

# Size does matter

The possibilities of cultivating *Jatropha curcas*  
for biofuel production in Cambodia.

December 2006

Expertise Centrum voor Duurzame Ontwikkeling (ECDO)

Brechje Asselbergs, Jochem Bokhorst, Ruben Harms, Jupijn van Hemert,  
Laura van der Noort, Corine ten Velden, Richard Vervuurt, Loes Wijnen,  
Levien van Zon

Supervisor: Lyanne Woltjer



UNIVERSITEIT VAN AMSTERDAM



## Acknowledgements

We would like to thank the following individuals for providing valuable information that helped us to write this report:

Prof. ir. C. Daey Ouwens (Technical University of Eindhoven, department of Technology for Sustainable Development, opgewekt.nu and FACT).

Dr. ir. Wolter Elbersen (Wageningen University, department of Agro technology and Food Innovations).

Dr. John Kleinen (University of Amsterdam, department of Sociology and Anthropology).

Frank Bergmans (MVO (Productship Margarin, Fats and Oils), at the department Sustainable Production and Market information).



## Executive Summary

This report explores the possibilities of cultivating the energy crop *Jatropha curcas* L. in Cambodia for the production of vegetable oil and biodiesel. Our aim is to determine how this can be done while improving the situation of the poorest and without putting food security at risk.

We have evaluated existing projects in a number of countries. Projects have been divided into three broad categories: national scale biofuel production (in which the national government is the main initiator), plantation scale production (in which farmers or farmer cooperatives produce biofuel as their primary source of income) and community scale production (whereby communities produce biofuel as an extra source of income or energy).

Producing biofuels on a national scale can decrease dependency on fossil fuel imports, create job opportunities, reduce air pollution in cities and possibly increase income per capita. However, when the production process is highly centralised, the rural poor will not benefit from these advantages. Also, it can lead to deforestation, erosion and water pollution. Besides this, national scale production seems unsuitable for a relatively small country like Cambodia, at least in the short term.

It is hard to find successful examples of *Jatropha* cultivation on a plantation scale. This is mainly due to low profit margins, low yields and unrealistic expectations. Although *Jatropha curcas* can grow on many kinds of soil, including marginal lands, it needs sufficient light, water and nutrients in order to produce an acceptable fruit yield. Other causes of failure are three to five year gestation period before the seeds can be harvested, the relatively large investments needed to establish a plantation, and the uncertain market prospects and prices.

Projects on a community scale have the best chance of success. Although until now only moderate successes have been booked, this type of production seems to create the most positive benefits. An integrated participative approach with a relatively decentralised, bottom-up organisation improves commitment of those involved in the process. *Jatropha curcas* hedges planted around fields can decrease water and wind erosion. The seeds can be harvested and the oil used for local applications, such as replacing firewood for cooking and lighting, and driving pumps, oil expellers, mills and generators.



# Table of Contents

Acknowledgements.....	1
Executive Summary.....	3
Table of Contents.....	5
1. Introduction.....	7
2. Background information.....	9
2.1 Biofuels.....	9
2.1.1 What are biofuels?.....	9
2.1.2 Applications of biodiesel and SVO.....	10
2.2 Jatropha curcas.....	12
2.3 Food security.....	14
2.4 Ecology & Environment.....	15
3. Cambodia.....	19
3.1 Government.....	19
3.2 Geography & Climate.....	19
3.3 People & Society.....	19
3.4 Incomes.....	20
3.5 Markets.....	20
3.6 Health & Social policy.....	21
4. National scale biofuel production.....	23
4.1 Introduction.....	23
4.2 Brazil.....	23
4.2.1 Government policies.....	23
4.2.2 Economical and social aspects.....	24
4.2.3 Environmental aspects.....	24
4.2.4 Food security.....	24
4.3.1 Government policies.....	25
4.3.2 Economic and social aspects.....	26
4.3.3 Ecological aspects.....	26
4.3.4 Food Security.....	27
4.4 Conclusion.....	28
5. Plantation scale biofuel production.....	29
5.1 Introduction.....	29
5.2 Case studies.....	29
5.3 Organisation & Government.....	30
5.4 Economic aspects.....	31
5.5 Socio-economic aspects.....	31
5.6 Ecological aspects.....	32
5.7 Food security.....	33
5.8 Conclusion.....	34

6. Community scale biofuel production.....	35
6.1 Introduction.....	35
6.2 Organizational Structure & Government Policies .....	35
6.3 Socio-economic aspects .....	36
6.4 Ecological aspects .....	37
6.5 Food security.....	38
6.6 Conclusion .....	38
7. Conclusions.....	39
7.1 General conclusions.....	39
Plantations.....	40
National programmes.....	40
7.2 Food security.....	41
Ecological.....	41
Socioeconomic.....	41
7.3 Sustainability.....	41
7.4 Conclusions for Cambodia .....	42
8. Recommendations.....	45
8.1 General recommendations.....	45
8.2 Recommendations for Cambodia.....	46
References.....	47
Further reading.....	53
Annex I.....	55



# I. Introduction

Because Cambodia currently has to import all the energy it uses, this makes the country very dependent on other countries for energy and incurs significant expenses on government and people for imported fuel. Even if the offshore oil and gas fields that were discovered in the Gulf of Thailand several years ago could be brought into production within a reasonable time frame, the country still lacks the infrastructure for large-scale energy delivery to its remote rural areas. A possible solution for these problems could be to look at locally produced, renewable alternatives for fossil fuels, such as biofuels.

One possibility that is often cited in this context is fuel production from a crop called *Jatropha curcas*. This plant carries seeds with a high oil percentage; when pressed the oil can be used as diesel fuel. *Jatropha curcas* already grows in Cambodia but is mainly used to create hedges to keep cattle from trespassing. Currently two NGOs, GERES and DATE are looking into the possibilities for initiating a *Jatropha* biofuel-project in Cambodia (Williams 2005). This report explores the possible effects that such a project might have on the local community, with a special focus on sustainability and effects on food security.

First it is important to give a clear definition of what we consider to be important for sustainable development in this context. According to most authors on the subject, the following dimensions are relevant (Vlasman & Dankelman 2002: 8):

1. The ecological dimension. The effects a development can have on the environment should always be considered. This can include deforestation, degradation of land and decrease of biodiversity, but also improper use of toxic chemicals and pollution due to transport.
2. The social dimension. Developments should decrease social problems, such as poverty, (gender) inequality, unemployment and bad employment circumstances.
3. The economic dimension. First, the development should generate sufficient income in order for it to be economically viable. Second, it should have positive effects on the economic development of the local area.
4. The political-institutional dimension. Developments can contribute to improving the stability of political and institutional conditions.
5. The North-South dimension. Developments should decrease the gap between 'North' and 'South' (rich and poor countries). This gap is for a large part still a remnant of the 'colonial' trade system, whereby the South mostly provides 'low grade' raw materials and the North mostly refines these into 'high grade' products and consumes them. In such a relationship, most economic development will remain in the North.
6. The time dimension. The solution that the development provides should not be temporary but should give a long term solution to problems.

For a development to be sustainable, it must have a positive influence on at least several of these dimensions without having a negative effect on the others (ECDO 2006, Vlasman & Dankelman 2002).

In order to determine if the production of biofuel in Cambodia can become a truly sustainable development, we shall attempt to answer the following research questions:

- What are the discussions on food security and biofuel production worldwide?
- How can the introduction of biodiesel or vegetable oil production in Cambodia be guided in such a way that it will not negatively influence basic food security, especially for the rural and urban poor?
- What indicators should be taken into account in relation to food security and biofuel production?

For this research we have looked at a number of existing projects on biofuel all over the world. We have broadly divided these projects into three categories, representing scenarios for biofuel production

on three different scales: on national scale, plantation scale and community scale. In this report we will discuss several examples of projects at each scale. We will use the main results of these case studies to draw up conclusions and recommendation concerning the project proposal for Cambodia, and projects for biodiesel and Jatropha oil production in general.

We are aware that our assignment was to consider Cambodia as our focus of attention, which makes study of mostly moderate scale projects a logical choice. However, we have decided to give some attention in chapter 4 to programs on a larger, national scale as well, although these may not be easily realised in Cambodia in the near future. Brazil is the only country so far that has managed to make biofuel one of its primary fuel sources, and India has plans for large-scale cultivation of Jatropha curcas for biodiesel production. Our goal is not to advise a program of such a large scale for Cambodia, but to give an overview of the advantages and disadvantages of large scale cultivation.

Most of our information was gathered by a literature study of academic papers, technical reports and Internet websites. Because the production of biofuel from Jatropha is a relatively new development, there has not yet been much academic research on the subject. In addition to literature we have used the knowledge of several experts on biofuels, Jatropha projects and the country Cambodia.

We will start this paper with providing background information on biofuels, the plant Jatropha curcas and the current discussions on food security. We will continue with a short introduction of Cambodia. Then we will look into the examples of biofuel projects on national, plantation and community scale. Based on these cases we will formulate our conclusions to answer our research questions. This will include several conclusions and recommendations specifically regarding the business plan for the Cambodian biodiesel project. We will conclude this paper with recommendations for biofuel production in general.

## 2. Background information

Before we start examining the projects in other countries, it is necessary to explain some of the concepts we will be using in this paper. First, we will look into biofuels. We will explain what they are and what their advantages are. Special attention will be given to the *Jatropha curcas* plant and reasons why it is often said to be a good crop for producing biodiesel. We will list a number of opportunities and risks.

Subsequently, we will define and discuss major factors relating to food security. Finally, we will briefly discuss a number of potential ecological issues.

### 2.1 Biofuels

#### 2.1.1 What are biofuels?

Biofuels are fuels derived from biomass. This can concern (parts of) organisms that recently lived, such as corn, rapeseed or firewood, or an organism's metabolic by-product, such as cow manure.

Biofuels have in common with fossil fuels (gasoline, coal) that the energy comes from stored solar energy in plants. However, contrary to fossil fuels, biofuels are renewable. Crops for the production of biofuels can be grown on land which can, at least in theory, be used indefinitely.

Apart from being renewable, another important advantage of biofuels over fossil fuels is that biofuels are potentially carbon-neutral. This means that during its life, the plant has absorbed the same amount of CO<sub>2</sub> as will be released when parts of the plant are burned as biofuel. However, in practice production and transport of most biofuels will also require energy, reducing efficiency and often causing extra CO<sub>2</sub> emission. The so-called first generation biofuels which are currently used reduce emissions up to 50% compared to fossil fuels. More advanced technology will enable the production of second generation biofuels. Potentially these can lead to up to 90% reduction of emissions (SenterNovem 2006). However, these techniques are still in the early stages of development and probably will not be on the market before 2010 (VROM 2006). Moreover, they require large technological inputs, making them unsuitable for use in developing countries in the foreseeable future.

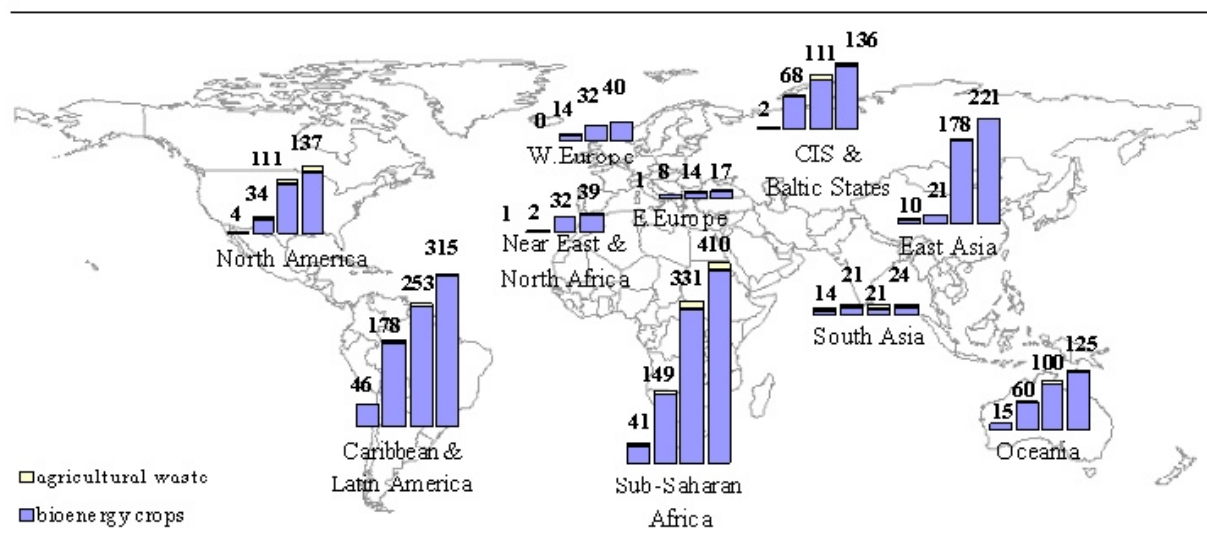


Figure 2.1: The bars represent low to high estimates for bioenergy production over a range of scenarios. These estimates are 13% to 147% of expected global primary energy demand in 2050. Source: E. Smeets, A. Faaij, I. Lewandowski – March 2004

The most important examples of biofuel-alternatives to fossil fuels are (SenterNovem 2006):

- Bio-ethanol, which can replace regular gasoline. It is made of fermented corn, sugar cane or other plant materials.
- Biodiesel, which can replace regular diesel. It can be made from many types of vegetable oil, for example oil derived from rapeseed, sunflower, soy beans, mustard seed, castor beans, oil palm and *Jatropha curcas* seeds. It is also possible to make biodiesel out of waste vegetable oil (WVO), animal fats and even algae (Knothe 2001, Sheehan et al. 1998). After a cleaning process, vegetable oil or fat can be relatively easily converted into biodiesel through a process of esterification, which is described in the next section.
- Pure oil, either straight vegetable oil (SVO) or waste vegetable oil (WVO). This can be used to replace diesel in engines and kerosene in lamps and stoves. However, these need to be modified or specially designed, because the oil has slightly different properties than petroleum-based oil. It can be used in unmodified diesel engines when mixed with petroleum-based diesel (Knothe 2001, VROM 2006). Engines modified to run on SVO can still run on regular diesel without further modifications (Pers. comm. Daey Ouwens 2006).
- Biogas, which can be made out of fermented biomass or biodegradable waste. The gas can be compressed and used for cooking, lighting, heating, or driving a gasoline or slightly modified diesel engine. It can be used as a replacement for Compressed Natural Gas (CNG), a fossil fuel source that is rapidly gaining popularity as fuel for vehicles in parts of South America and South Asia (IANGV 2006, Wikipedia 2006).

One of the plants that can be used for biofuel production is *Jatropha curcas*. The oil that can be won from its seeds can either be used as straight vegetable oil or converted into biodiesel. We will discuss other properties of this particular plant in paragraph 2.2.

### 2.1.2 Applications of biodiesel and SVO

The main difference between petroleum-based diesel and straight vegetable oil is that the latter has a higher viscosity than diesel. This causes problems in existing equipment. There are several ways to reduce the viscosity of the oil, the most common of which are conversion to methyl ester biodiesel, mixing with diesel and heating.

Conversion of vegetable oil to biodiesel is predominantly done using a base catalysed transesterification process. This chemical reaction is catalysed by a strong base (e.g. NaOH), and involves filtered fat or oil reacting with an alcohol (usually methanol) to form crude methyl ester 'biodiesel' and crude glycerol. The crude biodiesel can be further refined by washing with mildly acidic water, which will remove soap residues. The resulting biodiesel has a viscosity comparable to that of normal diesel. The crude glycerol can also be further refined to produce soaps and commercial grade glycerine products (Tyson 2003, Ramadhas et al. 2004, Sai Petrochemicals 2006). In theory the process is sufficiently simple to be performed in rural areas in developing countries. However, it requires significant amounts of methanol and a lot of energy for heating, making small-scale application difficult, especially in remote areas (Billen et al. 2004). In some regions esterification plants may already exist, for processing of waste cooking oil (Allen 2002).

Direct use of straight vegetable oil as fuel requires other methods to reduce its viscosity. Mixing SVO with petrol-based diesel or biodiesel will lower viscosity and allow the mixture to be used in an unmodified diesel engine. Mixtures with up to 50% SVO have been reported to work without noticeable problems in the short term (Pramanik 2002). However, this might still cause long-term problems, so mixtures with more than 25% SVO are generally not advised (Jones & Peterson 2002).

Pure SVO may be made to work in most diesel engines, but will cause problems in the long term. Especially in indirect injection (IDI) engines, the increased fuel droplet size on injection caused by the higher viscosity will lead to a build-up of unburnt fuel deposits in the engine, and eventual engine failure. Direct injection (DI) engines experience less problems, but will still suffer from carbon deposits and clogged filters and fuel lines in the long run, especially when they are not continuously used (Jones & Peterson 2002, Forson et al. 2003, Allen 2002). Diesel engines can be modified to avoid or reduce these

problems. Possible modifications include pre-heating the fuel, a higher injection pressure or a fuel switch that will enable the engine to start on normal diesel to warm up before switching to SVO. Modern engines will also need recalibration of their fuel injection system. Furthermore, even for modified engines, increased carbon deposits might still be a problem, and require regular servicing. The fuel filter and lubricating oil should be replaced regularly, and the engine requires more frequent cleaning than with petrol-based diesel (Billen et al. 2004).

The amount of carbon deposits caused by combustion of SVO is probably related to the fraction of incombustible contaminants the oil contains, such as free fatty-acids (FFA). In order to minimise negative impacts caused by deposits, contaminants should be removed where possible by filtering and refining the oil (Prateepchaikul & Apichato 2003, Allen 2002). One analysis of Jatropha oil showed that it contained around 4% FFA (Baganí 2006).

The high viscosity of SVO also causes problems for application in lamps and cooking stoves. In most types of oil lamps and stoves the fuel is transported from a reservoir using a textile wick. Higher viscosity limits the flow rate of SVO through the wick, so that the capillary force alone cannot maintain a sufficient fuel supply to keep it burning. Several 'appropriate technology' solutions exist for oil cooking stoves. These include pressurising the fuel supply with a hand pump (Stumpf 2001), using evaporation of water to disperse the oil, or placing the wick in a loosely fitting tube. The latter method has also been used successfully in oil lamps (Protzen 1997). Another simple solution for lamps is to decrease between burner and oil reservoir. An extreme example of this principle is the 'Binga oil lamp', which is constructed by simply placing a floating wick in a jar of Jatropha oil (Henning 2003a: 26, Baganí 2006). An additional problem with wick-based systems is the formation of carbon deposits on the wick. This means that the wick has to be cleaned or replaced after 2-8 hours.

