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

Revision 2

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

1. 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 op 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_2 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_2 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.

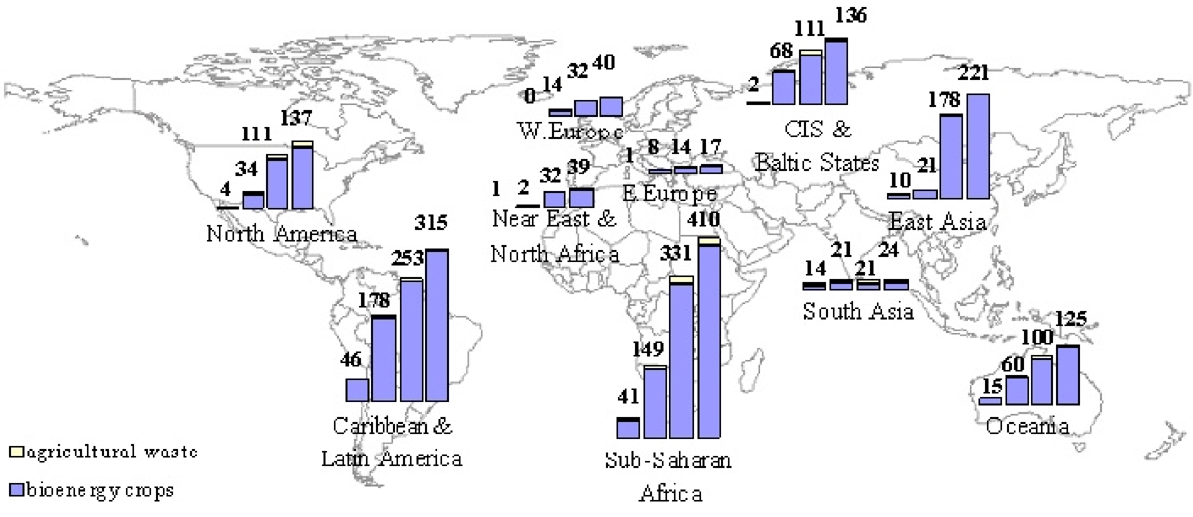


Figure 2.1: The bars represent low to high estimates for bioenergy production over a range of scenarios. These estimates are 13% to147% of expected global primary energy demand in 2050. Source: E. Smeets, A. Faaij, I. Lewandowski – March 2004

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, sometimes called PVO) 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 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 the distance between burner and oil reservoir. An extreme example of this principle is the 'Binga oil lamp' (see figure 2.2) , 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.

Recently, a very promising plant oil cooking stove (see figure 2.2) has been produced by the Bosch-Siemens Home Appliances Group (BSH), based on the design of Stumpf (2001). Mass production of this stove is expected to commence within the next few years. (BSH 2006)

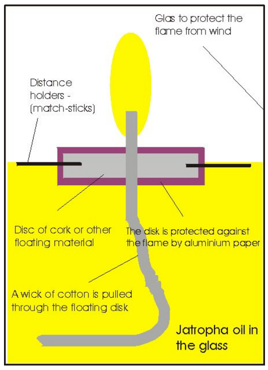


Figure 2.2: The BSH Protos and another type of plant oil stove, and a schematic drawing of the 'Binga oil lamp' (Baganí 2006)

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, MFC 2006).

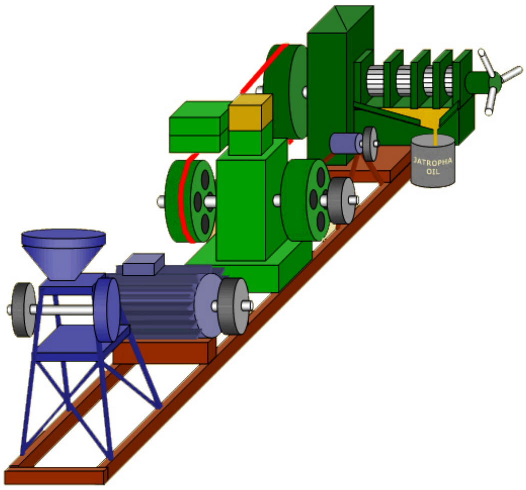


Figure 2.3: The Jatropha Energy System, fitted with (from left to right) a grinding mill, a generator, a Lister-type diesel engine, a battery charger and an oil press (source: MFC 2006).

