control over 70% of the world market. Countries that rely on the US exports will directly be influenced by the US biofuel production when the US exports lessen or end. Such developments can result in sharp rise of prices and even heavy social consequences (as seen in the corn price crisis in Mexico 2006)[43].

The subsidising of crops like rapeseed or sugar beet for fuel production makes such crops more attractive and more and more farmers might decide to produce them instead of another food crop for the national market, which in consequence has to be imported. Such imports cause environmental effects, mostly transport costs and emissions. A comprehensive ecological live cycle analysis of biofuels (Zah et al/Empa 2007), commissioned by the Swiss government acknowledges that such secondary environmental effects are minor. The same study has examined a number of parameters in different biofuels and concludes on results that make many biofuels seem much less ecological than one would have thought:

Biodiesel made from rapeseed, which accounts for almost the whole European biodiesel production gets a very bad rating regarding primary environmental effects: Compared to fossil diesel, the production and use of European rapeseed biodiesel reduces the emitted greenhouse gases by less than 20%[44] and the cumulated negative impact on the environment is even 2.5–4 times higher (Zah et al/Empa 2007). The reasons for this unfavourable environmental assessment are the intensive agriculture in the rapeseed production in general, a high input of conventional energy and over-fertilization of the soil.

Many actors promote Palm oil as a lucrative alternative choice for a biodiesel feedstock. Palm oil is the most surface-efficient oil plant; it yields more than 5000 l/ha compared to 1100–1800 l/ha from rapeseed (Schütz et al 2006). Even though palm oil gets a better rating than rapeseed oil in the Empa study (>35% reduction of greenhouse gases, cumulated negative environmental impact 1.5 times higher than from fossil diesel) the establishment of large-scale oil palm plantation has come under

[43] www.worldpress.org/Americas/2812.cfm | http://x.adelantesi.com/news/story.php?ID=397

[44] CO_2 is reduced more significantly but the production of rapeseed releases big amounts of N_2O a much stronger green house gas than CO_2 during growth, related to the necessary high fertilizer input.

strong pressure during the last years because in Malaysia and Indonesia such plantations are established on rainforest grounds. Environmentally, the most significant negative impact of palm oil production is the slash and burn practice of clearing the rainforest that causes not only dramatic biodiversity loss but also releases enormous amounts of CO_2 and other air polluting emissions increasing smog. The same holds for the production of soya oil in Brazil that is also used for biodiesel. Due to public pressure plans to use palm oil feedstock from Malaysia and Indonesia for new biodiesel plants were (temporarily) dropped in Germany. China however, is planning to establish the world's largest oil palm plantation on 1.8 M ha rainforest in Kalimantan, Indonesia for the production of biodiesel. (Schütz et al 2006.)

With regard to the ecological life cycle analysis, the energy recoveries from wood, grass and waste materials (used cooking oil, whey, cattle slurry, sewage sludge) performed best compared to fossil fuels. Not only are the high environmental impacts caused by the supply of raw materials eliminated, but also, pollutant emissions from refuse disposal are reduced. Likewise, good results are obtained from the use of wood and its gasification for energy, as the environmental impacts of obtaining the raw material are rather minimal. (Zah et al/Empa 2007.)

8 Conclusions

It must be underlined again that firm scientific knowledge on Jatropha is very limited. There have been many small-scale projects with Jatropha during the last 20 years but only few are well documented. A number of large-scale projects were started in different parts of the world just one or two years ago and therefore do not have the experience of at least 3–4 years to draw any important conclusions (also, the commercial ones will probably not provide such information readily). In Tanzania the first large-scale plantation was announced years ago but never launched. At the moment there are two serious large-scale projects but both of them have not yet started planting. Such projects generally have to be seen as experimental.

On the other hand the market for biofuel is growing rapidly in developed and emerging countries. But it is not clear how Jatropha will fit into this market. The time of another few years until meaningful amounts of Jatropha oil will be available for this market makes it even more difficult to predict the potential of Jatropha with certainty.