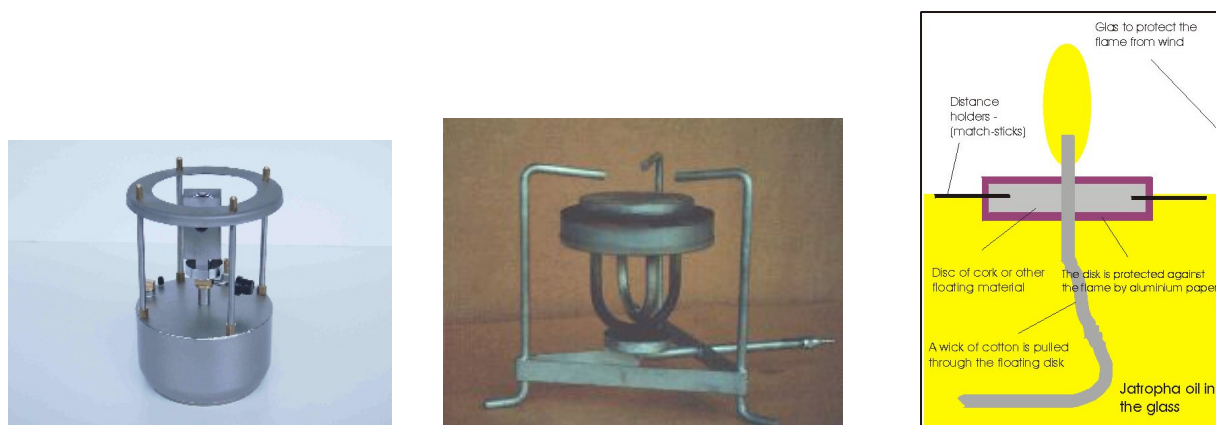


Figure 2.2: Two types of plant oil stoves, and a schematic drawing of the 'Binga oil lamp' (Baganí 2006)

An integrated solution to rural energy problems in developing countries (Barnes & Floor 1996) is the Jatropha Energy Platform, which is based on the so-called Multifunctional Platform For Village Power (PTFM). This is a modular system driven by a Lister-type slow speed diesel engine, which can in turn drive a number of other devices. The Jatropha Energy Platform, as used by the Mali-Folkecenter (MFC) in Mali, runs on Jatropha oil and contains an oil expeller, a generator, a small battery charger and a grinding mill. A single device can be used at any one time, by connecting it to the engine using a drive belt. Any type of mechanically driven device can in principle be included on the platform, past examples have included a water pump, a saw, a rice dehuller, a shea butter press and even a welding machine. The platform is easy to construct and maintain locally, as it is constructed entirely from parts and devices that are widely used throughout the developing world. (MFC 2006, Greco & Rademakers 2006, Burn & Coche 2000). However, when running an unmodified Lister-type diesel engine on unrefined SVO, problems might arise with the fuel injection system in the long run. Solutions are being developed, but they would add to the cost of the platform (Beckett et al 2006, SEAS 2006).

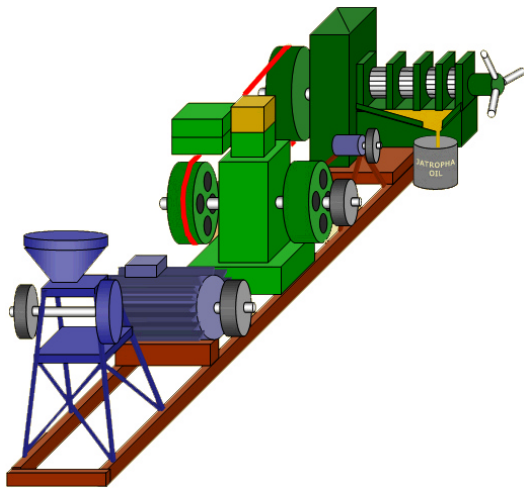


Figure 2.3: The Jatropha Energy System

## 2.2 *Jatropha curcas*

*Jatropha curcas* L. is a perennial drought-resistant shrub, originally from Latin America, and is known around the world under many names, most notably Physic Nut or Purging Nut. See FAO (2006: Ecoport ID 1297) and Heller (1996: 9) for an extensive list of local names. In the rest of this paper we will mostly refer to it as *Jatropha* or *J. curcas*.

*Jatropha* plants grow and are cultivated worldwide, from Central America to Africa and Asia. The plant has been used in the past for soap production and traditional medicine, but nowadays is mostly used as live fence (Heller 1996: 10, 20). *J. curcas* grows best in the drier regions of the tropics, with annual rainfall of 300-1000 mm per year. The plant is very drought-resistant and can endure long periods without rainfall. It is best adapted to temperatures around 20-28°C, but also grows under lower temperatures and can even withstand light frost. *J. curcas* grows on well-drained soils with good aeration, and is well-adapted to growing on nutrient poor or 'low potential' soils (Heller 1996: 35). Low potential soils can be defined as: "resource-poor or marginal agricultural lands, where inadequate or unreliable rainfall, adverse soil conditions, fertility and topography limit agricultural productivity and increase the risk of chronic land degradation" (Barbier 1997: 892). *J. curcas* grows relatively quickly, under good conditions it can start to produce fruits within 2-5 years. It can grow up to 5 meters in height, and in the wild the plants can live up to 50 years. Reports of average fruit yields in the literature vary widely, from around 200 g to 9 kg of seeds harvested per shrub. There has been some research into selection of high-yield varieties for use on plantations, but so far this has been only on a small scale, and results vary greatly between regions and with different cultivation methods. (Heller 1996, Henning 2000, Euler & Gorris 2004)

Apart from one less toxic kind of *J. curcas* found in Mexico (Heller 1996: 18, Makkar et al. 1998, Martinez-Herrera et al. 2006), the fruits *Jatropha* plants carry are toxic and inedible to man and animal (Heller 1996: 16-17, Begg & Gaskin 1994, Makkar & Becker 1998). The seeds of this fruit contain about 32-35% oil (by weight), although the percentage differs between varieties and with growing conditions. The oil can be extracted with a mechanical oil expeller (oil press), or using chemical extraction. Between 47%-90% of total oil content can be extracted with a mechanical press, depending on the type of device and techniques used (Heller 1996: 21, Henning 2000: 11). The remaining seedcake can be used as organic fertilizer, although it can be toxic to plants and insects in high concentrations so some care should be taken (Heller 1996: 22-23). The fruits are also used to make soap and for medical purposes (Heller 1996: 18-22).

It is important to mention that in order to produce an acceptable fruit yield, *J. curcas* needs sufficient light, water and nutrients (Euler & Gorris 2004: 3). Although it can survive or grow on low-nutrient or low-moisture soils, the fruit yield will be very low and there will be very few or no seeds to harvest. In order to produce biodiesel or SVO from *J. curcas* growing on low potential lands, fertilisers and/or irrigation systems will probably have to be used.



Figure 2.4: *Jatropha curcas* L. with fruits.  
Photo by Nichols G., Briza Publications.

The production of vegetable oil from *J. curcas* fruits consists of the following steps: harvesting of the fruits, drying, cleaning of the seeds, extracting oil, filtering oil and packaging (Williams 2005, Henning 2000). This is a fairly simple process that can easily be learned and requires only simple technology. Soap can be easily made with the further addition of caustic soda (Henning 2000: 20-25).

The production of biodiesel from the vegetable oil using transesterification is a somewhat more complicated process, and thus requires a more complicated installation, more chemicals and more knowledge. It would not really be feasible for small-scale farmers to do this themselves, a larger dedicated facility would probably be required to make this step cost-effective. Having such a facility for a farmer's cooperative or on a regional scale might be feasible.

There are several reasons why *J. curcas* is considered a suitable crop for the production of biodiesel or SVO. Using the criteria for sustainable development mentioned earlier we can distinguish the following advantages:

1. Ecological and environmental: Because *J. curcas* can grow on nearly any kind of land, it can be cultivated on land that is now useless. It can play a major role in the prevention of erosion and restoration of degraded soils. Because of its toxicity the plant is fairly resistant to pests. In Africa *Jatropha* hedges have been known to work as a shield against locust plagues (Daey Ouwens 2006). The emissions of engines, lamps and stoves that use biodiesel or SVO are much less harmful to the public health than emissions from petroleum-based fossil fuels. Both indoor air pollution in rural houses and outdoor air pollution in big cities could be greatly reduced.
2. Socio-economic: The production of biodiesel can create new jobs. As mentioned, the process of making vegetable oil and soap of *J. curcas* fruits is not very complicated and can be done by most people without the need of long-term training. Production of biodiesel from the vegetable oil could also create jobs if done locally. If income and jobs are generated, *J. curcas* can be a weapon against rural poverty.
3. Economic: If production of vegetable oil, soap and/or biodiesel can provide the people in a region with a higher income and less fuel expenses. When sold on the local or regional market, profits will remain and can be reinvested in the local region, which could provide more prosperity for all who live there. When biodiesel is sold internationally it can give a country a stronger economic position.
4. Political/institutional: It is hard to predict the influence biodiesel production might have on the political-institutional dimension. However, there is not much reason to think this influence would be negative, if any.
5. North-South: The production of *J. curcas* can make a region or a country less dependent on (imported) fossil fuels. When a country does not have fossil fuel reserves of its own, it could give them more independence from the countries that now provide them with energy supplies.



6. Time: If produced in a sustainable manner, biofuels are renewable and can therefore be produced for an indefinite period, unlike fossil fuels.

Unfortunately there are also potentially negative aspects connected to increased cultivation of *J. curcas* and large-scale production of biodiesel. Most of these are related to risks of increased socio-economic inequality and pressure on natural lands with increased scale of production, and increased dependence on unstable world market prices for income. Also, negative aspects associated with intensified agricultural practices and mono cultures may cause increased pressure on the environment and an increased vulnerability to plagues and pests (BIRD-K 2006, Euler & Gorriz 2004, Muller 2005).

There are also questions as to whether the unused wastelands targeted for cultivation of *Jatropha* crops are really unused. In many developing countries, even degraded 'wastelands' that can no longer be cultivated for mainstream agriculture are often inhabited and used by small livestock keepers, marginal farmers or landless people (BIRD-K 2006). Cultivation of biofuel crops on such lands can therefore lead to displacement of people who currently still depend on it.

Finally, although *J. curcas* can grow on marginal land which cannot be used for agriculture, it can also grow on land that can be used for agriculture. It is feared that the production of biodiesel, if successful on a larger scale, might lead to rapid expansion of production at the cost of food crops. This might eventually put food security at risk. The next paragraph will discuss this issue.

### 2.3 Food security

The definition of food security given by the UN World Food Summit in 1996 is that "all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996).

The key factors in food security are availability and accessibility. When at least one of these requirements isn't met, one can speak of a food insecure situation. There are roughly two types of food insecurity: chronic and temporary or seasonal. The latter can happen for instance in a dry period when no crops can be cultivated. The former is not dependent on seasons or short periods of social instability, but has deeper, usually socio-economic causes.

The causes of food insecurity can be socio-economic, ecological or political. Socio-economic causes for food insecurity are unfortunately quite common, and are usually related to accessibility of food: although there is enough food, the poorest groups in society do not have sufficient access to it. This may be chronic due to an unequal distribution of wealth, or due to long-lasting social conflicts. This type of food insecurity is especially common among landless poor and wage workers, but interestingly it even occurs among subsistence farmers. While they produce their own food, they often depend on selling most of it against low prices in order to satisfy other expenses such as other food and consumer products, fuel, health care and agricultural inputs (Kalibwani 2005).

Ecological causes of food insecurity are usually related to land degradation, water availability or pests. Short-term planning due to economic uncertainties and land-tenure problems, as well as insufficient resources for more sustainable agriculture, often lead to unsustainable agricultural practices, which in turn result in serious degradation of soil fertility. Where natural lands are still available (e.g. in forested areas), degraded land is often abandoned and new land is deforested and converted into unsustainable agriculture, further promoting erosion, nutrient depletion and other forms of degradation, and aggravating the problems in the long term (Barbier 1997). In areas where arable land is scarce (e.g. large parts of sub-Saharan Africa), soil degradation may directly endanger food security because of declining agricultural productivity and indirectly through rising prices for land and food.

Water availability is crucial for agricultural productivity, but a (seasonal) surplus of water may also damage crops. In arid (and even humid) areas, incidental, seasonal or year-round shortages of water may severely limit food production or cause crops to fail. Irrigation may be a solution, but is often not sustainable, thus threatening food production in the long term (Wallace 1997). In the humid tropics (especially in river deltas), but also in arid areas, the rain season may cause floods that make large parts of land unsuitable for growing food crops, with some exceptions such as rice. However, even rice production does need a fairly controlled environment, so excess flooding may still be a problem.



Political causes of food insecurity may involve insufficient attention to the agricultural sector, unequal distribution of food and economic policies that distort food markets (Kalibwani 2005). In developing countries, there is often an "urban bias" in policies to keep food prices low. While this may improve food access for the urban poor, it may also severely limit income for rural farmers, who are dependent on selling their food crops to meet other basic needs. Imports of cheap food from other countries and dumping of subsidised food surpluses by developed countries further aggravates this problem, and will cause the national market for food products to remain underdeveloped. Moreover, because governments in developing countries tend to focus on development of their industrial and export sectors (including cash-crops), the food sector is often ignored. Even worse, in most developing countries investments in agriculture extension services and farmer credit have decreased in recent decades to comply with IMF policy, leading to increased land degradation and rural poverty (Cohn et al. 2006).

The combination of soil degradation, rapid growth of the urban population in most developing countries and increasing land use requirements for urbanisation and non-food crops may pose a serious threat to food security for many (developing) countries in the near future. Competing 'high-valued' land-use requirements tend to push food agriculture activities into marginal lands, and increasing economic and population pressure further promote unsustainable agricultural practices (Lal 1997). Not only does this decrease the availability of prime land for food production and lead to accelerated land degradation, it can also lead to rising land and food prices and increased dependence on food imports, further aggravating food accessibility problems for the poorer groups in society.

In light of the socio-economic and political causes of food insecurity, the notion of food sovereignty has gained importance in the last few years. The Forum on Food Sovereignty at the World Food Summit in 2002 defined food sovereignty as "the right of peoples, communities, and countries to define their own agricultural, labour, fishing, food and land policies which are ecologically, socially, economically and culturally appropriate to their unique circumstances. It includes the true right to food and to produce food, which means that all people have the right to safe, nutritious and culturally appropriate food and to food-producing resources and the ability to sustain themselves and their societies. Food sovereignty means the primacy of people's and community's rights to food and food production, over trade concerns. This entails the support and promotion of local markets and producers over production for export and food imports." (UN 2004)

In general, the best way to ensure food security in the medium- to short-term seems to be to reduce poverty and inequality, while at the same time stopping or reversing environmental degradation, and promoting sustainable agriculture and food sovereignty. Cultivation of *J. curcas* and subsequent production of biodiesel from *Jatropha* oil might contribute to these goals, if implemented correctly. However, if certain boundary conditions are not met, *Jatropha* biodiesel cultivation might fail the goals needed to increase food security, and thus run the risk of actually endangering it. In chapters 4-7, we will study the boundary conditions that need to be met in more detail, and for several scenarios of biodiesel production.

## 2.4 Ecology & Environment

In this paragraph we will discuss some ecological and environmental issues related to the cultivation of energy crops, including *J. curcas*. The main problems concern disturbance of nutrient and water cycles, use of artificial chemicals, land-use changes and effects on biodiversity.

While use of biomass fuels closes the carbon cycle to a large extent, it often does not close other cycles, such as the water cycle and especially the nutrient cycle. Because plant material is removed to make biofuel, there is a net export of nutrients from the soil.

Many traditional agricultural methods, as have been practised for millennia, incorporate mechanisms to limit soil degradation. Examples of such traditional practises are crop rotation, application of 'green manure' and animal manure, and leaving land fallow (uncultivated) for periods of around 15-25 years to allow soil structure and nutrient levels to recover. Current non-sustainable agricultural practices however can lead to much higher nutrient losses due to erosion, burning, use of monocultures and increased production volumes, so that fallow cycles of up to 100 years would be needed to fully restore

nutrient levels. At the same time, use of fallow cycles has either disappeared or cycle lengths have been decreased to periods of 3-7 years (Vlek et al. 1997).

The rate at which nutrients are extracted is determined by how much of the plant is removed and how fast the nutrients are replenished, either naturally or artificially. In an ideal scenario, the harvest from biofuel crops would consist almost entirely of carbon-based plant material, and the rest of the plant would be left on the land. But of course in reality this is not the case, and some nutrients are always removed. *J. curcas* and similar perennial oil plants do score much better at nutrient conservation than bio-ethanol crops like sugar cane, 83% of which is usually discarded and burnt (Stedman-Edwards 2004). But none the less, a long fallow period or artificial replenishment of nutrients is still needed if crops like *J. curcas* are grown and harvested on a larger scale, especially on soils that are already degraded. Moreover, application of (inorganic) chemical fertilisers is not sufficient for sustainable agriculture on a longer-term, because they contain only part of the extracted nutrients. Chemical fertilisers contain mostly nitrogen (N), phosphorus (P), potassium (K) and sometimes calcium (Ca) and Magnesium (Mg), but usually lack important secondary and micro-nutrients. Additional application of organic fertilisers such as animal manure and plant material is required to avoid further degrading soil fertility in the long term (Vlek et al. 1997, Barbier 1997, Seyers 1997).

In the case of *J. Curcas*, this means that for sustainable production, rest-products such as the oil cake and glycerol should really be applied back to the soil instead of being used for other purposes. Otherwise, an alternative source of organic fertiliser should be found (Euler & Gorriz 2004). It also means that, in the absence of long fallow periods, some input of chemical fertilisers is needed. However, care should be taken to avoid runoff or leakage into the surrounding environment. Excessive use of fertiliser could lead to eutrophication and subsequent loss of natural biodiversity (Fritsche et al. 2005, Muller 2005, Stedman-Edwards 2004).