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 the drier regions of the tropics, with annual rainfall of 300-1000 mm per year. The plant is very draught-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 & Gorriz 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 & Gorriz 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. Excesive 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 every-day 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

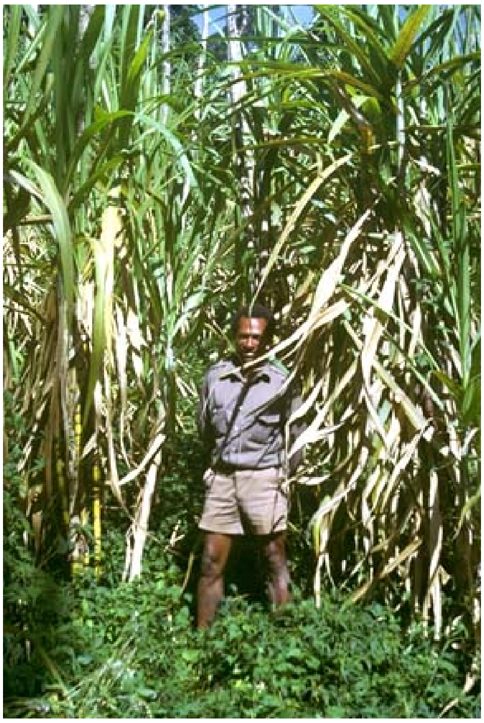
Ethanol has been in use as fuel in Brazil since the 1930's. It was produced from sugar cane in times of recession of the international sugar market. Ethanol was mixed with petrol but because of poor performance and high fuel consumption (the result of engines not being adjusted to ethanol) it was not 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_2-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_2 and SO_2 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^2/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^2 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 then 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)[b]	0.20	1.01	5.07
Foreign exchange saving by fuel substitution (million US$/year)[c]	67	334	1,672
Employment generation (man-days)[d]	200,000	1,000,000	5,000,000
Savings of CO_2 consumption by the use of the produced bio-diesel as automobile fuel (million tons/year)[e]	0.5	2.7	13.4
CO_2 sequestration in the biomass (million tons/year)[f]	0.9	4.6	22.9
Possible income from CO_2 reduction from emission trading (M US$)[g]	14.5	72.5	362.5

Notes:
[a] Assuming current production patterns do not change.
[b] Assuming production of 583 l per ha per year.
[c] Assuming an average international price of US$45/barrel of crude oil.
[d] Assuming average employment of one person for two ha.
[e] Assuming that the end use of bio-diesel reduces life cycle CO_2 emissions by 85% compared to use of petro-diesel and a production of 2.7 kg of CO_2 per litre of diesel and a density of 0.87 for diesel.
[f] 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_2 per metric ton of C.
[g] Calculating an average market value of US$10 per ton of CO_2 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 Wateshed 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 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 (Fritsche 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 2005, 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. (e.g. Wells 1999: 6)

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 of 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

Successful 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 tries to generate income in a sustainable manner. 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.

6.2 Mali

6.2.1 Organizational Structure & Government Policies

From 1987 to 1997 different small scale Jatropha projects where funded in Mali by German Technical Assistance (GTZ) and the 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 include desertification, low productivity in the traditional agricultural and livestock sectors, high population growth and a low literacy level. Also problematic in Mali is the substantial rural-to-urban migration, a very small export sector, and dependence on world market prices for export commodities and key imported goods such as fossil fuels (GTZ Mali 2006).

Mali-Folkecenter (MFC) is an NGO that promotes sustainable management and use of natural resources for development, especially in rural areas. This NGO has set up several projects that include the cultivation and use of Jatropha curcas. MFC cooperates with a large number of other actors, including local and national government agencies and departments, national and international development agencies and NGOs, the private sector, and most importantly local communities. Recently they have established a Malian Jatropha Promotion Network. This network includes more than 15 institutions (public organisations, research institutes, NGOs, private sector, rural municipality members and international development organisations). Its aim is to facilitate the exchange of information and experiences regarding the role of Jatropha curcas in rural development and the fight against desertification. (MFC 2006)

In its projects, MFC aims to take a participative 'bottom-up' approach, involving all relevant actors as early as possible in order to clarify the roles and responsibilities of each party. A lot of attention is given to education and awareness building, before commencing a project, especially when the benefit is not immediately obvious. In the case of Jatropha projects, this involves explaining the environmental and economic benefits of the plant, and encouraging local people to plant Jatropha seedlings to combat erosion. The cultivation of Jatropha also opens possibilities for new income-generating activities, as well as the production of fuel for local use. In general, communities have been very receptive to the idea. (MFC 2006)