Generally speaking this means that there is a big number of unknown factors to the production, the processing of Jatropha seeds and the marketing of Jatropha products like oil and biodiesel. Nevertheless, after the careful analysis of the information gathered from literature and various actors in the field the following conclusion can be drawn, knowing that they partly rely on assumptions.

Growing Jatropha

Jatropha will grow in the semi-arid areas of the Tanzanian Central Corridor. Under the prevailing conditions of marginal soil and climate and with low management (no irrigation, minimal fertilizing), yield expectations for mature plants – i.e. after 4–5 years only – should not exceed 2–3 kg per plant and year. Intercropping is advised in any case for several reasons: The establishment period of the first 3–4 years can be bridged with short-term income through annual crops like sunflowers; the Jatropha trees create a more favourable environment (shade, moist retention, nutrients through ploughing in of pruning) for other crops e.g. vegetables; the risk of hazards like pests, insects and fire is reduced and local farmers can be permanently involved in plantation activities. A planting distance of 3 by 3 meter can be advised, leaving enough room for plant development and intercropping. At this planting density 1000 plants are planted per hectare and the seed yield is 2–3 t/ha. The oil yield with currently used machinery is 400–600 l/ha. At a planting distance of 2.5 x 2.5 m 1600 plants will be found on 1 ha, yielding 3.2–4.8 t seeds or 640–960 l oil per ha. These calculations are conservative. Through irrigation, fertilizing and more efficient expelling technology the yields are expected to increase considerably. In large-scale plantations there should be an option for irrigation to minimize the risk of crop failure in drought years (and recovery time after). Moderate irrigation would make even more sense in intercropping, actually irrigating the intercropped plants.

Besides intercropping a second model that will help to increase JCL production is the plantation of JCL hedges, which produces the additional benefit of farm protection (and is done already in e.g. Singida Region).

Plains that can be temporarily flooded (even if this happens only every leap year) have to be avoided. Jatropha doesn't support water logging and flooding. Due to the flooding and the high evaporation the soil of these plains commonly have an elevated salt content. Jatropha is slightly salt tolerant but will perform worse on salty soil.

Experience from Kikuletwa Farm in Moshi has shown that on plantations chemical plant protection is necessary. It is not sure that this is also valid for drier areas but it has to be expected.

Production Economics

Again, the establishment time of a plantation is the first difficulty to overcome. During the first 3 years there will be almost no harvest at all. The Jatropha plant will survive under very harsh conditions but to achieve economically viable yields a minimal amount of water (precipitation or irrigation) and fertilizer (at least plant cuttings and recycling of seed cakes) should be considered. A major cost factor is the labour necessary for harvesting the seeds. Different sources provide contradictory indications on this but they agree that it is a very cost intensive factor in a plantation.

Looking at the profits the oil recovery rate is an important factor. The introduction of advanced expelling technology will make an enormous difference, increasing the oil yield by 25%.

Market

In Tanzania there is only a very small and slowly developing market for Jatropha oil. The sellers and buyers are for the time being mostly involved in Jatropha development activities themselves. There are many small-scale Jatropha activities that do not aim at a market but at self-sufficient systems for livelihood improvement e.g. village engines running on pure JCL oil and propelling mills, water pumps or electricity units. The spreading of innovations like the BSH plant oil cooking stove will probably be more dependent on local oil production than on a national distribution grid for JCL oil. Soap, produced from Jatropha oil on village level is the only marketable product at the moment but this market was not examined.

The current Tanzanian policy framework does not favour Jatropha as a source for fuel. Biodiesel underlies the same tax as fossil diesel. This makes it very difficult to produce biodiesel at a price that competes with fossil diesel. If this situation would change (e.g. tax exemption for biofuels) there are other challenges to overcome. Establishing a distribution for a new fuel is one of them. The most likely option is probably the blending of biodiesel with fossil diesel because this doesn't require any additional infrastructure. But therefore agreements with major petrol distributors have to be made. Another option is the direct supply to large diesel consumers like transport enterprises (shipping, train, trucks, busses). In both options the price will be crucial.