Modern agricultural techniques can help to reduce the rate of soil degradation, but correct application proves difficult, especially in developing countries where resources are often limited (Vlek et al. 1997, Barbier 1997). Another (partial) solution to soil degradation would be to re-introduce some traditional agricultural practices, such as mixed cropping, crop rotations, alley cropping, fallow periods and residue conservation. Mixed cropping or crop-rotation, especially with legumes, may decrease soil erosion and increase nutrient levels (Wani et al. 1995). Alley cropping involves alternating rows of production crops with rows of trees or shrubs, agronomic crops and possibly even rows of livestock pasture or uncultivated land. This reduces erosion, mitigates many problems of monocultures and increases biodiversity (USDA 1997). Residue conservation or conservation tillage involves distributing crop residues (rest products) uniformly over the soil surface, to decrease nutrient loss and erosion (McCarthy 2005).

With regard to the water cycle, water use in irrigation is often not sustainable, especially in arid areas. If groundwater is extracted at rates exceeding the natural replenishment rate, this may lead to exhaustion of existing aquifers. If an excessive amount of water from streams or rivers is used, this may lead to downstream aridification. Having said that, if planted correctly, *J. curcas* shrubs may actually help decrease evaporation, runoff and erosion, and increase infiltration.

While *J. curcas* seems to be fairly resistant to insects due to its toxicity, it is still known to suffer from damage by certain plant diseases and insects (Grimm & Maes 1997, Euler & Gorriz 2004, Heller 1996, FAO 2006). Use of pesticides and herbicides, especially needed in monocultures, may affect biodiversity in and around plantations of *J. curcas*.

The final, and perhaps biggest ecological problem of intensified production of biofuels and cash-crops in general is the destruction of natural habitats to create new plantations and infrastructure. The extent to which this may happen depends on a number of factors, including the availability and accessibility of 'new' land, government interventions (both positive and negative), the socio-economic and land tenure situations in a country, and the degradation rates of existing agricultural land due to unsustainable agricultural practices (Barbier 1997). Conversion of rainforest into biofuel plantations has been seen in a number of countries, including Indonesia, Malaysia and Brazil (Wakker 2005, Hirsch 2006), and this will certainly become a bigger problem if biofuel production becomes more profitable.

Using degraded (former) agricultural lands for cultivation of biofuel crops may offer a partial solution to this problem. However, as mentioned before, lands that are currently not used for agriculture may perform other important social or natural functions. Furthermore, like undisturbed natural areas, unused land can also be the habitat of many plants and animals that cannot live in cultivated areas. Therefore, cultivating such unused lands may further reduce biodiversity in populated areas, and can further marginalize species that are already under threat of extinction (Avery 2006: 8).

In general, it can be said that sustainable production of biofuels is possible up to a certain level with traditional or modern agricultural methods, but it is difficult and certain conditions need to be fulfilled. Nutrient cycles should be closed, where possible at the farm or community level. Erosion and other forms of soil degradation should be limited as much as possible. Water use should not exceed sustainable levels and use of chemical fertilisers, pesticides and herbicides should be limited. Most importantly, to limit effects on biodiversity (and livelihood of landless people) great care should be taken in designating 'unused' and natural land for cultivation, thus seriously limiting the scope for sustainable large-scale production of biofuels.



### 3. Cambodia

#### 3.1 Government

The government in Cambodia is officially a democracy under a constitutional monarchy (Freedom House 2006). This democracy was established in 1993, when the first (relatively) free elections were held. Cambodians elected a 120 members large parliament under surveillance of a UN force: the United Nations Transitional Authority in Cambodia (Untac). In the same year, the constitution was promulgated, and the Untac-mission went home after two years of surveillance.

#### 3.2 Geography & Climate

In 1970, two-thirds of the total land surface of Cambodia existed of tropical and subtropical forests. About thirty years later, this was reduced to half of the surface. In 2002 the government stated that all deforestation be suspended until further research was done, but illegal cutting continues on a large scale. This cutting happens for the sale of the wood, but also to clear land for agriculture. Recently parts of the forests have been allocated to be national parks, but they make up only 18% of the total land surface.

In the south-east, north and east, Cambodia is bordered by several mountain chains. Most of the lower plains are in the basin of the Mekong River and the Tonle Sap lake. A quarter of the total land surface consists of rice-fields, although there are big differences in fertility of agricultural land. The yields in the south-west for instance are much lower than in the north-west and south-east. This is due to higher fertility in the latter but also to the presence of a good irrigation system. These factors account for huge differences in yields: they can vary from mean yearly yields of 1000 kg/ha for poor soils to 2.5 tons/ha for fertile soils.

The mean temperature in Cambodia is 27 °C. The climate has a clearly definable wet and dry season; the wet season is from May to October and brings in monsoon rains from the south-east. The dry season is from November to April. April is the hottest month with temperatures rising to 40 °C (Kleinen and Mar 2004).



#### 3.3 People & Society

The population of Cambodia consists mainly of Khmers (Cambodians); other ethnic groups (among which Vietnamese and Chinese) form small minorities. The population counts almost 14 million people, of which 95% are Buddhist and 5% other religions. Religion is very important for Cambodians in everyday life. Women have a very important position in the (rural) household: they work on the land and are responsible for food. Therefore the woman may decide where her family will live.

Corruption is a very big problem: politicians, the military and policemen can be bribed or can be engaged in the illegal drugs business. Officially there is a freedom of press, but journalists can be intimidated. Moreover, all newspapers are 'coloured': every political party owns a newspaper, and there is not an attractive market for investors, so an independent paper cannot be established yet. The government dominates radio and television (Freedom House 2006). Political opponents still occasionally 'disappear'.

In the decades preceding 1993, the Cambodian people have almost continually been confronted with wars: they got involved in the Vietnam War and therefore got subjected to American bombardments, had a harsh communist government under the Khmer Rouge, were occupied by Vietnam, and meanwhile different kinds of guerilla movements posed a threat in the woods and countryside. In those days hundred thousands of people were killed and many more fled to the big cities or out of the country.

These experiences have been very influential to the lives and attitudes of the Cambodian people (Kleinen and Mar 2004).

The educational level in Cambodia is very low, especially in the countryside. When the Khmer Rouge was in charge, many intellectuals and teachers were killed, or fled the country. Nowadays, about 1.7 million children are getting elementary education. School is obliged, but for many people it is hard to pay; some sources say that 50% of the children leave school too early. Secondary education is followed only by about a hundred thousand children. Another problem is the shortage of teachers. This is partly due to the former government of the Khmer Rouge and partly because the salaries for teachers are too low to be able to live from. It still happens that certificates and university degrees can be purchased (Kleinen and Mar 2004: p. 34-35).

In rural areas, land fragmentation and landlessness is becoming a serious problem. Important factors are the hereditary redistribution of land and selling land in order to pay off debts or health care costs (Sedara and Acharya 2002).

### 3.4 Incomes

Cambodia is officially named by the UN as one of the 'least developed countries' (LDC's) in the world. (UNESCAP 2002) 85% of the population lives in the countryside; 75% of them are still engaged in subsistence farming. However, in 2004 the agricultural sector accounted for only 35% of the GDP (industry accounted for 30% and services for 35%), and 40% of the population was estimated to live below the poverty line (CIA 2006).

In the mid-1980s land in Cambodia was redistributed, and in 1989 private ownership was reintroduced. Many rural households live near the poverty line: they have small pieces of land (around 0.5 ha) which they use for subsistence farming and for some income. Rice is by far the most produced crop. There are also a lot of people who have no land at all. Those who do have land are fully dependant on the harvest; when bad, they have no other source of income. This forms especially a problem when a family member gets ill. Farming employs the farmers for only five months per year. In the other seven months they try to get other, usually low paid jobs. For men this can be in construction or transport, for women in the garment industry. A lot of men and women cross the border with Thailand illegally to work, because the wages are higher.

### 3.5 Markets

The rural economy has more and more been commercialised and exposed to larger markets. However, not much is done to alter the structure of supply or organisation of production within the rural economy. This is one of the reasons why the claims on forests and fish are increasing. Many landless people in rural areas depend to some extent on common property resources (CPR), mainly fish and forest resources. Also farmers traditionally use forests and fisheries for extra income. Another important factor is the rapid growth of population: more people need food, but also more people need jobs. So the rapid depletion of common property resources accounts for more food insecurity, less jobs, and is very damaging to the environment (Sophal and Acharya 2002). Due to this rapid population growth and to speculation of land, there is far too little land available for agriculture to feed the population. This means that they are strongly dependent on imported food.

An important factor which accounts for the underdeveloped status of the country is the almost total lack of basic infrastructure in the countryside (CIA 2006). Other factors are credit constraints, inadequate irrigation and insufficient market linkages (Sophal and Acharya 2002).

The Cambodian economy is growing: over the last years the mean growth rate was 5% per year. Important fast-growing industries are the garment sector and tourism. Moreover, also the governmental fiscal and monetary policy accounted for some stability. This economic growth goes along with increasing 'Westernization' of the country: western products (food and non-food) are imported on a large scale. However, so far the government has not been able to translate this economic growth into effective poverty reduction, since wages for uneducated labourers even declined. The development of the economy illustrates the gap between the few big cities (Phnom Penh, Siem Reap and Sihanoukville) and the countryside: the economic growth is so far only noticeable in the cities (Kleinen and Mar 2004).

A problem forms the development of the economy with regard to the long term. Cambodia receives a lot of money from donors such as the World Bank and IMF, who only donate on the condition that corruption in the government will be reduced (CIA 2006).

### 3.6 Health & Social policy

Health care is private, which means that prices are very high. This is a very heavy burden for the poor, especially for those who live in rural areas since they have to use bad infrastructure to get to a hospital in the first place. This is one cause for landlessness: people sell all their goods, land included, if this can get them medical help. The state of health care is also very weak; foreign NGO's form the backbone of health care. Another big problem is the illegally selling of medicines that are too old or prohibited (Kleinen and Mar 2004).

Government policy on social security is absent. This makes people dependent on family or large aid programs. The absence of social security is crucial to a lot of people, because they have to manage their financial problems all by themselves if a serious illness or bad harvest occurs.





## 4. National scale biofuel production

### 4.1 Introduction

In this section we consider two cases which are typical for the large scale cultivation of bio-energy. By large scale we mean the combination of the use of great amounts of land, the intensive promotion of the production of biofuels through state policies and production by big companies. The cases that have been selected are the cultivation of ethanol in Brazil and J. curcas in India.

The reason for selecting Brazil is its scale of cultivation and the scale of national government policies. We are aware of the differences in cultivation methods, costs, environmental effects of cultivation and use of ethanol compared to J. curcas but consider this a valuable case in the discussion of bio-energy for its scale and long existence.

The Indian case has some complications as well. Most of our findings are based on government programs which are still in the phase of infancy. In other words, we cannot judge the program on its merits, only on its prospects. The reason for choosing India, although the case is a bit problematic, has been its scale, the size of government policies and, most importantly, the use of J. curcas.

For both cases we will discuss the following aspects: the backgrounds on the implementation of government policies, the social, economical and ecological effects (as far as they are mentioned in other academic literature) and the possible relation to food security.

### 4.2 Brazil

#### 4.2.1 Government policies

Ethanol has been in use as fuel in Brazil since the 1930's. It was produced from sugar cane in times of recession of the international sugar market. Ethanol was mixed with petrol but because of poor performance and high fuel consumption (the result of engines not being adjusted to ethanol) it was not very popular.

In 1975, as a reaction to the international oil crisis, the Brazilian government implemented a national program, PROÁLCOOL, to promote ethanol. Mixed fuels were created as well as the first engine purely run on ethanol (IFQC 2004). Besides, the cultivation of ethanol was promoted in several financial ways: the price of ethanol was guaranteed at a maximum of 65% of the gasoline price, loans for ethanol producers were subsidised, taxes for ethanol fuelled cars were reduced, sales of ethanol at fuel stations became compulsory and the government controlled the stocks (Klabin 2005: 4).

The program was, and is, highly successful in reducing foreign oil consumption. Energy imports were reduced to only 10% of the overall consumption (against 81% in 1980) (Schaeffer et al. 2005: 285). As a result of this program the ethanol production has grown rapidly over the last twenty years. In 2004, the production capacity was 16 billion litres per year, from which 2.5 billion litres were exported. In the same year 3.5 million cars were running on pure ethanol (IFQC 2004). About 2% of the agricultural area of Brazil is used by sugar cane (Schaeffer et al. 2005: 288). However, due to the massive land area of Brazil, this is still around 17 million ha.

After the success of the National Alcohol Program PROÁLCOOL, Brazil has continued its bio-energy policy. In 1993 a law was enacted establishing that automotive petrol must contain 22 vol.% of ethanol (IFQC 2004). In 2002, the government started the Program of incentive to Alternative Sources of Electrical Energy (PROINFA) to promote other forms of renewable energies, like wind energy, hydro power and biomass (Klabin 2005: 6).

#### 4.2.2 Economical and social aspects

Ethanol production is an important industry in Brazil. However, it requires a costly production process, so that its economic success depends strongly on the international oil prices. With present production efficiency, oil prices are required to be around US\$ 30 per barrel for ethanol production to be cost-effective (La Rovere 2004). The current (December 2006) oil price is slightly over US\$ 60 per barrel, which means that at the moment ethanol production is economically quite stable. However, the costs used to be much higher than production costs for gasoline; the production efficiency has improved enormously over the last 30 years. The success of the ethanol industry would thus have been absolutely impossible without the financial support of the government.

A big advantage of ethanol, compared to other biofuels, is that in case of low oil prices one can switch to the production of sugar.

One important effect of the introduction of ethanol production is the creation of about one million jobs. Because most of these jobs are situated in the rural areas, the ethanol program has reduced the migration from the rural area to the big cities (La Rovere 2004).

On the other hand, subsidies to promote ethanol were mainly to the benefit of big companies and investors, and have, therefore, increased the differences in wealth between Brazil's upper and lower class (Prado 2006).



#### 4.2.3 Environmental aspects

As a result of the use of ethanol, Brazil's energy system is relatively clean. The effects of the use of ethanol on air quality and CO<sub>2</sub>-emission are hard to investigate quantitatively, because they are dominated by the fast growth of industry over the last 20 years. In any case, the use of ethanol fuelled cars has reduced the emission of CO<sub>2</sub> and SO<sub>2</sub> and improved the air quality considerably, especially in large cities. The sugar cane cultivation itself, however, causes serious air pollution in the rural areas. For manual harvesting of sugar cane the fields are usually burned, resulting in big smoke clouds during the harvesting season. Lately, this problem has been reduced because machines are more often used to harvest the cane, making the burning of the fields unnecessary (La Rovere 2004).

The cultivation of sugar cane contributes to the deforestation of Brazil's rainforest, but only in small proportions relative to other causes of deforestation. Between 2000 and 2005 on average 22.000 km<sup>2</sup>/year of rainforest was destroyed, but only 1% of this area was used for large scale commercial agriculture, the majority is cleared for cattle ranches and small-scale agriculture (Butler 2006).

Other ecological problems associated with the production process are soil erosion, nutrient depletion, use of pesticides, excessive use and leakage of chemical fertiliser and the use of enormous amounts of water for the cleaning of the cane. The discharging of the sewage to the rivers, containing large amounts of pesticides and fertiliser also causes downstream eutrophication and pollution, thus reducing biodiversity even at some distance from the plantations (Dias de Oliveira 2005, Stedman-Edwards 2004).

#### 4.2.4 Food security

There has been a lot of discussion on the effects of ethanol production on food security, but not much scientific research. Fact is that increasing food prices have caused serious problems for the poorest part of the population.

A possible cause of these food shortages is that land previously used for food cultivation, is now used for the cultivation of sugar cane. On the other hand, some people emphasize that Brazil is one of the biggest food exporters of the world, and that the production of food per capita has increased after the introduction of the National Alcohol Program. In other words, according to these arguments, there are no food shortages; the problems with food security are not an effect of wrong land use, but of an unfair distribution of wealth (Bedi).

### 4.3 India

In this paragraph we will discuss the implementation of J. curcas as biofuel in India. First we will look at the organisational structure of India and its government policies on J. curcas. Furthermore we will look at socio-economic, ecological and food-security aspects of J. curcas implementation.

#### 4.3.1 Government policies

The Indian economy relies heavily on oil imports; about 70% of the total oil consumption is imported. With increasing oil prices and the unstable nature of the oil market, India is trying to find answers to its big dependency on foreign oil (Francis et al. 2005).

Production of biodiesel, mainly using oil from J. curcas (and to a lesser extent from *Pongamia pinnata*, a native oil producing tree), is the main instrument with which the Indian government hopes to reduce the amount of fossil fuels needed for the economy. By the year 2011 a planned 20% of the total diesel consumption is to come from *Jatropha* biodiesel, with biodiesel production planned to reach around 13 million tonnes annually by 2013. This is quite an ambitious target, given that in 2004 production was less than 1,000 tonnes per year (Euler & Gorriz 2004). Originally, 5% replacement was already planned for 2006, but even the 5% blending of ethanol, mandatory in most states in India since November 2006, is currently hardly reached (Sai Petrochemicals 2006, Desai 2006).

To reach 20% diesel replacement, the Indian government has indicated that about 120.000 km<sup>2</sup> of wasteland (11-12 million ha, roughly 3-4 times the size of the Netherlands) is available for the production of J. curcas in the future. Currently around 400,000 ha are allocated, with full yields to be realised in 2007. We found no current data for *Jatropha* land-use, but based on the results of a 2004 survey (Euler & Gorriz, 2004) probably only a fraction of this is cultivated. The J. curcas programme is still very much in its infancy. The emphasis of J. curcas is more on research and promotion in this stage.

A National Biodiesel Policy was announced by the Indian government in 2005, but has yet to materialise. Some key points have however been made public earlier. There is to be a zero excise duty for biodiesel. Initially the price of biodiesel is likely to be higher than the price of normal diesel, so national or state government facilitation to lower prices is vital to its success. A lower VAT rate for biofuels will however be unlikely. Finally, the government announced that it will support *Jatropha* cultivation activities under the National Rural Employment Guarantee Act (NREGA), ensuring one member of each household below the poverty line a daily minimum wage of Rs. 60 (currently US\$ 1.34) for 100 days per year for unskilled manual work.