6.2.2 Socio-economic aspects

Although roughly two-thirds of Mali is covered by desert, an estimated 80-95% of the country's total energy consumption is provided by firewood and charcoal. This not only puts a large strain on the country's remaining forest resources, but it also has consequences for the role of women. In rural areas of Mali, it is not uncommon for women to spend more than two-thirds of their time collecting wood. In urban areas, the purchase of firewood represents about 10-15% of the household expenses, the financial burden of which is borne by women. On the other hand, the collection and selling of firewood represents the main source of income for many families in rural Mali. Wood can be collected any time of year, and stocks can be sold whenever cash is needed. This illustrates the complex role of firewood relating to poverty and gender issues. (Cisse 2006)

The cultivation of Jatropha offers prospects for replacing firewood as the main source of household energy and income in rural areas. Furthermore, unlike firewood, Jatropha oil can also be used to drive diesel engines, thus providing a much more versatile source of rural energy. And finally, the cultivation of Jatropha curcas may positively affect the role of women in Malian society, as well as their income and health.

Traditionally, rural women in Mali used Jatropha curcas for medicine (the seeds as laxative, the latex to stop bleeding and against infections, and the leaves against malaria) and for soap production (MFC 2006). However, oil extraction yields were generally low, the soap made was of low quality and the production was very labour-intensive. 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 total additional income generated is estimated to be around 3,800 US Dollar, or about 130 monthly rural incomes. The accuracy of this estimate is however not known. It is expected to be somewhat on the high side, the actual income generated will probably be lower.

While the use of Jatropha oil for soap production may provide an additional source of income for women, it also has drawbacks. Opportunities for using Jatropha oil as an energy source are not utilised this way, so the problems associated with the collection and use of firewood still remain. Moreover, projects that promoted the planting of Jatropha for soap-making by women in the 1990's, experienced gender-related problems. Because women in Mali generally cannot not own land, all the Jatropha plants are automatically owned by men. As soon as the income-generating potential of soap-making became clear, some men started to claim the profits, as the soap was made using 'their' Jatropha plants. (Henning 2003b, MFC 2006)

To address such issues, MFC has started to take a more participative approach in their projects. Instead of initiating a project 'top-down', all actors are involved and their roles are clarified in an early stage. This participative approach has apparently been quite successful in reducing the amount of 'nasty surprises'. It has for example allowed plots of unused land to be allocated by land chiefs to women's groups for Jatropha plantations. (MFC 2006)

MFC is also involved in activities whereby Jatropha oil is used as an energy source. In 2000, the United Nations Environment Programme (UNEP) initiated the African Rural Energy Enterprise Development (AREED) initiative. AREED offers rural energy entrepreneurs in five African countries a combination of enterprise development services and start-up financing, and MFC is the main Malian partner organisation. As part of this programme, MFC helps finance the development and distribution of a 'Jatropha Energy Platform'. This is a version of the Multifunctional Platform For Village Power (PTFM, see § 2.1.2) that runs on straight Jatropha oil, and includes an oil-press for Jatropha seeds. (MFC 2006, Greco & Rademakers 2006)

In Mali, rural women are traditionally responsible for most of the food production (notably the cultivation and processing of millet, sorghum and other important staple crops), food processing, collection of firewood for cooking and sale, and collection of water. They also grow vegetable gardens for household use and sale in local marketplaces, and they collect shea tree nuts and process these into shea butter, which can again be sold on the local market. (Wells 1999: 6, Diagana 2001)

The devices commonly mounted on a PTFM may include a mechanical mill, a rice huller, a shea butter press and a water pump, all of which serve to assist women in their daily tasks. Moreover, distribution of the platform is demand-driven and on a commercial basis, and it is usually paid for and managed by women's associations. The services provided by the PTFM are therefore essentially managed and sold by women entrepreneurs, mostly to female clients, making the PTFM an effective tool for empowerment. Several case studies in Mali have shown that the impacts of the PTFM can be significant and are mostly beneficial, especially for women. (Havet 2003, Diagana 2001, Burn & Coche 2000)

The Sustainable Energy Advisory Facility (SEAF) project in which MFC participated identified several problems with early Jatropha Energy Platforms distributed by MFC. Platforms were often badly maintained because spare parts and expertise were not available locally, organisational and financial management was often insufficient, and an adequate supply of Jatropha oil could not be supplied. To address these problems, training was provided in operation and maintenance of the equipment, as well as in management capacity building and creation of management structures. The Sundara-type oil expeller that was originally used by MFC was imported from Nepal. In cooperation with Ateliers Militaires Centraux de Markala (AMC), one of Mali's leading metal workshops, the design was modified so that the oil expellers could be produced in Mali. (MFC 2006)