Indications strongly suggest that the demand for Tanzanian biodiesel is there already. Diligent has received several enquiries from international companies who are interested in fuelling there fleet sustainably but also, Diligent claims that the company could sell "millions of litres" through their parent company in Holland. Today, even though the demand for biodiesel is there, nobody is producing biodiesel in Tanzania. What is being produced is oil, which is used directly in suitable engines respectively modified diesel engines.

The international market for biofuels certainly holds a big potential demand for Jatropha oil as a feedstock for the production of biodiesel. In Europe and the US[45] the capacities for the production of biodiesel (refineries) are expanding at a high pace while the limits for the production of feedstock in Europe are in sight already. New sources for feedstock will be needed if the European countries want to comply with the targets they have set for the substitution of part of their fuel demand.

Also on this market the price will be essential. At the moment biodiesel producers in Germany are buying crude rapeseed oil for € 0.55 per litre (TZS 935, $ 0.75). With advanced technology reducing the seed input to 4 kg per litre of oil the direct feedstock cost in Tanzania would come down to a promising price of 400–500 TZS per litre of oil. However, this is the current situation but meaningful amounts of Tanzanian Jatropha seeds will be processed in 3–4 years at the earliest.

A part from the local production costs three factors will be very important for the future attractiveness of Jatropha as an international feedstock for biodiesel: the global oil price, the development of subsidies for European and US feedstock and the development of tax reductions (the latter of course applies to the biofuel industry in general).

Not only the limitation of agricultural surfaces for rapeseed cultivation (soya in the US) will raise chances for an alternative biodiesel feedstock. The second important factor is the growing critique towards the use of food crops for fuel and the negative environmental impact of the highly mechanized energy and fertilizer intensive US and European agriculture. Certainly the US and european agricultural lobby will fight hard for its rapeseed and soya production (and the subsidies tht are coming along) but even if their production capacities are reached there will still be need for imported feedstock. Because Jatropha can be grown on marginal soils where it is very difficult to harvest food crop it will be an ideal alternative. Also, the environmental footprint will look attractive because little energy and fertilizer are needed.

The question seems to be less “will there be a market for Jatropha oil?” but much more: “Will Jatropha oil be there for the market (and when and how much)?” If the biofuel market doesn’t change dramatically over the next years (except for the expected growth) it will be open for Jatropha oil as a feedstock. If Tanzanian initiatives manage to produce this feedstock at an adequate price they will get their share in this market.

Opportunities for Rural Income Generation

In the past most Jatropha projects were based on the “Jatropha System” approach, which aims at community development through an integrated small-scale approach. The economical argument of village level value adding seems to make sense. Through the production of e.g. soap from Jatropha oil there is more value creation in the village and the farmers earn more than from simply selling the seeds. However, in practice the “Jatropha System” approach has not proven to be a model of success as described in several GTZ studies and it seems that development funding drives all the existing projects.

For the development of Jatropha as a fuel crop – for national or international markets – it is necessary to realize an ample production and this will require major players who setup large-scale processing

[45] US biodiesel production (2006) 765,000 t; capacity (2007): 2.9 M t, capacity under construction (2007): 5.8 M t: http://www.biodiesel.org/news/bulletin/2007/050107.htm

units for oil expelling. To reach the needed quantities of feedstock in a conceivable time it will probably be indispensable to establish plantation estates. In the ideal case those who build up such capacities will encourage outgrowers to plant Jatropha – in their own interest to elevate the future yield. This makes sense especially where farmers already have plants but do not use the seeds (mostly as hedges, in Singida for example). Here, a limited yield can be harvested today.

In any case such entrepreneurship will bring about income opportunities. In the targeted semi-arid areas there is plenty of land available but there are only few income opportunities, also because of lacking markets. Estate plantations will offer a lot of seasonal work because the most labour intensive work, the seed harvesting, can hardly be mechanised. If the large-scale producers also work with outgrowers those will be able to generate direct income through the selling of seeds.