Furthermore, the Andhra Pradesh state government has announced a draft biodiesel policy that includes a risk fund of about 2 billion rupees (35 million euro) for funding loans to support small and marginal farmers with maximum five acre land holding. The draft policy also aims to promote contract farming, with a fixed minimum buy-back price for *Jatropha* seeds, and the establishment of a "biodiesel board". This board will have legal authority to monitor agreements made and to encourage and assist biodiesel production (Sai Petrochemicals 2006).

The institutional structure planned for India's National Program on *Jatropha* seems to be fairly well thought through, with coordination activities on the national level, involvement of public, non-government and private stakeholders from different sectors, and various micro-missions to take national responsibility for different tasks. Good and open inter-institutional cooperation is seen as a key to success (Euler & Gorriz 2004). The importance of a cooperative approach is further underlined by the recent opposition that has mostly arisen among several communities (e.g. CGNet 1996) and NGOs, who consider the National Programme to be a potential environmental and social disaster.

### 4.3.2 Economic and social aspects

One of the most widely advertised aspects of *Jatropha* biodiesel production seems to be the potential employment opportunities it might generate. Mainly because the work with *J. curcas* requires no high education level, and the most suitable sites for plantation are found in poor rural regions, the rural poor are expected to profit. Some projections for economic, employment and environmental benefits from Francis et al. (2005) are illustrated in the table below.

	Year		
	2010	2020	2030
Wasteland to be cultivated (million ha)	0.4	2	10
Production of bio-diesel (million tons/year) <sup>b</sup>	0.20	1.01	5.07
Foreign exchange saving by fuel substitution (million US\$/year) <sup>c</sup>	67	334	1,672
Employment generation (man-days) <sup>d</sup>	200,000	1,000,000	5,000,000
Savings of CO <sub>2</sub> consumption by the use of the produced bio-diesel as automobile fuel (million tons/year) <sup>e</sup>	0.5	2.7	13.4
CO <sub>2</sub> sequestration in the biomass (million tons/year) <sup>f</sup>	0.9	4.6	22.9
Possible income from CO <sub>2</sub> reduction from emission trading (M US\$) <sup>g</sup>	14.5	72.5	362.5

Notes:

<sup>a</sup> Assuming current production patterns do not change.

<sup>b</sup> Assuming production of 583 l per ha per year.

<sup>c</sup> Assuming an average international price of US\$45/barrel of crude oil.

<sup>d</sup> Assuming average employment of one person for two ha.

<sup>e</sup> Assuming that the end use of bio-diesel reduces life cycle CO<sub>2</sub> emissions by 85% compared to use of petro-diesel and a production of 2.7 kg of CO<sub>2</sub> per litre of diesel and a density of 0.87 for diesel.

<sup>f</sup> Except seeds taking an average of 2.5 metric ton of biomass increment per ha per year containing 25% C thus sequestering 3.66 metric tons of CO<sub>2</sub> per metric ton of C.

<sup>g</sup> Calculating an average market value of US\$10 per ton of CO<sub>2</sub> in international carbon markets.

Table 4.1: Projections for *J. curcas* in India (Francis et al. 2005)

Even though these figures are much lower and more realistic than the 2003 government projections (Euler & Gorriz 2004), they might still be considered somewhat on the optimistic side. Commercial production of biodiesel has not yet started in India. Two production plants are being constructed in Andhra Pradesh, but are not yet operational (Gonsalves 2006). The total production capacity of these plants is planned at around 0.12 million tonnes per year. However, sufficient supply of *Jatropha* oil might also be a problem, as it takes around 5 years to reach economic fruit yields, and interest among farmers for *Jatropha* cultivation is currently low because of low profit margins (Gonsalves 2006, Euler & Gorriz 2004).

Another problem might be the designation of 11 million ha of 'wasteland', because in the densely populated India this land is often used by poor livestock keepers and other landless people. When this land is cultivated, both people and livestock would need another place to go (BIRD-K 2006). However, this problem will arise mostly in areas where land-use patterns and rights are not clearly established (Euler & Gorriz 2004).

Factors that may influence economic viability of biodiesel production on a national scale include fossil oil prices, the market demand for biodiesel, the availability of infrastructure, and the distance to oil expellers and biodiesel production plants (Francis et al. 2005). A decentralised production system seems to be preferable, not only to reduce transportation costs but also because it will generate the most employment in rural areas where unemployment is currently high. However, due to economies of scale and lower overhead a central processing facility might be cheaper, relatively speaking, and therefore lead to lower biodiesel prices at the cost of less employment and income generation for the rural poor. More or less the same consideration holds for plantation scales, as larger scale plantations will be able to produce at a lower cost, but will provide less benefits and employment opportunities for rural poor.

### 4.3.3 Ecological aspects

The current scale of *J. curcas* exploitation in India is still relatively small. Therefore, little is known about the ecological impacts of large-scale cultivation of *Jatropha curcas*.

The semi-arid climate in large parts of India is quite suitable for *Jatropha* cultivation. Current plans for cultivation envisage use of marginal or degraded land, but most successful experiences in India have been limited to fairly nutrient-rich, well-irrigated land, where the crops were well-maintained. Large-scale cultivation on wastelands by poor farmers, with little or no resources for irrigation and sustainable use of fertilisers may be unrealistic or unsustainable (Euler & Gorriz 2004).

The urban environment, especially in large cities, might benefit from the large scale use of biofuels instead of fossil fuels. Especially emissions of sulphur and lead would be expected to decrease.

Forest Areas	Agriculture (Boundary Plantation)	Agriculture (agriforestry)	Cultivable Fallow Lands	Wastelands under Integrated Watershed Development	Striplands; roads Railways canal banks	Total	Additional Wastelands
3.0	3.0	2.0	2.4	2.0	1.0	13.4	4.0

Table 4.2: Land available for *J. curcas curcas* plantations (million hectares)

#### 4.3.4 Food Security

The use of abundant wasteland in India for biodiesel cultivation should in theory prevent any land-use conflicts between *J. curcas* and food crops (Francis et al. 2005). However, this wasteland has been created to a large extent by exhaustion and degradation of good agricultural land, due to unsustainable farming practices and high population pressure. The per capita availability of agricultural land declined from 0.48 ha in 1951 to 0.14 ha in 2001 (Francis et al. 2005). Cultivation of *J. curcas* as monoculture will not do anything to alleviate this basic problem. Moreover, if the same unsustainable practices are used to cultivate *Jatropha*, the land degradation problems might actually become worse. Another risk is that when cultivation becomes profitable, or if cultivation may prove unsuccessful on marginal soils, good agricultural lands will be used instead of wastelands.

Further effects on food security for the rural poor will depend on the generation of employment and additional income.

#### 4.4 Conclusion

If biofuel is to be substituted for fossil fuel at a national scale, for instance to reduce dependence on oil imports, a large-scale and long-term national programme is required. A significant amount of land should be available for cultivation, and infrastructure needs to be created for production, processing and transport.

Such a large scale production and application of biofuels has both positive and negative consequences.

Large-scale positive consequences may be an improvement of urban air quality, a rise of employment for the rural poor, and a possible rise of per capita income as a result of a decrease in national energy imports and the growth in the biofuel industry.

Socio-economic and food-security consequences for rural poor depend mostly on the profitability of production and the amount of centralisation of the production chain. A centralised production chain with large scale plantations and processing facilities will generate the least benefits for poor people in rural areas, and might have mostly negative consequences for plantation workers, as seems to be the case in Brazil. Decentralised production and processing, as mostly envisaged by the Indian government, might generate a lot of employment opportunities. However, care should be taken to provide appropriate public facilities, create financial incentives to promote production by small-scale farmers (such as loans), and choose appropriate unused areas for cultivation. Profitability of biodiesel production may also be influenced by the government through measures that increase the demand, such as compulsory mixing of up to 20% biofuel, tax breaks and guaranteed prices.

Negative ecological consequences may however arise as a result of large-scale production, such as deforestation, excessive water-use, nutrient depletion, eutrophication and pollution.

Negative social effects seem to arise mostly when cultivation takes place in large-scale plantations owned by companies or large landowners. This will be discussed in more detail in the next chapter.

## 5. Plantation scale biofuel production

### 5.1 Introduction

In this scenario study we will discuss the possibilities for producing biodiesel from *J. curcas* on a plantation scale. By this we mean that *J. curcas* is grown in plantations by local farmers or farmer cooperatives as a primary source of income, and the biodiesel is sold on a regional, national (domestic) or international (export) market. Processing of the *Jatropha* oil and by-products can be done on a local, regional or national level.

In this scenario *Jatropha curcas* should basically be considered a 'cash crop', a crop primarily grown for money instead of subsistence. This means that we can place the discussion about its relation to food security, socio-economic and environmental issues in the broader context of cash-crops in general.

### 5.2 Case studies

Unfortunately, to date we have been able to find only a few examples of initiatives to produce *J. curcas* biodiesel at this scale.

"Proyecto Tempate" was a program in Nicaragua, financed by the Austrian government, and implemented by a number of parties including a consulting firm, three universities and PETRONIC, the Nicaraguan national energy authority (Foidl et al. 1996, Grimm 1996). *Jatropha curcas* was to be grown by farmers and farmer cooperatives, mostly on degraded lands, and a central processing facility was to be set up for extraction of oil and transesterification. The program ran from 1991 to 1999, and was ultimately unsuccessful in establishing viable biodiesel plantations in Nicaragua. An analysis of the project by Euler & Gorriz (2004) stated a number of reasons for this failure, the most important of which were:

1. Expectations were too high, projections of fruit yields and economic returns were unrealistic. Farmers abandoned the crop when actual yields failed to match expectations;
2. The project was organised 'top-down', the producers were insufficiently integrated and had insufficient knowledge about cultivation of *J. curcas*; and
3. Yields from cultivation on degraded lands were very low, if any.

Additional problems with finances and bad project management also contributed to the failure of Proyecto Tempate (Euler & Gorriz 2004).



Figure 5.1: A one-year old plantation of *J. curcas* by Tree Oils India Ltd.



In India there are and have been many initiatives to grow *J. curcas* on a plantation level, but not much information is available on actual results. An (non-exhaustive) survey by Euler & Gorriz (2004) revealed that many of the efforts so far seem to have been rather disappointing in terms of yields. The *Jatropha* plantations with good yields were those on fertile land with high inputs in terms of work, irrigation and fertiliser use. Although India has many local oil mills and an established market for oil crops, market prices for *Jatropha* seeds are still too low (around Rs. 5 per kg in 2004, which translates to around 9 ct. EUR) to make cultivation of *J. curcas* a very profitable affair.

The production of bio-ethanol from sugar cane in Brazil, as described in the previous chapter, may also serve as a useful example to illustrate several potential problems of plantation-based biofuel production. The same applies to the oil palm plantations Indonesia and Malaysia, the negative aspects of which have been described in a report by Wakker (2005).

### 5.3 Organisation & Government

Growing cash crops is often most attractive for people or companies who own a significant amount of land, and have enough financial reserves to invest in setting up a plantation. Because of scale effects (and for a number of other reasons, including political power), larger landowners will usually be able to out compete smaller farmers.

In general, smallholder farmers will only be able to compete if they are either backed by a large organisation (cooperation or government) or organised into a large organisation (cooperative or producer organisation). Cooperatives can provide the scale effects, security and infrastructure needed to balance large-scale producers and processors. They can also generate a number of additional benefits, such as better integration of production and processing, better closure of nutrient chains, more sustainability and better representation of long-term interests, increased solidarity and social cohesion, and increased social empowerment (Pimbert 2006, Cohn et al. 2006). However, cooperatives will only work in situations where sufficient commitment from and cooperation by the participants are guaranteed. Furthermore, because the market for cash crops is often highly competitive and margins are often extremely low, cooperatives may not be able to compete on price alone, and may have to resort to producing for niche markets such as Fair Trade or Organic products. Because such niche markets are unlikely to emerge for biofuels, cooperatives could end up having a hard time competing on a free market. However, because of their potential benefits, cooperative production of biodiesel is to be preferred over production by large landowners or companies.

For establishment of *J. curcas* as large-scale biodiesel crop, a 'bottom-up' organisation of production (with 'top-down' support) may even be critical, as successful *Jatropha* production needs long-term commitment. Decentralised producer organisations or cooperatives could play a vital role in establishing optimal growing conditions and (integrated) agricultural techniques in different environments, as they already do for traditional food crops (Pimbert 2006, Cohn et al. 2006). For this to be successful, expectations do however need to be more realistic than is currently the case in many projects and initiatives, as unrealistic expectations can be very damaging to the long-term success of *J. curcas* (Euler & Gorriz 2004, Chambers et al. 1993).

The government has an important role to play by stimulating the production of *Jatropha* biodiesel. As described in chapter 4, government policy can create or increase demand for biodiesel and stabilise market prices. The government can also provide agricultural extension services to small-scale plantation farmers and provide credit facilities to overcome high investment costs. In order to really increase rural income, governments should support small farmers and cooperatives, instead of large companies.

Another role of the government is to regulate the cultivation and production of biodiesel in order to protect the natural environment and limit social impacts. Promoting or supporting sustainable and possibly more traditional agricultural practices will help limit natural degradation and might preserve cultural heritage and indigenous knowledge. To prevent social problems, the government should clarify land tenure rights and support gender equality.



## 5.4 Economic aspects

For biodiesel plantations to be viable, the production of biodiesel should at least be profitable. Current experiences with *J. curcas* plantations in India seem to indicate that the profit margin is still too low for large-scale production of *Jatropha* seeds to be viable (Euler & Gorriz 2004). The production costs are relatively high, due to required inputs of land, work, fertiliser, irrigation and pesticides. The maximum seed yield reported in the field in India is around 2.5 kg (fresh weight) per plant per year for rain-fed plantations, and 5 kg with irrigation. However, this yield is often not reached in plantations due to suboptimal conditions, insufficient inputs and large variation between plants. Maximum yields encountered by Euler & Gorriz (2004) on plantations in India were in the range 0.75-2.0 kg per plant per year, and even less under bad conditions such as drought or nutrient-poor soils. The price for *Jatropha* seeds on the market would have to be almost twice the price in 2004 for production to be worthwhile, even though India already has an established market for oil plants. The economic projections for plantations given by the Indian government seem over-optimistic. Average yields quoted in their projection are 1.5 kg per plant per year, oil recovery from the seeds is expected to be 91%, and the oil cake and glycerol are to be sold to compensate for the cost of processing the seeds into biodiesel. However, at a *Jatropha* biodiesel production of 1% of current fossil diesel use in India, the present market for glycerol would already be saturated. And as already stated, it would be better if the oil cake and glycerol be returned to the soil, to avoid nutrient depletion and extra expenses for chemical fertiliser. Further processing into biogas might still be possible before nutrient cycling, but experience with biogas production from *Jatropha* oil cake is still rather limited (López et al. 1997, Thite 2005).

Another problem in establishing profitable production of perennial biodiesel crops such as *J. curcas* is the start-up time, as became clear from the Nicaraguan experience. It takes at least 3 years for the plant to reach maturity and produce a harvestable yield, and at least 5 years to reach maximum or economic yields. In Proyecto Tempate the farmers were incorrectly informed, and expected average yields of 30 kg per plant per year within 3 years (Euler & Gorriz, 2004). When actual yields stayed behind expectations, most farmers discontinued their *Jatropha* plantations. But even with more realistic expectations, bridging a 3-5 year income gap is a problem for most farmers, especially when investments in inputs are needed and profit margins are low or uncertain. Mixed cropping or multiple crops, good credit facilities and policy measures to subsidise biodiesel production or increase demand might help to alleviate such start-up problems. Additionally, processing facilities need to be built and nurseries need to be set up, which may also require a significant amount of private or public investment.

## 5.5 Socio-economic aspects

Social and economic impacts of biodiesel plantations in any area will depend very much on the existing socio-economic and ecological situation, on how the plantations and the production chain are organised and on whether biodiesel is produced for export or for domestic use.

It is often claimed that switching from small-scale or subsistence farming to cash crops will be beneficial in poor rural areas, because it will lead to a general increase of income and jobs. However, as cash crops in general are more efficiently produced on larger scale plantations, expansion of cash crop production is often at the expense of small-scale producers and subsistence farmers (Fritzsche et al. 2005). Intensive production of crops requires investments in irrigation, fertiliser, equipment and labour, and is therefore not an option for everyone. Competition from larger plantations as well as rising prices for fertile land in many areas has been known to either drive smaller farmers out of business, or push them to marginal lands (Muller 2005, Cohn et al. 2006). In other words, there seems to be a general tendency of cash crop cultivation to actually increase existing income differences and inequality, instead of yielding higher benefits to the rural poor.

This certainly seems to be the case for bio-ethanol production in Brazil and palm oil production in Indonesia. Land tenure conflicts, corruption and intimidation are widespread in Indonesia, linked to large scale palm oil plantations. Small farmers cannot compete or are simply driven off their lands. They either have to move to more marginal areas or find work elsewhere, often as plantation worker on a large plantation. The plantation workers are often exploited by plantation owners and have to work for low

wages under hazardous conditions, with no long-term income security (Stedman-Edwards 2004, Wakker 2005, Cohn et al. 2006).

Producing crops for export may have benefits in terms of better credit possibilities, better availability of chemical fertiliser and equipment and increased income for farmers (Govereh & Jayne 2003). On the other hand, world markets can be extremely volatile and prices are often low. Furthermore, buyers might often prefer contracting large scale producers over small-scale producers, thereby again increasing income differences. Additionally, orientation on export may result in local markets remaining underdeveloped (Kalibwani 2005, Fritsche et al. 2005, Cohn et al. 2006, Pimbert 2006).

One of the problems with export crops is that the processing chain is often located abroad. The price for raw products is usually relatively low; most of the profit is made in 'value-added' processing, which may also generate a significant number of jobs (Fritsche et al. 2005). For export crops this often means that much of the benefit in terms of jobs and profit goes to developed countries. For this reason, and because cash cropping for export was institutionalised in the colonial period, many people regard this system as a form of 'neo-colonialism' (Kalibwani 2006, Shiva 2004). In order to generate more benefits for developing countries, more of the processing chain for export products should be located there, preferably decentralised and mostly in poor areas where unemployment is currently high.