The main problem to be addressed now is to ensure that the platform can be kept running on Jatropha oil instead of diesel. The use of unfiltered Jatropha oil has a negative long-term impact on the Lister-type diesel engine used on the platforms. These problems can be mostly solved by filtering the oil. MFC is currently developing simple sedimentation and filtration systems for Jatropha oil, constructed from local materials that are easily available. They are also working with Engineers Without Borders USA to identify and remove these and other technical constraints, so that Jatropha oil can be more widely used in PTFM installations. (MFC 2006)

As for the supply of Jatropha oil, there seems to be surprisingly little data on the current extent and success of Jatropha cultivation in Mali. In 2003 MFC established 45-50 ha of Jatropha plantations in the south of Mali, in association with a number of village communities (MFC 2006). The current status of these plantations is however unclear. Also for smaller-scale Jatropha cultivation in gardens and in hedges around fields, there seems to be no recent data available. In 1996 it was estimated that 10,000 km of Jatropha hedges were present in Mali, with a growth rate of 2,000 km per year (EIE 2006). It is however unclear how this estimate was obtained, and if it is still accurate today.

6.2.3 Ecological aspects

As a country situated on the border between Sahel and Sahara, Mali's main environmental problems include deforestation and (partly as a result of this) desertification. The main cause of deforestation in Mali is the collection of firewood. Furthermore, population growth combined with migration from the northern desert areas to the more fertile south, has caused rapid soil degradation and pollution in the southern parts of the country. If Mali is to sustain its growing population in the coming decades, better management of soil, water and forest resources is essential. Therefore it is important to look for alternative sources of household energy and income, that may replace firewood. (UN 2006: 489-491)

If planted correctly, Jatropha hedges can help decrease erosion and increase infiltration of rainwater. The oil from its seeds may provide an alternative source of household energy and income, reducing the need for firewood. When planted around existing fields or plantations, the hedges control unwanted animal access to the fields and reduce water and wind erosion. Furthermore, the Jatropha plants may profit from the runoff of water, fertiliser and pesticides from the field they surround, thus potentially increasing fruit yields and decreasing maintenance needs (Euler & Gorriz 2004). The press-cake from the seeds can be applied to the fields as organic fertiliser, decreasing soil nutrient loss and somewhat reducing the need for chemical fertiliser (see chapter 2).

The cultivation of Jatropha as hedges around existing fields has a mostly positive environmental impact, it does not negatively affect other local agricultural products and it continues the traditional use of Jatropha as a natural fence. The Mali cotton-growing company, CMDT (Compagnie Malienne de

Développement Textile), reportedly promotes the use of Jatropha hedges to protect cotton fields from cattle (Henning 2003b). However, it is not know if, and for what purpose the seeds of these Jatropha plants are being used by the local population.

Community Jatropha plantations may produce a bigger fruit yield than can be obtained from hedges alone. The impact of such plantations will vary with the location, the intensity of production and other factors. If planted on degraded land or wasteland, the impact is expected to be positive, but the oil production will probably be low. See paragraph 5.6 for a more detailed discussion on this subject.

6.3 Tanzania

6.3.1 Organizational Structure & Government Policies

Tanzania is an oil importing country, making alternative fuel sources an interesting option for the government. Until now, research on and extension services for oil seed crops in Tanzania has been limited, and there have been no government policies that financially support the cultivation and exploitation of potential biofuel crops such as Jatropha curcas (GTZ 2005).

In Tanzania there are several projects that use Jatropha curcas as a development tool. The plant itself was already in use as a natural fence, and was probably introduced by Germans colonialists in the early 20th century. But the further applications of this plant are not very well known among the population (Persha 2003: 5). The Tanzanian project ARI-MONDULI (Alternative Resources Income project for Monduli women), aimed to use Jatropha-derived products to create an alternative income source for women. The project ran from June 2000 to December 2004. It was executed by Heifer Project International (HPI) Tanzania and managed by the Tanzanian non-profit companies Kakute Ltd. and Faida Market Link (formerly Faida-SEP), and the UNDP Global Environment Facility (GEF) East African Cross-Border Biodiversity Project (CBBP). The ARI-MONDULI project was financed by the American McKnight Foundation. (Manyanga 2006, Kakute 2005, Henning 2003b: 10)

In 2005 a sister organisation of Kakute was created, Jatropha Products Tanzania Limited (JPTL). Many of the Kakute staff were transferred to JPTL, which aims to further develop the Jatropha sub-sector in Tanzania, using the accumulated experiences from the ARI-MONDULI project. Several new partnerships have been formed, to provide R&D related to Jatropha and its applications, and for further development of the market. (Manyanga 2006, Arusha Times 2006)