It should be noticed that the benefits in terms of monetary revenue would be rather modest. If a household manages 1000 Jatropha plants (about one hectare intercropped or 750 m of hedges) it would earn about TZS 200,000 yearly (1000 * 2 kg * 100 TZS) once the plants are mature.

It is possible however, that the establishment of a market for Jatropha seeds and the improved farm conditions through the Jatropha cultivation will open opportunities for other crops and other markets to the outgrowers.

The establishment of Jatropha processing points in rural areas facilitates further opportunities for community development through the use of Jatropha oil in the sense of "the Jatropha System".

9 Sources

9.1 Literature

[In brackets: number of document on JCL-CD ROM. Not all documents on the CD have been directly used for this study.]

Duke J A (1983): Handbook of Energy Crops. Unpublished, only available online: www.hort.purdue.edu/newcrop/duke_energy/Jatropha_curcas.html [36]

D1 oils plc (2006/a): Interview with Elliott Mannis, Chief Executive D1 oils plc. [48] Download: www.d1plc.com/aboutDownloads.php

D1 oils plc (2006/b): Annual report and accounts 2006. [49] Download: www.d1plc.com

Energy Africa Ltd./Grimsby L (2007): An Assessment of Jatropha Curcas (L) Production and Processing in East Africa. [38]

Euler H, Gorriz D (2004): Case Study "Jatropha Curcas"; commissioned by GTZ & GFU. [50]

GTZ (2003): Liquid Biofuels for Transportation in Tanzania – Potential and Implications for Sustainable Agriculture and Energy in the 21st Century. [07]

GTZ, EUEI/Gaul M (2006): Berichterstattung über den Strategiebildungsprozess zur Herstellung und Nutzung von Biokraftstoffen im ländlichen Grenzgebiet zwischen der Dominikanischen Republik und Haiti. [17]

GTZ, Sustainet/Gaul M (2005): Jatropha Curcas Production Systems for Small Farms: Research, Demonstration and Information Exchange. [18]

GTZ/Wiesenhütter J (2003): Nutzung von Purgiernuss (Jatropha curcas L.) zur Desertifikationsbekämpfung und Armutsminderung. [09]

Heinimann A et al. (2005): Baseline Information for Morogoro, Dodoma, Singida, Tabora, Shinyanga (Tanzania). ESAPP – Eastern and Southern Africa Partnership Programme. [No digital copy.]

Heller J (1996): Physic nut. Jatropha curcas L. Promoting the conservation and use of underutilized and neglected crops. 1. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome. [10]

Henning R (2004): The Jatropha System – Integrated Rural Development by Utilisation of Jatropha curcas L. (JCL) as Raw Material and as Renewable Energy. [04]

Henning R/GTZ (2000): The Jatropha Booklet – A Guide to the Jatropha System and its Dissemination in Zambia. [12]

Kannan R (2002): Collection, cultivation and processing of Jatropha curcas at Palni Hills with special emphasis on pollination aspects at different altitudes. [51]

Schütz H et al (2006): Flächenkonkurrenz bei der weltweiten Bioenergieproduktion. Forum Umwelt und Entwicklung, Wuppertal/Bonn. [45]

Van Eijck J (2006): Transition towards Jatropha Biofuels in Tanzania? – An analysis with Strategic Niche Management. [16]

VBD Verband der Deutschen Biokraftstoffindustrie e.V. (2007): Jahresbericht 2006/2007. [47] Download: www.biokraftstoffverband.de

Zah R et al/Empa (2007): Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen. [46] Download: www.empa.ch/plugin/template/empa/3/60112/---/l=2/changeLang=true/lartid=60112/orga=/type=/theme=/bestellbar=/new_abt=/uacc=

Zeddies J (2006): Rohstoffverfügbarkeit für die Produktion von Biofraftstoffen in Deutschland und der EU-25. Universität Hohenheim. [40]

9.2 Personal Communications

Van Eijck, Janske: General Manager, Diligent Tanzania Ltd., Arusha (22/2/07)

Burland, Peter: Aloë vera and JCL farmer, Kikuletwa farm, Moshi (24/2/07)