Finally, the switch from subsistence farming to cash crops is known to have important implications for gender relations in many areas, most notably Africa. On one hand, the increased income may increase opportunities for formal education, which may have a positive effect on gender equality (Govereh & Jayne 2003). On the other hand, in many areas women are traditionally responsible for food production, earning them respect and making them the primary reservoir of indigenous knowledge on (sustainable) agriculture. With the switch to cash crops, women often lose their primary role in society, and much indigenous knowledge is lost as well.

## 5.6 Ecological aspects

Growing biofuel crops according to 'modern' intensive farming practises would imply monoculture-plantations with high inputs in terms of pesticides, chemical fertiliser and irrigation. As was already discussed in chapter 2, several problems associated with such 'artificial ecosystems', especially when resources are limited, seem to make intensive production inherently unsustainable, and probably less sustainable than small-scale extensive production or traditional farming methods in developing countries (Muller 2005, Vlek et al. 1997).

The major problems of monoculture plantations include:

- Increased risk of soil erosion and mechanical degradation, because of limited land cover, planting in rows, and sometimes due to irrigation.
- Increased risk of nutrient depletion, due to short or no fallow periods, removal of plant material and improper or insufficient application of fertilisers.
- Problems associated with irrigation, such as depletion of aquifers, soil salination and downstream aridification.
- Pollution of soil, groundwater and surface water due to excessive use of pesticides, herbicides and fertiliser.
- Increased susceptibility to pests, plant diseases and extreme weather events, due to high plant densities and relatively uniform genetic makeup.

Many projects, including the National Programme of the Indian government, assume extra income from selling *Jatropha* seed cake as organic fertiliser or (after hypothetical detoxification) as animal feed. However, to make cultivation sustainable in terms of nutrients, it might be necessary to apply the seed cake and possibly even the glycerol back to the land on which the *Jatropha* plants grow (Euler & Gorriz 2004, BIRD-K 2006). A balanced mixture of chemical and organic fertiliser might achieve the same effect, but is probably more expensive in developing countries due to the high marketing and transport costs of chemical fertilisers (Vlek et al. 1997). If chemical fertilisers are applied, care should be taken to avoid runoff or leakage into the surrounding environment. Excessive use of fertiliser could lead to

eutrophication and subsequent loss of natural biodiversity, as is the case with the sugar cane plantations in Brazil (Stedman-Edwards, 2004; Fritsche et al, 2005; Muller, 2005).

If planted correctly, especially as hedges, *J. curcas* shrubs may help decrease evaporation, runoff and erosion and increase infiltration. However, further research is needed as to what conditions must be met and the effect of monocultures vs. mixed cultures. When *J. curcas* is planted in humid climates, irrigation is probably not an issue but other problems may arise such as rotting of the plant in waterlogged soils, as was seen in several Indian plantations (Euler & Gorriz 2004).

Use of pesticides in intensive production of cash crops such as sugar cane, cotton and oil palm is known to pose a threat to the environment as well as to the health of plantation workers (Stedman-Edwards 2004, Wakker 2005, Muller 2005). While *J. curcas* seems to be fairly resistant to insects in general, experiences and research in Nicaragua and India have shown that a number of insects may still damage the plant and significantly affect yields. Most notably, certain species of jewel bugs (Scutelleridae), leaf footed bugs (Coreidae), a number of other Heteroptera species, stem borers (Cerambycidae), grasshoppers, leaf-eating beetles, caterpillars and leaf hoppers were recorded as pests in the Nicaraguan plantations (Grimm & Maes, 1997), and termites attacked plants in a number of Indian plantations (Euler & Gorriz, 2004). Monocultures, especially on larger scales, are always more susceptible to pests than mixed cultures, so will also require larger amounts of pesticides.

Deforestation of natural lands in order to cultivate 'environmentally friendly' energy crops is a practice seen in many countries, including Brazil, Indonesia and Malaysia (Stedman-Edwards 2004, Wakker 2005, Hirsch 2006, Butler 2006). The argument that biofuel will only be grown on lands that are currently degraded seems over-optimistic. Especially if production should be profitable and costs of fertilisers and irrigation is taken into account, it may prove much more attractive to start biofuel plantations on newly created land.

In short, to make intensive production of *J. curcas* in plantations more ecologically sustainable, it should not be grown on newly converted lands, and proper attention needs to be given to balanced use of organic and inorganic nutrients, erosion prevention, long-term management of water-resources and limited use of pesticides. Mixed cropping and alternative pest control measures also deserve further attention (Syers 1997, Wallace & Batchelor 1997, Vlek et al. 1997, BIRD-K 2006, Euler & Gorriz 2004).

## 5.7 Food security

Effects on food security will depend on who gets the most financial benefits from biodiesel production, on land use patterns and on ecological effects. With regard to land use patterns, if prime land is used for production and food crops are displaced to more marginal soils, food security may be endangered. If ecology or soil quality is improved by *Jatropha* cultivation, this may positively influence food security in the long run. On the other hand, if soils are further degraded, food security will be decreased in the long run. Considering experiences with large-scale plantations of oil palm and sugar cane, monoculture and intensified production may be a risk factor.

Currently, *Jatropha* plantations are not sufficiently profitable to have a significant impact on food security, positive or negative. However, this may change when oil prices rise.

## 5.8 Conclusion

Positive examples of *Jatropha curcas* plantations, especially on degraded soils, seem to be scarce. This is mainly due to the limited amount of profit that can currently be generated by cultivating *Jatropha*, selling fruits, seeds or oil and producing biodiesel. Relatively large investments are needed to establish a plantation, especially when irrigation is needed. However, the low profit margin, uncertain market and the 3-5 year delay before seeds can be harvested (gestation period) make that *Jatropha* plantations are currently not a very attractive option, especially for small farmers.

Moreover, cultivation of *Jatropha curcas* at a plantation scale creates several potential risks in relation to sustainability, and in relation to poverty reduction and food security for poor farmers. And as a result of scale effects, more political power and larger investment capabilities, large landowners and companies can easily out-compete small-scale plantation farmers. In order to balance this competition, the small farmers need to be backed by a strong organisation, such as the government or a producer organisation or cooperative.

## 6. Community scale biofuel production

### 6.1 Introduction

The majority of poor people in the world lives in rural areas and is subsistence farmer (IFAD 2001). One way of helping these rural poor in the fight against poverty is to set up a project which will generate some income in the long run. Doing this on a local scale might help to ensure that benefits will reach the people who need it the most. Such 'community scale' projects work with local people who, depending on how the project is organised, may be personally involved with the maintenance of the project.

Especially in Africa there are a number of projects that include small-scale *Jatropha curcas* cultivation as a source of income. Use of *J. curcas* is already widespread in many areas as live fence, and several projects focus on deriving additional benefits from the *Jatropha* fruits, which can be processed into oil, soap and organic fertiliser. Selling these products might provide people in rural areas with additional sources of income.

As case studies we have taken two such projects, one in Mali and one in Tanzania, which we will discuss in this chapter.

#### Mali

From 1987 to 1997 different small scale *Jatropha* projects were funded in Mali by German Technical Assistance (GTZ) and United Nations Development Programme (UNDP).

These projects try to combat poverty in Mali in different ways. With around 70% of the population living below the poverty threshold (UNDP 2000), Mali counts as one of the poorest countries in the world. Major problems to be addressed are low productivity in the traditional agricultural and livestock sector, high population growth and a low literacy level. Also problematic in Mali is the substantial rural-to-urban migration, a very small export amount and dependence on world market prices for export commodities and key imported goods such as fossil fuels (GTZ Mali 2006).

#### Tanzania

In Tanzania there are several projects which use *Jatropha curcas* as a development tool. The plant itself did not have to be introduced, because it was used as a natural fence by some farmers. But the other uses of this plant were not very well known (Persha 2003: 5). The Tanzanian project, ARI – Monduli (Introducing *Jatropha* to create Alternative Resources Income for Women in Monduli District, Tanzania) has tried to use it as an alternative income source for women. The project is organised by Kakute Ltd, a Tanzanian company that was founded in 1995 and focuses on the reduction of poverty by using business opportunities. It works by promoting and training people with new technologies to produce alternative fuels and organic products (Kakute Ltd. 1995).

### 6.2 Organizational Structure & Government Policies

#### Mali

MFC (Mali Folk Centre) cooperate with CNESOLER (Centre National d'Energie Solaire et des Energies Renouvelables, the Malian National Centre for Solar and Renewable Energy) and other actors including national and international development agencies and NGOs, ministries, municipalities and the private sector. MFC takes a participative approach, often in villages at risk from desertification, with men as well as women, to discuss and clarify roles as early as possible (MFC 2006). MFC generally does a lot of awareness and educational work to build a consensus in a village before commencing a *Jatropha* project. This involves explaining the benefits of the *Jatropha* plant, both environmental and economic, and encouraging local people to plant *Jatropha* to combat deforestation and desertification as an extra protection to wind and water erosion. The planting of *Jatropha* also allows initiation of new income generating activities as well as the production of fuel. In general, local communities have been very receptive to the idea.

In the past, the projects in Mali experienced gender-related problems. Women are not allowed to own land in Mali. The *Jatropha* plants were cultivated and harvested by women, but as soon as income was

generated from soap production, it was claimed by their men (Henning 2003b). This unclear division of roles between men and women and conflicts over land ownership often frustrated the production chain, and made projects unmanageable. Now MFC takes a more bottom-up approach, whereby the roles for men and women in the seed-harvesting and production activities are determined in participation with the community (MFC 2006).

#### Tanzania

In this project, Kakute Ltd. works together with several NGOs (CBBP, FAIDA, HPI and GEF) and in close co-operation with the Heifer International Foundation. The project started in 2001 with a pilot that had done research on the technical and economic features of *Jatropha* cultivation (Persha 2003: 10). And also to prepare the ground for a follow-up project with the main goal on developing a small scale, commercial *Jatropha* oil industry (ARI-Monduli 2001). This pilot was financed by the American McKnight Foundation (Henning 2003b: 10). It was reviewed in 2003 and ended in 2004 (Persha 2003: 10). After the pilot-project ended, several other *Jatropha* activities were initiated in three different villages throughout the Monduli-district.

Tanzania is an oil importing country, making alternative fuel sources an interesting option for the government. Up until now, research and extension services for oil seeds crops have been inadequate, causing an insufficient performance of the oil seed sub-sector. Up to date, none of these policies has financially supported the cultivation and exploitation potential biofuel crops such as *Jatropha* (GTZ 2005). Recently however, the government seems to have initiated a national project, *Jatropha* Products Tanzania Limited (JPTL) (Arusha Times 2006).

### 6.3 Socio-economic aspects

There are several ways in which cultivation of *Jatropha* can contribute to the socio-economic situation of poor people in rural areas. Cultivation of *Jatropha* plants, picking the fruits, pressing the seeds, producing soap and selling the end products may all generate local employment and income. Fuel expenses might be reduced if the oil is used instead of fossil fuels for cooking, lighting, heating and driving equipment. Replacement of firewood by *Jatropha* oil for cooking, heat and lighting may greatly reduce health problems caused by inhalation of smoke, and save especially women the (sometimes significant) time otherwise needed to collect firewood. *Jatropha* hedges may reduce crop losses caused by wandering livestock or wind and water erosion, and the press-cake can be used as organic fertiliser.

#### Mali

Traditionally, rural women in Mali used *Jatropha curcas* for medicine (seeds as laxative, latex to stop bleeding and against infections, leaves against malaria) and for soap production (MFC 2006). However, oil extraction yields were generally low, the soap made was of low quality and involved very intensive labour. Oil extraction using an oil press can deliver higher quality soap in greater amount, in a shorter time. The women might sell this soap in local markets and nearby towns, increasing their possibilities of earning income with local resources (Henning 1996).

Henning (1996) gives a rough calculation to illustrate the income generating potential of *Jatropha* for rural women in a Mali village. Based on an average length of 15 km *Jatropha* hedges per village, producing a seed yield of 15 tons, an oil yield of 3,000 litres is assumed. If 2,000 litres of the oil are used for soap production, the additional income generated is estimated to be around 3,800 US Dollar, or about 130 monthly rural incomes. It is however not known how accurate this estimate is, the actual income generated will probably be lower.

*Jatropha* hedges may also help reduce disputes between farmers and livestock owners regarding crop damage, as well as among farmers themselves regarding the boundaries of their fields. They can provide local jobs, lessening the need for local villagers to migrate to cities to find employment (Henning 2006), thus increasing social stability and reducing internal conflict.

A case study by Burn & Coche (2000) on a different project, the Multifunctional Platform For Village Power (PTFM, see § 2.1.2) in Mali shows that the provision of rural energy can have beneficial results, especially for women. Because the main tasks performed by the PTFM are traditionally performed by

women (grinding, rice hulling and water collection), the platforms are managed by women's associations. Therefore, the PTFM not only saves women a lot of work and time, it is also a good tool for empowerment. The PTFM has already been shown to run on straight Jatropha oil and MFC is among the organisations using it in Jatropha projects (MFC 2006, Greco & Rademakers 2006).

#### Tanzania

Jatropha provides several means for women to acquire an income. One is by collection of seeds, which are sold to Kakute. Kakute extracts the oil and uses the glycerol of soap. This does not require investing a lot of money, but it also provides the least amount of added value. This means that women do not generate a high income for themselves. Another is through the selling of oil. But if women collect the seeds, extract the oil and make the soap, they would add the most value themselves, which would provide them with the most income. This means that they have to put in more effort and more investment (See annex A). All the investment was still done by the NGOs but with the hope that the women would one day be able to support themselves (KIT 2006: 43-45).



The Masai women of Engaruka are mostly interested in selling soap, because the added value of a finished product means that more income is generated. When the project ended however, they fell back to their original position as chain actors selling seeds and oil, leaving the production of soap to Kakute Ltd. (Henning 2003b: 20, KIT 2006: 45). The reason for this is the fact that they do not own the tools or machinery for processing the oil (Persha 2003: 10). Furthermore, the business they were trying to set up was too small to be profitable.

The women groups did sell soap at the beginning of the project, but because they received pre-processed oil in return for their seeds, their profits were not large enough for each woman to profit from this individually. The lack of a good infrastructure and an outside market decreases the chances of making long-term profits. Also the selling of the seedlings is not very profitable for the women groups because nobody is really interested in buying them. Only if people get the seedlings for free then they are willing to use them. For these reasons the project is not very sustainable and profitable (Persha 2003: 5).

The core of the project is the dissemination of an environmentally friendly and alternative source of income for pastoralist women. Kakute provided groups of women with seeds, seedlings and cuttings, and offered them technical assistance and extension on how to grow them. It also trained them how to process the seeds to make oil and soap. Over a dozen groups of women in Arusha and Manyara regions have become involved in production and processing of Jatropha, benefiting more than 500 households (KIT Netherlands Royal Tropical Institute, Faida MaLi and the International Institute of Rural Reconstruction IIRR 2006: 41)

Although all land is owned by men in Tanzania, the women have the right to collect the seeds from the family hedges, and to process or sell them. The women have control over this money which is earned in this way. Also the village gave them plots where they can plant Jatropha for their own profit. To make sure that Kakute is able to empower the women they have implemented the policy that they will only buy seeds from women and not from men (Henning 2003b: 15). The oil from the seeds of the Jatropha can also be used in specially adapted cooking stoves, which are provided within the region by Kakute. This means that women do not have to spend a lot of time searching for fuel-wood.

## 6.4 Ecological aspects

In situations where seeds are only collected from natural fences on the edge of fields, there are no monoculture plantations of *Jatropha curcas*, no significant maintenance of the plants is required, and harmful pesticides or fertilizer do not need to be used. If it is planted around cash-crops, Jatropha hedges can profit from the runoff of water, fertiliser and pesticides from the field it surrounds (Euler & Gorris 2004). The Jatropha fences control unwanted animal access to the fields, and if planted correctly

can reduce water and wind erosion and runoff. The press-cake from the seeds can be applied to the fields as organic fertiliser, decreasing nutrient loss and somewhat reducing the need for chemical fertiliser (see chapter 2).

#### Mali

The Mali cotton-growing company, CMDT (Compagnie Malienne de Développement Textile), uses *Jatropha* hedges to protect cotton fields from cattle. This mixed cropping seems to fit the situation best as the original function of *Jatropha* as a natural fence is continued and other local products are not affected by *Jatropha* planting. In 2001 MFC had their pick-up truck adapted to be able to run on straight *Jatropha* oil (MFC 2006).

#### Tanzania

The Masai plain near Arusha suffers from serious erosion due to overgrazing (see picture on the right). The reason is the installation of a permanent water basin, which attracts cattle from a large area. Kakute has planted *Jatropha* trees, which are not browsed by the animals, to protect the soil. The Masai women in Engaruka, Tanzania, report that they were cutting trees and selling wood along the road to get some income. Due to the revenues gained by the use of the *Jatropha* plant, they have stopped doing this. Their income is higher due to the extra income generated by *Jatropha* products (Henning 2003b: 16). There is also another positive effect to the use of *J. curcas* on the environment. Some soils which are degraded could be restored again to be used for food-production (GTZ 2005). This can have an effect on one of the three villages (Olarash), because it is situated on eroded and degraded land (Persha 2003: 2-3).



### 6.5 Food security

In the case of small scale plantations where *Jatropha* hedges are used as natural fences on arid land there is no direct danger to food security because the hedges require little maintenance and investment. The side-effects of planting *Jatropha* hedges are mostly positive, protecting food crops, cash-crops and soil quality. If women can use the fruits to generate extra income from soap production, or if the oil can replace firewood, effects on poverty reduction, gender equality and food security may also be positive. However, a case study by Henning (2003) concluded that many of the African *Jatropha* projects were not yet sufficiently successful to have a significant impact on food security, although there have been some moderate successes.

### 6.6 Conclusion

It might be possible for harvesting and plantation of *Jatropha* seeds to supply an additional income for the rural poor without endangering food security. The results of several small-scale *Jatropha* projects in Africa to date show that the chances of this system being successfully implemented are high with rising oil prices, provided that a cautious approach is taken especially for the role of the woman in harvesting and processing the seeds. If a more integrated and bottom-up approach is taken when setting up projects, the roles of men and women in the production of *Jatropha* seeds can be better defined and might not lead to local conflict (Henning 2003b).

Furthermore, *Jatropha* hedges have important benefits, such as reduced wind and water erosion.



## 7. Conclusions

### 7.1 General conclusions

To date, there have not been many examples of truly successful projects involving sustainable cultivation of *Jatropha curcas* as a source of biofuel. The main reasons why projects seem to fail are:

1. No or insufficient income generation due to a low profit margin and/or low yields;
2. Projects participants are insufficiently involved in setting up the project; and
3. Farmers are insufficiently informed, leading to inappropriate farming practises and unrealistic expectations.

In most projects, income generation is assumed to be the primary benefit. However, in light of the above this may not be realistic, at least not at this moment. Current profit margins are too low for *Jatropha* to compete with other crops. It may be better to focus on cultivating *Jatropha* as hedges or mixed crop, with harvesting of fruits and production of oil for local use. Especially in remote areas, the oil may be used to replace firewood and as rural energy supply for lamps, stoves, heaters, generators, pumps and agricultural equipment. However, modified or specially designed versions of these devices are needed in order to use pure unrefined vegetable oil. If such equipment is not available, the oil still needs to be mixed with petroleum-based fuels. Additionally, an oil expeller or oil press would need to be available, at least at the community level.

In many publications and projects regarding *Jatropha curcas* biofuel, targets and requirements for application of oil, seed cake and glycerol are not clearly defined. It is often unclear if the oil produced is to be used locally as SVO, is to be mixed with fossil fuels or is to be processed into biodiesel.

As already mentioned, use of pure *Jatropha* oil requires the availability of modified or specialised lamps, stoves and engines. While the technology involved is relatively simple, not much attention seems to be given to local production of such equipment or training for modification of existing equipment. Also, in the case of soap production, the oil is basically 'cleaned' in part by adding sodium hydroxide (caustic soda), after which the rest product is used to make soap. However, if soap production is not a target, mechanical filtering and a simple chemical cleaning process might still be required for some applications, such as use of the oil in diesel engines.

Production of biodiesel from *Jatropha* oil needs facilities that are often not available at the local scale, and in most areas have not even been built at regional or national scale, even when biodiesel production is an explicit target. Other infrastructure requirements are also still unclear in many cases.

In order to make production of *Jatropha* oil or biodiesel profitable, plans and projections often include the sale of seed cake and glycerol. However, application of the seed cake back to the soil as fertiliser is probably required to make cultivation sustainable without requiring expensive chemical fertilisers. Furthermore, the market demand for glycerol is limited and unrefined glycerol needs further processing in order to be sold as a high-grade product. The glycerol might actually have more value as a fertiliser, and should probably be used locally to help fight soil degradation.

Projected yields for *Jatropha* seeds are often unrealistic, given that yields will strongly depend on soil- and water conditions, climate, cultivation techniques, and plant genotype. Furthermore, it is often unclear if given yield figures are fresh-weight or dry-weight, and on which trials, sources or experiences they are based. It is certainly true that *J. curcas* will grow under a wide range of conditions, even on degraded soils in arid areas. However, experiences in several countries have shown that seed yields will be limited on low potential or degraded soils, without irrigation and without pruning. To get an economic yield, additional inputs of organic and chemical fertilisers, water and work may thus be required. Yield figures from unmanaged *Jatropha* hedges may be misleading, because they are often planted around fields of other crops (e.g. cotton in Mali) and might therefore indirectly receive additional inputs of water, fertiliser and pesticides from the main crop. The current high yield and low input figures that are quoted in many publications have contributed to a *Jatropha* 'hype' among policy

makers and NGO's. However, use of more realistic figures is important to avoid disappointment with actual results in a later stage, and financial damage because of investments with no returns.

Planting of *J. curcas* for restoration of degraded soils, as wind barrier to decrease erosion or as fallow crop might have a positive impact on soil quality, but might not always be compatible with production of *Jatropha* oil. Because the plant has to grow under harsh conditions, seed yields may be low or even non-existent. Furthermore, harvesting of fruits will negatively affect the nutrient balance, especially if the seed cake and glycerol are not applied back to the soil.

### Plantations

The investment costs associated with *Jatropha* plantations may be a problem, especially for small-scale farmers, and especially when irrigation and use of fertiliser is required. Because of its 2-5 year gestation period, it will take several years before a *Jatropha* shrub produces an economic seed yield. Therefore, it is important to establish good long-term (micro)credit facilities for small-scale farmers, which are easily accessible and have moderate interest rates. Also, good agricultural extension services and knowledge sharing activities might help to counter unsustainable agricultural practices.

Furthermore, dependence on *J. curcas* alone might not be a good idea because of the long gestation period and uncertain economic future for biofuels. Mixed cropping might not only provide more financial stability, but it may also help decrease erosion and runoff, reduce nutrient depletion rates and increase biodiversity.

Although *Jatropha* may yield more social and ecological benefits than most other cash crops, monocultures may still have negative side effects. Sensitivity to pests and plant diseases will be increased, more input of fertiliser and water will probably be needed, and risks of erosion and soil degradation also increase.

Larger scale plantations may be more profitable, but may also have more negative social side-effects. Large plantations generate employment for the poor, but long-term income is often not guaranteed for plantation workers and employment conditions may be bad. Because large investments are needed and due to economies of scale, establishing production of *J. curcas* on plantations will tend to be easier for large landowners and companies, which may severely limit benefits for the rural poor and opportunities for small farmers. There are many examples of large biofuel plantations that have caused a decrease in income and gender equality. Production on small-scale plantations by farmers united in a cooperative or producer organisation will probably yield more benefits.

### National programmes

Large scale production of biodiesel requires significant investments in order to establish processing plants, and infrastructure for transportation and sales.

Land tenure conflicts or uncertainties may cause problems for small farmers and lead to unsustainable farming practices. Public wastelands targeted for *Jatropha* production may have other existing functions, especially for poor and landless people. This needs to be addressed and alternatives to their current use need to be provided before such lands are assigned to cultivation of energy crops such as *J. curcas*.

Cultivation of *J. curcas* for biodiesel production may lead to an increased sensitivity to market price fluctuations on the income on small farmers and others in the production chain. The price for *Jatropha* biodiesel will also be influenced by fluctuations in fossil fuel availability and price. Government policies may be needed to stabilise prices and stimulate demand for biodiesel.

As long as the supply of fossil fuels is sufficient, biofuels are expected to remain more expensive than fossil fuels, simply because biofuel production requires more inputs in terms of land and work. With a significant rise in oil prices this situation may however change, especially in developing countries that do not have easy access to fossil fuels. When this happens, *Jatropha* biodiesel plantations may become a viable option, even without government intervention.

If it can be made profitable, cultivation of *J. curcas* and biodiesel production in rural areas may lead to extra income and job creation for the rural poor. An important part of this income will be made in value

added processing, so it is important to keep this processing local and decentralised where possible. Additionally, because of the expected investment in rural areas this might bring in terms of job creation and infrastructure, it might even help reduce rural-urban migration streams.

The trade in CO<sub>2</sub> emission rights may boost profitability of biofuel production in developing countries, but it is unlikely that these extra benefits will end up with the poorest groups in society.

## 7.2 Food security

It is possible to produce *Jatropha* biodiesel without threatening food security, but at least the following conditions should be fulfilled:

### Ecological

- The rate of nutrient extraction from the soil should not exceed natural replacement rates, or extracted nutrients should be replaced artificially. Attention needs to be given not just to Nitrogen, Phosphorus and Potassium (NPK), but also to other important secondary- and micro-nutrients.
- Irrigation should be sustainable.
- The planting of *J. curcas* should not increase erosion and other forms of mechanical soil degradation.

### Socioeconomic

- Production of *J. curcas* seeds and biofuel should not lead to a net decrease in income in the mid- to long-term for those involved.
- Production should not lead to a significant increase in financial risks, e.g. because of loans needed for investments or because of increased dependence on volatile market prices for income.
- Production should not increase financial inequality, e.g. by favouring large land-owners or companies, further marginalising rural poor due to increasing land prices, etc.
- Production should not increase gender inequality, e.g. by further marginalising the role of women in communities or families.
- Cultivation of public "wasteland" should not displace landless people living on it without offering a good alternative.

Conversely, *Jatropha* biodiesel production may actually improve food security relative to the existing situation, if one or more of the following conditions are met:

- A decrease in soil erosion, an increase in soil infiltration and water retaining capacity.
- Restoration of soil nutrient levels.
- Partial or full replacement of firewood as rural fuel supply for cooking, heating, light, etc.
- Partial or full replacement of diesel, thus reducing expenses for and dependence on fossil fuels.
- Generation of extra income for marginal groups.
- Increase in gender equality, e.g. by allowing women to generate their own income.
- An increase in agricultural diversity, thus reducing problems related to monocultures and spreading the risk of market- or crop-failure over multiple crops.

## 7.3 Sustainability

In order to make production of *Jatropha* biodiesel sustainable over a longer time-period, at least the above criteria for food security should be met. In addition:

- Attention needs to be given to avoiding overuse or improper use of chemical fertiliser.
- Natural land should not be newly converted to agricultural land for biodiesel production or in order to maintain production of other crops. Existing land should be used, and degraded lands restored where possible.

Due to their requirements in terms of land and the expected future development of better energy sources, biodiesel and bio-ethanol should probably not be considered as sustainable long-term energy sources. Instead, they should be regarded as temporary options, which may provide a transition period until more sustainable energy sources become widely available. The added benefit of job creation may make biofuels an especially attractive transition option for developing countries, also because biofuel does not require large technological investments and will extend the life of current combustion engine-based technology.

#### 7.4 Conclusions for Cambodia

Access to energy sources is a problem in Cambodia, especially in remote rural areas. Small-scale cultivation of *J. curcas* and other oil crops may provide an interesting solution to the rural energy problem. Large scale cultivation of *J. curcas* on plantations does not seem to be a realistic option for Cambodia in the short term, due to the required investments in infrastructure and the fact that large scale cultivation of *J. curcas* may prove problematic in the wet lowland areas of Cambodia. It can however be grown in rows on rice bunds (the dykes surrounding rice fields) (FAO 2006).

For food, the rural Cambodian population depends mostly on rice production, on imported food and to some extent on fish, fruits and other products from 'common property resources' such as forests, lakes and rivers. Therefore, the food security situation of the rural population depends for a large part on their income, the amount of land they own, the ownership of forest and fish resources and environmental damage to these common resources. In order to safeguard food security, biofuel production should provide additional income or other benefits, and not involve risky long-term investments. It also should not negatively impact forests and fish stocks. Increasing landlessness by making establishment of large-scale commercial plantations attractive to large landowners should be avoided.

With regard to the business plan for a Khmer Biofuel Enterprise (Williamson 2005), we have the following comments:

The goals of the plan seem to be two-sided. On one-hand the goal seems to be community scale production for local use and integrated development, along the lines of the "Jatropha System" (see Henning 2004 and Baganí 2006 for a description). But on the other hand, the plan includes a market analysis of fossil diesel, regularly refers to fuel independence and fuel security for Cambodia as one of its goals, talks about putting a competitive project on the market and seems to imply plantation scale cultivation. Target groups as well as the intended scale of the project remain unclear.

The projected initial annual output of *Jatropha* oil is 55,000 litres per year, which is less than 1% of the Cambodian diesel demand, and the oil is mainly intended for use in stationary applications such as pumps and generators. It is not to be processed into biodiesel, but sold directly as filtered, unprocessed vegetable oil. The seed cake is to be sold as fertiliser. The analysis of costs and benefits estimates yields around 2,500 kg per hectare. On normal soil this would require a plant spacing of 3 x 2 m, which would mean a plant density of 1670 plants per hectare (TNAU 2006) and would require an average annual yield of around 1.5 kg per plant. This is the same figure as is used as estimate by the Indian government. Given a theoretical maximum yield on rainfed soils of around 2.5 kg per plant, this does not seem unreasonable, provided conditions are good. However, yields can vary significantly between soil and climate types, and it is not clear on what kind of conditions the Indian yield estimate is based.

The plan assumes that pure *Jatropha* oil can be used in direct-injection diesel engines without problems. However, if the oil is not further refined, carbon deposits and lubrication problems resulting from the *Jatropha* oil may cause problems and lead to eventual engine failure. Without further processing, which is not included in the plan, uses (and with it market demand) for the oil will be severely limited. Even if problems do not arise, it will be very difficult to compete with fossil diesel in areas where it can be easily

obtained. Petrol-based diesel is more widely available, can be generally used in all diesel engines without modifications, and has a predictable and still relatively low price. Jatropha oil has no added advantage, except in remote areas where fossil fuel is difficult or expensive to obtain.

Finally, selling the seed cake might lead to export of nutrients from Jatropha cultivation site, causing nutrient depletion.



## 8. Recommendations

### 8.1 General recommendations

Given the results of our research, we can give the following recommendations:

The most benefits for rural poverty production and food security are obtained when *J. curcas* is planted on a small scale by communities or individuals in order to provide energy in rural areas where this is currently problematic. *Jatropha* oil can be used in (modified) cooking stoves and lamps, and to drive generators and water pumps. Best practices for such an application of *Jatropha* might include:

- Use of integrated, sustainable and preferably traditional agricultural methods that guarantee maintenance or improvement of soil quality and water supplies. The *Jatropha* seed cake that remains after oil extraction should be locally re-used as fertiliser.
- Mixed cropping or hedges instead of monocultures.
- Bottom-up organisation of projects, in order to ensure commitment, make the best use of local knowledge, and increase empowerment. Both women and men should be involved, to avoid gender issues.
- Decentralised development of agricultural knowledge by local farmers, to determine the best cultivation practices for *J. curcas* under a range of local conditions.

Because unrefined vegetable oil has different properties than petroleum-based oil products, specially designed or modified equipment is needed. Local technicians should be trained to modify existing diesel engines. Several simple designs are available for lamps and cooking stoves suitable for use with vegetable oil. These could be produced and sold by local companies and craftsmen. Oil expellers or presses should also be available, and should preferably be produced locally. If they are imported from elsewhere, local expertise and materials should be available to maintain expellers and presses, and to fix them when they are broken.

Growing *J. curcas* in plantations for larger-scale production of biodiesel will probably result in less overall benefits than the small-scale scenario described above, although it may lead to a much wider adoption of CO<sub>2</sub>-neutral fuels. In order to still maximise benefits, we recommend that:

- Farmers should be more involved and better integrated in projects and plans to produce biodiesel on a larger scale. Projects should preferably be organised bottom-up, at least partially, to improve commitment and make better use of local knowledge. Information given should be accurate, and expectations should be realistic.
- The availability of agricultural extension services and appropriate credit schemes should be assured, either provided by government or NGOs.
- Care should be taken to close nutrient cycles and avoid depletion of water resources. Appropriate extension services as well as proper awareness-creation and training for farmers can be important in this respect.
- More research is needed to determine the best agricultural practices to ensure both productivity and sustainability. Such knowledge could be developed at least in part by (experienced) farmers in the field.
- Consideration should be given to the fact that maximum sustainable yields will vary with local conditions, and will depend especially on soil type.
- Possibilities for mixed cropping, for instance with leguminous crops, should be further explored.
- Possibilities for biogas production from *Jatropha* seed cake should be further explored. Nutrients in the residue should be recycled.

- The possibility of setting up producer organisations (farmer cooperatives) should be considered.
- Production for export delivers the least benefits. Biodiesel should preferably be produced for the domestic or regional market.

If production and use of *Jatropha* biodiesel are adopted into a national programme, the following additional points need to be considered:

- The government should provide proper agricultural extension services and appropriate credit options.
- Land tenure problems need to be clarified, especially with regard to public lands. Public land should not simply be sold to the highest bidder.
- *Jatropha* cultivation should not be contracted to large producers. Instead, small-scale production and processing should be promoted.
- The processing chain should be decentralised where possible, to maximise job creation in rural areas with high unemployment.
- Sustainable production methods should be promoted and made attractive. Deforestation and pollution should be actively discouraged.
- The market demand for biodiesel can be stimulated by policy measures, such as lowering the excise duty on biodiesel and introducing a compulsory percentage of biodiesel to be mixed in all fossil diesel.
- Given the rapidly growing energy needs and the finite amount of suitable agricultural land, biofuel should not be considered a sustainable long-term energy source. Instead, it should be regarded as a temporary option, to provide a transition period until more sustainable energy sources become widely available.

## 8.2 Recommendations for Cambodia

These are our recommendations for the GERES and DATe biofuel project in Cambodia:

- Clear target groups should be established, as well as realistic short-term goals. We recommend starting with mixed crop, community-scale plantations, or use of seeds from existing *Jatropha* hedges. Local applications for the oil should be defined and tested. Income generation should probably not be a primary short-term goal, unless profitability can be ensured.
- Trials should be started as soon as possible, in order to determine suitable ecological conditions and agricultural practices for sustainable *J. curcas* cultivation in the Cambodian climate, as well as realistic yield estimations. Current yield estimates in the literature should not be assumed to hold for conditions in Cambodia, or to be generally applicable.
- An important focal point should be technical as well as agricultural training. *Jatropha* oil is worthless if it cannot be used by anyone. And appropriate agricultural techniques should be used in order for *Jatropha* cultivation to be successful and sustainable, and to avoid damage to food security, biodiversity and the local environment.
- Alternative oil crops such as *Elaeis* oil palm species and *Pongamia pinnata* could also be considered, as *J. curcas* is not expected to perform well under the full range of ecological conditions in Cambodia (e.g. waterlogged soils). Large scale commercial plantations, especially of oil palm, should however be avoided, as these may have serious negative impact on local socio-economic and ecological conditions.
- Further refinement of the straight *Jatropha* oil is advised. Removal of free fatty acids might reduce problems with carbon deposition in the long term.