Doherty, Malcolm: Project responsible, Sun Biofuels Ltd., Dar es Salaam (28/3/07)

Hosianna: Kakute, Arusha (23/2/07)

Grimsby, Lars Kåre: Consultant, Envirocare, DSM; Energy Africa Ltd. Mombasa (22–24/2/07)

10 Appendix: Actors, Contacts, Activities

Project name Contact	**Activities**	**Grow seeds**	**Buy seeds**	**Prod oil**	**Prod soap**	**Prod bio-d**	**Promotion**	**Gear**	**Research**
ARI Arumeru, Usa river, Arumeru Cf. Kakute (facilitator)	Alternative Resources Income for Women: Oil, Soap	x		x	x				
ARI Monduli, Monduli Cf. Kakute (facilitator)	Alternative Resources Income for Women: Oil, Soap	x		x	x				
BSH/GTZ, Arusha Through Mr. Ndilanha @ probec.gtz-tanzania@gtz.de	Development of PROTOS plant oil stove						x	x	x
Diligent TZ, Arusha 027 250 17 91 request@diligent-tanzania.com	Oil/biodiesel for TZ market and export, research, consulting	x	x	x		(x)	x	x	x
Jatropha Products Tanzania Limited (JPTL), Arusha Cf. Kakute	“serves as clearing house for consultation, research and development of Jatropha products”						x		
Jua Katika Mbinga (RUV) info@energiebau.de http://www.sonne-ueber-mbinga.de/en/	Solar-Hybridsystem: PV-Collectors linked with plant oil electricity generator for village facilities	x		x					
Kakute Ltd., Arusha 0744-66 26 46, 027 254 45 49 kakute@tz2000.com	Soap (ARI Monduli); consulting; produces ram presses, oil-lights, develope stove	x	x	(x)	x		x	x	?
Kikuletwa farm, Moshi Peter Burland, Ramadan Kidunda: 0756 79 76 35		x							x
Kiumma dev. project, near Tunduru (RUV) (Kakute involvement) http://www.aan-energie.de	Oil → electricity	x		x					
MVIWATA-Private sector approach, Morogoro mviwata@africaonline.co.tz 023 260 41 84	Oil	x	x	x		?			

Project name Contact	**Activities**	**Grow seeds**	**Buy seeds**	**Prod oil**	**Prod soap**	**Prod bio-d**	**Prom otion**	**Gear**	**Rease arch**
Prokon (D)/DiADEM e. V., Mpanda (RUK) PROKON Kapital GmbH, Germany, l.kirchner@prokon-capital.de (Kakute involvement)	Create market for JCL oil; modify engines		x	x				x	
Seliani Agriculture Research Institute Arusha (SARI) Collaboration with Kakute	Seedcakes as fertiliser								x
Sisal Factory, Kilosa No contact known	50,000 ha JCL for own energy needs (planned)	x		x					
Sun Biofuel, Kisarawe Malcolm Doherty, Dar jamainfo@yahoo.co.uk	Large-scale farm, intercropped; production for international market			x		x			
Tatedo, Dar energy@tatedo.org	Run MFP, research in biodiesel production		x	x		x	x		
The Jatropha Energy System, Haubi (DOD) giovannivdg@agroils.com	Oil → electricity	x		x					
University of Dar es Salaam (UDSM) Collaboration with Kakute	Bio diesel, stoves							x	x
Vyahumu Trust, Morogoro Mr. Lehada Cyprian Shila, vyahumu@hotmail.com 023 260 03 91, 0754 67 20 79	Production of Sayari oil Expeller; oil			x				x	
Rulenge Vocational Training Centre, Rulenge (KAG) www.jatropha.de/tanzania/rulenge/Introduction.htm	Oil for for lamps and income generation	x		x	x				
Envirocare: Kilindi/Nguru mts., near Handeni (TAN) www.envirocaretz.com/news/190906.htm	Research farm/woman groups	x							x

Many more links to JCL actors and projects worldwide can be found on: www.jatropha.de/