## References

- Allen, M. (2002), 'Straighter-than-straight vegetable oils as diesel fuels'. [http://journeytoforever.org/biodiesel\\_SVO-Allen.html](http://journeytoforever.org/biodiesel_SVO-Allen.html)
- Altin, R.; Cetinkaya, S. & Yucesu, H. S. (2001), 'The potential of using vegetable oil fuels as fuel for diesel engines', *Energy Conversion and Management* 42(5), 529-538.
- ARI-Monduli (2006), 'Introducing Jatropha to create Alternative Resources Income for Women in Monduli District, Tanzania (2001 - 2001)'. Website. November 2006. <http://x-borderbiodiversity.tripod.com/ari.htm>
- The Arusha Times (2006), Jatropha becomes national project.
- Avery, D. (2006), 'Biofuels, food or wildlife? The massive landcost of U.S. ethanol', Competitive Enterprise Institute. <http://www.cei.org/pdf/5532.pdf>
- Baganí (2006), 'The Jatropha System'. Website. November 2006. <http://www.jatropha.de>
- Baganí (2002), 'Alternative Resources for Income Generating for Women in Monduli'. <http://www.jatropha.de/tanzania/ari-monduli-description.htm>
- Barbier, E. B. (1997), 'The economic determinants of land degradation in developing countries', *Phil. Trans. R. Soc. B* 352(1356), 891-899.
- Barnes, D. F. & Floor, W. M. (1996), 'Rural Energy In Developing Countries: A Challenge for Economic Development', *Annual Review of Energy and the Environment* 21(1), 497-530.
- Beckett, N.; Karpinski, S.; Rudavsky, R.; Nolen, C. & Donnay, M. (2006), 'Straight Vegetable Oil Modification Kit to a Diesel Engine', School of Engineering and Applied Science, Columbia University. <http://cusj.columbia.edu/symposium/include/getdoc.php?id=28&article=7&mode=pdf>
- Bedi, E. (date unknown), 'Food or fuel?', Foundation for Alternative Energy (FAE). [http://journeytoforever.org/biofuel\\_food.html](http://journeytoforever.org/biofuel_food.html)
- Begg, J. & Gaskin, T. (1994), 'IPCS INTOX Databank, Poisons Information Monograph (PIM) 570, Jatropha curcas L.'. <http://www.intox.org/databank/documents/plant/jatropha/jcurc.htm>
- Billen, J.; van Nuijsenburger, M.; Oomen, A.; Reniers, J.; Schmeits, J. & van Wezel, R. (2004), 'Biodiesel II - Or vegetable oil', Eindhoven University of Technology (TU/e), The Netherlands. [http://www.senternovem.nl/mmfiles/149046\\_tcm24-124363.pdf](http://www.senternovem.nl/mmfiles/149046_tcm24-124363.pdf)
- BIRD-K (2006), 'The biofuel hype: Chance or challenge for sustainable agriculture?' in: Sustainable agriculture: A pathway out of poverty for India's rural poor.', GTZ Sustainet, Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn. , pp. 144. [http://www.mamud.com/Docs/sustainet\\_india08\\_lowres.pdf](http://www.mamud.com/Docs/sustainet_india08_lowres.pdf)
- Burn, N. & Coche, L. (2000), 'The Case Study on the Multifunctional Platform', Multifunctional platform Mali Project. <http://www.ptfm.net/old/Mali%20Final%20English%201.pdf>
- Butler, R. A. (2006), 'Deforestation in the Amazon', National Institute of Space Research (INPE). <http://www.mongabay.com/brazil.html>
- CGnet (2006), "'Say No To Jatropha" campaign, discussion group'. Website. November 2006. <http://in.groups.yahoo.com/group/jatropha>
- Chambers, R.; Conroy, C. & Leach, M. (1993), 'Trees as Savings and Security for the Rural Poor', International Institute for Environment and Development (IIED), London. <http://www.iied.org/pubs/pdf/full/6025IIED.pdf>

CIA (2006), 'The World Factbook'. Website. November 2006  
<https://www.cia.gov/cia/publications/factbook/geos/cb.html>

Cohn, A.; Cook, J.; Fernández, M.; Reider, R. & Steward, C., ed. (2006), *Agroecology and the Struggle for Food Sovereignty in the Americas*, International Institute for Environment and Development (IIED), the Yale School of Forestry and Environmental Studies (Yale F&ES), and the IUCN Commission on Environmental, Economic and Social Policy (CEESP). <http://www.iied.org/pubs/pdf/full/I4506IIED.pdf>

Daey Ouwers, C. (2006), Interview, 9 November 2006.

Desai, D. (2006), 'Can India Follow Brazil?'. <http://www.ethanolindia.net/Brazil.html>

Dias De Oliveira, M. E.; Vaughan, B. E. & Rykiel, E. J. (2005), 'Ethanol as Fuel: Energy, Carbon Dioxide Balances, and Ecological Footprint', *BioScience* 55(7), 593-602.

Dooley, E. E. (2005), 'Brazilian Biodiesel Blasts Off', *Environmental Health Perspectives* 113(8), A517.

Dove Biotech (date unknown), 'Jatropha Curcas L. - An international botanical answer to biodiesel production & renewable energy', Dove Biotech Ltd. <http://www.dovebiotech.com/pdf/JATROPHA%20CURCAS%20L.pdf>

ECDO (2006), 'Introduction Sustainable Development', Expertisecentrum Duurzame Ontwikkeling (ECDO), University of Amsterdam.  
<http://www.cms.uva.nl/ecdo/object.cfm/objectid=47E80B11-CBB9-4D80-8B95291D551FF607>

Euler, H. & Gorris, D. (2004), 'Case Study Jatropha Curcas India', Global Facilitation Unit for Underutilized Species (GFU), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.  
[http://www.underutilized-species.org/Documents/PUBLICATIONS/jatropha\\_curcas\\_india.pdf](http://www.underutilized-species.org/Documents/PUBLICATIONS/jatropha_curcas_india.pdf)

FAO (2006), 'EcoPort record 1297: Jatropha curcas'. Website.  
<http://ecoport.org/perl/ecoport15.pl?SearchType=entityDisplay&entityId=1297>

FAO (2000), 'Special Report: FAO/WFP crop and food supply assessment mission to Cambodia', FAO Global Information and Early Warning System on Food and Agriculture World Food Programme.  
[http://www.reliefweb.int/library/documents/FAO\\_Cambodia29dec.pdf](http://www.reliefweb.int/library/documents/FAO_Cambodia29dec.pdf)

FAO (1996), 'Rome Declaration on World Food Security and World Food Summit Plan of Action' (document W3613/E), Food and Agriculture Organization of the United Nations, World Food Summit, 13-17 November 1996, Rome, Italy. <http://www.fao.org/docrep/003/w3613e/w3613e00.htm>

Foidl, N.; Foidl, G.; Sanchez, M.; Mittelbach, M. & Hackel, S. (1996), 'Jatropha curcas L. as a source for the production of biofuel in Nicaragua', *Bioresource Technology* 58(1), 77-82.

Forson, F. K.; Oduro, E. K. & Hammond-Donkoh, E. (2004), 'Performance of jatropha oil blends in a diesel engine', *Renewable Energy* 29(7), 1135-1145.

Francis, G.; Edinger, R. & Becker, K. (2005), 'A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of Jatropha plantations', *Natural Resources Forum* 29(1), 12-24.

Fritsche, U.; Hünecke, K. & Wiegmann, K. (2005), 'Criteria for Assessing Environmental, Economic, and Social Aspects of Biofuels in Developing Countries in ecological, social, and economic terms', Öko-Institut e.V. (Institute for Applied Ecology), Germany. <http://www.oeko.de/oekodoc/234/2005-002-en.pdf>

Gonsalves, J. B. (2006), 'An Assessment of the Biofuels Industry in India' United Nations Conference on Trade and Development, Geneva, 18 October 2006', UNCTAD/DITC/TED/2006/6.  
[http://www.unctad.org/en/docs/ditcted20066\\_en.pdf](http://www.unctad.org/en/docs/ditcted20066_en.pdf)

Govere, J. & Jayne, T. (2003), 'Cash cropping and food crop productivity: synergies or trade-offs?', *Agricultural Economics* 28(1), 39-50.

Greco, G. V. D. & Rademakers, L. (2006), 'The Jatropha Energy System: An integrated approach to decentralized and sustainable energy production at the village level'. <http://www.isf.lilik.it/files/jatropha/jes.pdf>

Grimm, C. (1996), The Jatropha project in Nicaragua, in Reinhard Henning & Yaya Sidibé, ed., 'Bagani Tulu (newsletter), edition 1', Projet Pourghère, Bamako, Mali, pp. 10-14. <http://www.jatropha.de/b-t-1/jcl-nica.htm>

Grimm, C. & Maes, J. (1997), Arthropod fauna associated with *Jatropha curcas* L. in Nicaragua: a synopsis of species, their biology and pest status, in G.M. Gübitz; M. Mittelbach & M. Trabi, ed., 'Biofuels and industrial products from *Jatropha curcas*', Dbv-Verlag, Graz, pp. 31-39.

GTZ (2006), 'GTZ in Mali'. Website. November 2006. <http://gtz.de/en/weltweit/afrika/589.htm>

GTZ (2005), 'Liquid Biofuels for Transportation in Tanzania: Potential and Implications for Sustainable Agriculture and Energy in the 21st Century', Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. <http://www.gtz.de/de/dokumente/en-biofuels-for-transportation-in-tanzania-2005.pdf>

Heller, J. (1996), Physic nut, *Jatropha curcas* L., Vol. I, International Plant Genetic Resources Institute (IPGRI). [http://www.ipgri.cgiar.org/publications/pubfile.asp?ID\\_PUB=161](http://www.ipgri.cgiar.org/publications/pubfile.asp?ID_PUB=161)

Henning, R. (1996), Combating Desertification: The Jatropha Project of Mali, West Africa, in: The Arid Lands Newsletter. <http://ag.arizona.edu/OALS/ALN/aln40/jatropha.html>

Henning, R. K. (2004), 'The Jatropha System', Integrated Rural Development by Utilisation of *Jatropha curcas* L. (JCL) as Raw Material and as Renewable Energy'. <http://www.jatropha.de/Journal/The%20Jatropha%20paper%20June%202004.pdf>

Henning, R. K. (2003a), 'The Jatropha Booklet - A Guide to Jatropha Promotion in Africa', Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. <http://www.jatropha.de/documents/jcl-booklet-africa.pdf>

Henning, R. K. (2003b), 'Jatropha curcas L. in Africa - an Evaluation', Global Facilitation Unit for Underutilized Species (GFU), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. [http://www.underutilized-species.org/record\\_details.asp?id=417](http://www.underutilized-species.org/record_details.asp?id=417)

Hirsch, T. (2006), 'Biofuels are booming in Brazil', Economic and Social Research Council. [http://www.esrc.ac.uk/ESRCInfoCentre/about/CI/CP/Our\\_Society\\_Today/Spotlights\\_2006/biofuels.aspx?ComponentId=15253&SourcePageId=13440](http://www.esrc.ac.uk/ESRCInfoCentre/about/CI/CP/Our_Society_Today/Spotlights_2006/biofuels.aspx?ComponentId=15253&SourcePageId=13440)

Freedom House (2006), Website. November 2006. <http://www.freedomhouse.org>

IANGV (2006), 'IANGV 2006 International Statistics', International Association for Natural Gas Vehicles. <http://www.iangv.org/content/view/17/35/>

IFAD (2001), 'Rural Poverty Report 2001 - The Challenge of Ending Rural Poverty', International Fund for Agricultural Development. <http://www.ifad.org/poverty/>

IFQC (2004), 'Setting a Fuel Quality Standard for Fuel Ethanol', International Fuel Quality Center. <http://www.deh.gov.au/atmosphere/fuelquality/publications/pubs/ifqc-report.pdf>

Jones, S. & Peterson, C. L. (2002), 'Using Unmodified Vegetable Oils as a Diesel Fuel Extender – A Literature Review', Department of Biological and Agricultural Engineering, University of Idaho. [http://scholar.google.com/scholar?q=cache:4YVTFZgTHtUJ:www.uidaho.edu/bae/biodiesel/raw%2520vegetable%2520Oils\\_literature%2520review.doc](http://scholar.google.com/scholar?q=cache:4YVTFZgTHtUJ:www.uidaho.edu/bae/biodiesel/raw%2520vegetable%2520Oils_literature%2520review.doc)

Kakute Ltd. (2006), 'Kakute Limited - The Company For Technology Dissemination and Training'. Website. November 2006. <http://x-borderbiodiversity.tripod.com/kakute.htm>

Kalibwani, F. (2005), 'Food security in Southern Africa: Current status, key policy processes and key players at regional level', Southern African Regional Poverty Network (SARPN), Overseas Development Institute (ODI), Food and Natural Resources Policy Analysis Network (FANRPAN). [http://www.sarpn.org.za/documents/d0001701/Food-security\\_paper\\_Oct2005.pdf](http://www.sarpn.org.za/documents/d0001701/Food-security_paper_Oct2005.pdf)

- Kim Sedara, C. S. & Acharya, S. (2002), 'Working Paper 24: Land, Rural Livelihoods and Food Security in Cambodia: A Perspective from Field Reconnaissance', Cambodia Development Resource Institute (CDRI).  
<http://www.cdri.org.kh/webdata/download/wp/wp24e.pdf>
- KIT; MaLi, F. & IIRR (2006), Chain Empowerment: Supporting African farmers to develop markets, Royal Tropical Institute, Amsterdam; Faida Market Link, Arusha; and International Institute of Rural Reconstruction, Nairobi.
- Klabin, I. (2005), 'Roundtable: Successes With Bioenergy - The Brazilian Experience', Brazilian Foundation for Sustainable Development - FBDS. <http://www.fbds.org.br/Apresentacoes/FBDS-AgriculForum.pdf>
- Kleinen, J. & Mar, T. (2004), 'Cambodja: Mensen, politiek, economie, cultuur, milieu', Netherlands Royal Tropical Institute (KIT) and Novib (OXFAM Netherlands).
- Knothe, G. (2001), 'Historical Perspectives on Vegetable Oil-Based Diesel Fuels', Inform 12:11, 1103-1107.  
[http://www.nbb.org/resources/reportsdatabase/reports/gen/20011101\\_gen-346.pdf](http://www.nbb.org/resources/reportsdatabase/reports/gen/20011101_gen-346.pdf)
- La Rovere, E. (2004), 'The Brazilian Ethanol Program: Biofuels for Transport', International Conference for Renewable Energies. [http://www.renewables2004.de/ppt/Presentation4-SessionIVB\(11-12.30h\)-LaRovere.ppt](http://www.renewables2004.de/ppt/Presentation4-SessionIVB(11-12.30h)-LaRovere.ppt)
- Lal, R. (1997), 'Degradation and resilience of soils', Phil. Trans. R. Soc. B 352(1356), 997-1010.
- López, O.; Foidl, G. & Foidl, N. (1997), Production of biogas from *Jatropha curcas* fruitshells, in G.M. Gübitz; M. Mittelbach & M. Trabi, ed., 'Biofuels and industrial products from *Jatropha curcas*', Dbv-Verlag, Graz, pp. 118-122.
- Abhishek Maharishi (2006), 'Centre of Excellence for *Jatropha* Biodiesel Promotion'. Website. November 2006  
[http://jatrohabiodiesel.org/aboutjatrophaPlant.php?\\_divid=menu1](http://jatrohabiodiesel.org/aboutjatrophaPlant.php?_divid=menu1)
- Makkar, H. & Becker, K. (1998), *Jatropha curcas* toxicity: Identification of toxic principle(s), in T. Garland & A.C. Barr, ed., 'Toxic Plants and Other Natural Toxicants', New York: CAB International, , pp. 554-558.
- Makkar, H. P. S.; Becker, K. & Schmook, B. (1998), 'Edible provenances of *Jatropha curcas* from Quintana Roo state of Mexico and effect of roasting on antinutrient and toxic factors in seeds', Plant Foods for Human Nutrition (Formerly Qualitas Plantarum) 52(1), 31-36.
- Martinez-Herrera, J.; Siddhuraju, P.; Francis, G.; Davilla-Ortiz, G. & Becker, K. (2006), 'Chemical composition, toxic/antimetabolic constituents, and effects of different treatments on their levels in four provenances of *Jatropha curcas* L. from Mexico', Food Chemistry 96, 80-89.
- Martinot, E.; Chaurey, A.; Lew, D.; Moreira, J. R. & Wamukonya, N. (2002), 'Renewable energy markets in developing countries', Annual Review of Energy and the Environment 27(1), 309-348.
- McCarthy, J. R. (2005), 'Conservation Tillage and Residue Management to Reduce Soil Erosion', University of Missouri. <http://muextension.missouri.edu/explore/agguides/agengin/g01650.htm>
- MFC (2006), 'Mali-Folkecenter'. Website. November 2006. <http://www.malifolkecenter.org>
- Muller, A. (2005), 'Burning the Future - Long-term and Large-scale Problems of Bioenergy'.  
[http://www.cepe.ch/download/staff/adrian/Muller\\_Bioenergy\\_230705.pdf](http://www.cepe.ch/download/staff/adrian/Muller_Bioenergy_230705.pdf)
- Persha, L. (2003), 'Follow-up report on CBBP activities in the Monduli-district', CBBP.  
[http://www.xborderbiodiversity.org/dcforum/User\\_files/MonduliDistrict\\_CBBPactivityFollowUp\\_2003.pdf](http://www.xborderbiodiversity.org/dcforum/User_files/MonduliDistrict_CBBPactivityFollowUp_2003.pdf)
- Pimbert, M. (2006), 'Reclaiming autonomous food systems: the role of local organizations in farming, environment and people's access to food', Sustainable Agriculture, Biodiversity and Livelihoods Program, International Institute for Environment and Development (IIED), London.  
<http://www.iied.org/NR/agbioliv/documents/PimbertSSLandConference.pdf>
- Prado, L. (2006), 'The Brazilian Biodiesel Program is Bad for the Very Poor in Rural Areas'.  
<http://www.portofentry.com/site/root/resources/analysis/4210.html>

Pramanik, K. (2003), 'Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine', *Renewable Energy* 28(2), 239-248.

Prateepchaikul, G. & Apichato, T. (2003), 'Palm Oil as a Fuel for Agricultural Diesel Engines: Comparative Testing against Diesel Oil', *SONGKLANAKARIN Journal of Science and Technology* Vol.25 No.3 25(3).

Protzen, E. (1997), 'On the Development of a Prototype Jatropha-Oil fueled Jiko and a Jatropha-Oil fueled Lamp'. <http://www.jatropha.org/lamps/protzen2.html>

PTFM Network (2006), 'The Multifunctional Platform'. Website. November 2006 <http://www.ptfm.net>

Ramadhas, A. S.; Jayaraj, S. & Muraleedharan, C. (2004), 'Use of vegetable oils as I.C. engine fuels-A review', *Renewable Energy* 29(5), 727-742.

Sai Petrochemicals (2006), 'Biodiesel in India'. Website. December 2006 [http://www.svlele.com/biodiesel\\_in\\_india.htm](http://www.svlele.com/biodiesel_in_india.htm)

Schaeffer, R.; Szklo, A. S.; Cima, F. M. & Machado, G. (2005), 'Indicators for sustainable energy development: Brazil's case study', *Natural Resources Forum* 29(4), 284-297.

Singh, B.; Swaminathan, R. & Ponraj, V., ed. (2006), *Biodiesel Conference Towards Energy Independence – Focus on Jatropha*, Rashtrapati Bhawan, New Delhi. <http://presidentofindia.nic.in/presentation/splangl89PDF%20Format786.pdf>

SEAS (2006), 'Team Lister Green'. Website. Columbia University School of Engineering and Applied Science, November 2006. <http://www.me.columbia.edu/me3410/spring06/group01/index.html>

Sedara, K.; Sophal, C. & Acharya, S. (2002), 'Land, rural livelihoods and food security in Cambodia: a perspective from field reconnaissance, Working Paper 24', Cambodia Development Resource Institute. <http://www.cdri.org.kh/webdata/download/wp/wp24e.pdf>

SenterNovem (2006), 'De meest gestelde vragen en wetenswaardigheden over biobrandstoffen', SenterNovem. [http://www.gave.novem.nl/figuur025/faq\\_dutch.html](http://www.gave.novem.nl/figuur025/faq_dutch.html) 9-12-2006

Shaine Tyson, K. (2006), 'Biodiesel Technology and Feedstocks', Presentation. <http://www.easterncct.edu/depts/sustainenergy/calendar/biodiesel/Tyson%20-%20Biodiesel%20Technology%20and%20Feedstocks.pdf>

Sheehan, J.; Dunahay, T.; Benemann, J. & Roessler, P. (1998), 'A look back at the U.S. Department of Energy Aquatic Species program: Biodiesel from Algae', National Renewable Energy Laboratory (NREL). [http://www1.eere.energy.gov/biomass/pdfs/biodiesel\\_from\\_algae.pdf](http://www1.eere.energy.gov/biomass/pdfs/biodiesel_from_algae.pdf)

Shiva, V. (2004), 'The future of food: countering globalisation and recolonisation of Indian agriculture', *Futures* 36, 715-732.

Slingerland, S. & van Geuns, L. (2005), 'Drivers for an International Biofuels Market', Clingendael International Energy Programme.

Sophal, C. & Acharya, S. (2002), 'Facing the challenge of rural livelihoods: a perspective from nine villages in Cambodia, Working Paper 25', Cambodia Development Resource Institute. <http://www.cdri.org.kh/webdata/download/wp/wp25e.pdf>

Stedman-Edwards, P. (2004), 'Review of Commodities – Rice, cane sugar, and cotton'. <http://www.panda.org/downloads/policy/commodityreviewdraftistedmanedwards.doc>

- Stumpf, E. (2001), 'Plant oil as cooking fuel: development of a household cooking stove for tropical and subtropical countries', Institute for Agricultural Engineering in the Tropics and Subtropics, Hohenheim University.  
[http://www.thinkcycle.org/tc-filesystem/download/development\\_by\\_design\\_2001/plant\\_oil\\_cooking\\_stove\\_for\\_developing\\_countries/Plant\\_Oil\\_Cooking\\_Stove.pdf](http://www.thinkcycle.org/tc-filesystem/download/development_by_design_2001/plant_oil_cooking_stove_for_developing_countries/Plant_Oil_Cooking_Stove.pdf)
- Syers, J. K. (1997), 'Managing soils for long-term productivity', Phil. Trans. R. Soc. B 352(1356), 1011-1021.
- Thite, H. R. (2005), 'Biogas 2 Energy', Website. <http://www.biogas2energy.blogspot.com/>
- TNAU (2006), 'Technologies Developed'. Tamil Nadu Agricultural University, Website. December 2006.  
<http://www.tnau.ac.in/tech/swc/>
- UN (2004), 'Economic, Social and Cultural Rights - The right to food. Report submitted by the Special Rapporteur on the right to food, Jean Ziegler, in accordance with Commission on Human Rights resolution 2003/25.' (report E/CN.4/2004/10), United Nations Economic and Social Council, Commission on Human Rights.  
[http://www.unhchr.ch/huridocda/huridoca.nsf/\(Symbol\)/E.CN.4.2004.10.En](http://www.unhchr.ch/huridocda/huridoca.nsf/(Symbol)/E.CN.4.2004.10.En)
- UNDP (2000), 'Poverty Report', United Nations Development Program.  
<http://www.undp.org/povertyreport/countryprofiles/mali1.html>
- UNESCAP (2002), 'Reducing poverty and promoting social protection', Social Policy Paper No. 5, (ST/ESCAP/2168), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).  
<http://localhost.unescap.org/esid/psis/publications/spps/05/2168.pdf>
- USDA (1997), 'Alley Cropping - Conservation Practice Job Sheet 311', USDA.  
[http://www.ma.nrcs.usda.gov/news/publications/Alley\\_Cropping.pdf](http://www.ma.nrcs.usda.gov/news/publications/Alley_Cropping.pdf)
- Vlasman, A. & Dankelman, I. (2002), 'Denkraam voor duurzame ontwikkelingen. Duurzame ontwikkeling en toekomstdenken. Een inleiding.', DHO. <http://www.dho.nl/documents/Denkraam.pdf>
- Vlek, P. L. G.; Kühne, R. F. & Denich, M. (1997), 'Nutrient resources for crop production in the tropics', Phil. Trans. R. Soc. B 352(1356), 975-985.
- VROM (2006), 'Dossier Biobrandstoffen: Vraag en antwoord'. Website. Ministerie van Verkeer Ruimtelijke Ordening en Mobiliteit, November 2006 <http://www.vrom.nl/pagina.html?id=20930>
- Wakker, E. (2005), 'Greasy palms - The social and ecological impacts of large-scale oil palm plantation development in Southeast Asia', Friends of the Earth (FOE). [http://www.foe.co.uk/resource/reports/greasy\\_palms\\_impacts.pdf](http://www.foe.co.uk/resource/reports/greasy_palms_impacts.pdf)
- Wallace, J. S. & Batchelor, C. H. (1997), 'Managing water resources for crop production', Phil. Trans. R. Soc. B 352(1356), 937-947.
- Wani, S. P.; Rupela, O. P. & Lee, K. K. (1995), 'Sustainable agriculture in the semi-arid tropics through biological nitrogen fixation in grain legumes', Plant and Soil 174(1), 29-49.
- Wikipedia (2006), 'Compressed Natural Gas', Website. [http://en.wikipedia.org/wiki/Compressed\\_Natural\\_Gas](http://en.wikipedia.org/wiki/Compressed_Natural_Gas)
- Williamson, A. (2005), 'Initial Business Plan', Khmer Biofuel Enterprise.
- Ziegler, J. (2004), 'ECONOMIC, SOCIAL AND CULTURAL RIGHTS - The right to food, Report submitted by the Special Rapporteur on the right to food, Jean Ziegler, in accordance with Commission on Human Rights resolution 2003/25', United Nations Economic and Social Council, Commission on Human Rights.  
[http://www.unhchr.ch/huridocda/huridoca.nsf/\(Symbol\)/E.CN.4.2004.10.En?OpenDocument](http://www.unhchr.ch/huridocda/huridoca.nsf/(Symbol)/E.CN.4.2004.10.En?OpenDocument)

## Further reading

Bender, M. (1999), 'Economic feasibility review for community-scale farmer cooperatives for biodiesel', *Bioresource Technology* 70, 81-87.

Cabraal, R. A.; Barnes, D. F. & Agarwal, S. G. (2005), 'PRODUCTIVE USES OF ENERGY FOR RURAL DEVELOPMENT', *Annual Review of Environment and Resources* 30(1), 117-144.

Chambers, R.; Conroy, C. & Leach, M. (1993), 'Trees as Savings and Security for the Rural Poor', *International Institute for Environment and Development (IIED)*, London. <http://www.iied.org/pubs/pdf/full/6025IIED.pdf>

Ehrlich, P. R.; Ehrlich, A. H. & Daily, G. C. (1993), 'Food Security, Population and Environment', *Population and Development Review* 19(1), 1--32.

El Bassam, N. (2001), 'Renewable energy for rural communities', *Renewable Energy* 24(3-4), 401--408.

El Bassam, N. (1998), *Energy Plant Species*, James & James / Earthscan.

Filho, P. G. & Bad, O. (2004), 'Biomass resources for energy in North- Eastern Brazil', *Applied Energy* 77:1, 51-67.

Friedrich, S. (2004), A world wide review of the commercial production of biodiesel – A technological, economic and ecological investigation based on case studies, Vol. Band 41, Des Institutes für Technologie und Nachhaltiges Produktmanagement der Wirtschaftsuniversität Wien, o.Univ. Prof. Dr. Gerhard Vogel.  
[http://itnp.wu-wien.ac.at/archiv\\_doc/BAND41\\_FRIEDRICH.PDF](http://itnp.wu-wien.ac.at/archiv_doc/BAND41_FRIEDRICH.PDF)

Geuns, L. & Slingerland, S. (2005), 'Drivers for an International Biofuels Market. Discussion paper', *Clingendael Institute*. [http://www.clingendael.nl/publications/2005/20051209\\_ciep\\_misc\\_biofuelsmarket.pdf](http://www.clingendael.nl/publications/2005/20051209_ciep_misc_biofuelsmarket.pdf)

Giampietro, M.; Ulgiati, S. & Pimentel, D. (1997), 'Feasibility of Large-Scale Biofuel Production', *BioScience* 47(9), 587-600.

GET (2005), 'Renewable Energy Resources: the Past, Present and Future' (PP/09/05 Background Paper), German Economic Team in Belarus. <http://research.by/pdf/pp2005e09.pdf>

Giampietro, M.; Ulgiati, S. & Pimentel, D. (1997), 'Feasibility of Large-Scale Biofuel Production', *BioScience* 47(9), 587-600.

Gladwin, C. H.; Thomson, A. M.; Peterson, J. S. & Anderson, A. S. (2001), 'Addressing food security in Africa via multiple livelihood strategies of women farmers', *Food Policy* 26(2), 177--207.

Hazell, P. & von Braun, J. (2006), Biofuels: A Win-Win Approach That Can Serve the Poor in: 'IPFRI Forum, June 2006', *International Food Policy Research Institute (IPFRI)*, pp. 8-9.

Hazekamp, T. (2004), 'Development of Underutilized Species - An Analysis of Best Practices based on Case Studies for Devil's Claw, Quinoa and Physic Nut', *Global Facilitation Unit for Underutilized Species (GFU)*, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.  
[http://www.underutilized-species.org/record\\_details.asp?id=1](http://www.underutilized-species.org/record_details.asp?id=1)

Henning, R. K. (2002), 'Using the Indigenous Knowledge of Jatropha: The use of Jatropha curcas oil as raw material and fuel', *IK Notes* 47(47), *World Bank*. <http://www.worldbank.org/afr/ik/iknt47.pdf>

Henning, R. K. (1998), 'Use of Jatropha curcas L. (JCL): A household perspective and its contribution to rural employment creation Experiences of the Jatropha Project in Mali, West Africa, 1987 to 1997'.  
<http://www.jatropha.de/harare98.htm>

Kojima, M. & Johnson, T. (2005), 'Potential for Biofuels for Transport in Developing Countries', *UNDP / World Bank Energy Sector Management Assistance Programme (ESMAP)*.  
[http://wbln0018.worldbank.org/esmap/site.nsf/files/312-05+Biofuels+for\\_Web.pdf/\\$FILE/312-05+Biofuels+for\\_Web.pdf](http://wbln0018.worldbank.org/esmap/site.nsf/files/312-05+Biofuels+for_Web.pdf/$FILE/312-05+Biofuels+for_Web.pdf)

- Martinot, E. (April 19 2006), 'Global Renewable Energy Markets and Policies', ABA Renewable Energy Resource Subcommittee National Teleconference.
- Maxwell, D. & Wiebe, K. (1999), 'Land Tenure and Food Security: Exploring Dynamic Linkages', *Development and Change* 30(4), 825-849.
- Niven, R. K. (2005), 'Ethanol in gasoline: environmental impacts and sustainable review article', *Renewable & sustainable energy reviews* 6, 535.
- Partners for Africa and Stockholm Environment Institute (SEI) (2005), 'Newsletter: Renewable Energy Partnerships for Poverty Eradication and Sustainable Development - Policy Debate on Global Biofuels Development'.  
<http://www.sei.se/red/RED-June-2005.pdf>
- Pimentel, D.; McNair, M.; Buck, L.; Pimentel, M. & Kamil, J. (1997), 'The Value of Forests to World Food Security', *Human Ecology* 25(1), 91-120.
- Pinto, A. C.; Guariero, L. L. N. & et al., M. J. C. R. (2006), 'Biodiesel: an overview', *Journal of the Brazilian Chemical Society* 16, 1313.
- Raynolds, L. T. (2002), 'Poverty Alleviation Through Participation in Fair Trade Coffee Networks: Existing Research and Critical Issues', Sociology Department, Colorado State University. Background Paper Prepared for Project Funded by the Community and Resource Development Program, The Ford Foundation, New York.  
<http://www.colostate.edu/Depts/Sociology/FairTradeResearchGroup/doc/rayback.pdf>
- Sanchez, P. A.; Buresh, R. J. & Leakey, R. R. B. (1997), 'Trees, soils, and food security', *Phil. Trans. R. Soc. B* 352(1356), 949-961.
- Sass, J. (2002), 'Women, Men, and Environmental Change: The Gender Dimensions of Environmental Policies and Programs', Population Reference Bureau (PRB). [http://www.prb.org/pdf/WomenMenEnviron\\_Eng.pdf](http://www.prb.org/pdf/WomenMenEnviron_Eng.pdf)
- Shah, S.; Sharma, S. & Gupta, M. (2004), 'Biodiesel Preparation by Lipase-Catalyzed Transesterification of Jatropha Oil', *Energy & Fuels* 18(1), 154-159.
- Tickner, V. (1996), 'Food Security in Cambodia: A Preliminary Assessment', United Nations Research Institute for Social Development (UNRISD).  
[http://www.unrisd.org/unrisd/website/document.nsf/d2a23ad2d50cb2a280256eb300385855/64b8dcc549d8524980256b67005b6c36/\\$FILE/dp80.pdf](http://www.unrisd.org/unrisd/website/document.nsf/d2a23ad2d50cb2a280256eb300385855/64b8dcc549d8524980256b67005b6c36/$FILE/dp80.pdf)
- Tinker, P. B. (1997), 'The environmental implications of intensified land use in developing countries', *Phil. Trans. R. Soc. B* 352(1356), 1023-1033.
- Wiesenhütter, J. (2003), 'Use of the Physic Nut (*Jatropha curcas* L.) to Combat Desertification and Reduce Poverty', Convention Project to Combat Desertification (CCD Project), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).  
[http://www.underutilized-species.org/documents/PUBLICATIONS/use\\_of\\_jatropha\\_curcas\\_en.pdf](http://www.underutilized-species.org/documents/PUBLICATIONS/use_of_jatropha_curcas_en.pdf)
- WSU (2002), 'An Industry and Market Study on Six Plant Products in Southern Africa: Jatropha or Physic Nut', International Programs, Washington State University.  
<http://209.85.135.104/search?q=cache:I56KxXJZWAsj:oregonstate.edu/international/outreach/rlc/resources/jatropha.pdf>



## Annex I.

### Collection and sale of seeds

**Collection of seeds:** (figures from KAKUTE, 2003)

Collection of seeds: 2 kg in 1 hour

Sale of seeds: 150 TZS per kg

<b>Value added for 1 hour work</b>	<b>300 TZS</b>	<b>0,29 USD per hour</b>
------------------------------------	----------------	--------------------------

### Extraction and sale of oil

**Oil extraction:** (figures from KAKUTE, 2003)

5 kg of seed for 1 litre of oil is 1,7 hours of work

1,0 hours of work to extract 1 litre of oil

<b>Input:</b>	<b>5 kg of seed</b>	<b>750 TZS</b>	<b>0,71 USD per</b>
	1,5 hours of work to extract 1 litre of oil		
	depreciation of ram press 0,02 USD / kg		
	for 5 kg:	105 TZS	0,10 USD per
<b>Output:</b>	<b>Sale of 1 litre of oil</b>	<b>2.000 TZS</b>	<b>1,90 USD</b>
<b>Value added for 1 hour of work</b>		<b>1.145 TZS</b>	<b>1,09 USD per</b>

### Production and sale of soap

**Soap making:** (figures from KAKUTE, 2003)

16 hours work for 252 bars of soap

1 bar sold for 500 TZS

Purchase of 20 litres of oil à 2.000 TZS = 40.000

Purchase of 3 kg of Caustic Soda à 2.000 TZS = 6.000 TZS

Plastic for wrapping soap = 3.000 TZS

10 hours for miscelenous work (organising purchase of oil, wrapping the soap, etc)

<b>Input:</b>	<b>20 l oil</b>	<b>40.000 TZS</b>	<b>38,10 USD</b>
	Plastic	3.000 TZS	2,86 USD
	Caustic Soda	6.000 TZS	5,71 USD
	Total input for 26 hours work	49.000 TZS	46,67 USD
<b>Output:</b>	<b>252 bars à 500 TZS</b>	<b>126.000 TZS</b>	<b>120,00 USD</b>
<b>Total of revenues</b>		<b>77.000 TZS</b>	<b>73,33 USD</b>
<b>Value added for 1 hour of work</b>		<b>2.962 TZS</b>	<b>2,82 USD per hour</b>