6.3.2 Socio-economic aspects

Jatropha provides several opportunities for women to acquire an income. One is by collection of seeds, which are sold to Kakute for the production of herbal soap. This requires few investments, but it also provides the least amount of added value for the women, and therefore the least income. Some women groups however, produce the oil themselves from seeds using a ram press. Finally, some groups also produce Jatropha seedlings, plant and tend the crop, and harvest the seeds. The latter options require more work and larger investments, but also generate more added value and therefore more income per unit work (see Annex A). During the ARI-MONDULI project, seeds, seedlings, cuttings, training, technical assistance and extension services were provided by Kakute. When the project ended however, these services ceased and many women's groups discontinued their Jatropha activities. (KIT 2006: 43-45)

In the early phases of the project, the women's groups were trained to make and market soap themselves, because selling a finished product would create the most added value. However, none of the groups were able to create enough profit to sustain this practice beyond small-scale production for domestic use and sometimes sale within the village. The businesses were too small, and lacked market access and/or a good market to be able to generate a significant income for all participants. Eventually the larger-scale production and marketing of soap was left entirely to Kakute. However, this approach also experienced problems, including an insufficient supply of seeds to increase production, and insufficient capacity within Kakute to further develop the market, which is one of the main reasons why JPTL was established. (Henning 2003b: 20, KIT 2006: 43-45, Persha 2003: 5, Manyanga 2006)

The supply of Jatropha seeds suffers from a limiting vicious circle. Interest from farmers and women's groups for cultivating Jatropha seedlings and seeds is limited as long as the demand and profit margins are low. Meanwhile, the production of Jatropha soap cannot be expanded as long as a sufficient supply of seeds or oil cannot be guaranteed. In order to break this circle, JPTL will attempt to form a strategic alliance with several women's groups, for the structural production of Jatropha seeds and oil. In effect, this comes down to creating one or a few strong producer organisations, which act as umbrella-associations able to negotiate on behalf of the women. A potential problem is that there are no credit sources for women's groups in the region. Currently funding for several groups is provided by the McKnight Foundation, but this is not very sustainable. (Manyanga 2006, KIT 2006: 43-45)

Although the use of Jatropha oil for soap production has proven relatively successful in this region, its use as fuel has so far been very limited. Oil lamps have been distributed by Kakute and the Tanzania Traditional Energy Development and Environment Organisation (TaTEDO). Furthermore, Kakute has been developing a prototype Jatropha oil stove together with the University of Dar Es Salaam (UDSM) and other parters since 1997. This has however proven more difficult than originally anticipated (Protzen 1997, Otto 2006). But more importantly, Jatropha oil seems to be too expensive and the supply insufficient to be a viable alternative to kerosene or diesel, at least at this moment. (Ngoo 2006, Manyanga 2006)

Currently, the GTZ Programme for Biomass Energy Conservation in Southern Africa (GTZ-PROBEC) is testing the newly developed BSH Protos plant-oil stove with Jatropha oil in 25 Tanzanian households. The Bosch-Siemens Home Appliances Group (BSH) is exploring the possibilities for local production of the Protos stove in Tanzania (BSH 2006, Roth 2006). The stove, if successful, may provide a breakthrough in the use of Jatropha oil as a fuel, breaking the vicious circle of low supply and demand. It may however take several years before production of the stove is at a sufficient level.

CBBP and TaTEDO have been promoting the use of sustainable rural energy technologies in the Monduli, Bukoba and Same districts for several years. These technologies have mostly included fuel-efficient wood stoves and biogas cooking stoves, in an effort to decrease the use of firewood. However, experiences from these and other projects indicate that acceptance of such 'new' technologies is strongly related to cultural preferences, which may differ strongly even between villages. Women in some villages rejected the 'improved' cooking stoves, because the stoves did not fit their way of cooking or were for various other reasons not regarded an improvement. For instance, the smoke generated by wood fires may have a negative health impact, but it also serves to keep away insects. Finally, it was noted that equipment which was given away for free was often not well maintained, and was easily discarded when broken. On the other hand, equipment for which the owners had paid was generally much better maintained, and more often fixed when broken. This leads to the conclusion that distribution of new energy technologies should probably be demand-driven. Furthermore, in many cases energy technologies may actually be most effectively disseminated through the local private sector, instead of through NGO's or government channels. (Ngoo 2006, Persha 2003, Van Bastelaar 2004)

6.3.3 Ecological aspects

Desertification and deforestation are serious problems in Tanzania as well, although not as serious as in Mali. However, much of Tanzania consists of semi-arid lands, which are sensitive to overgrazing and erosion. Consequently, rapid population growth and an accompanying increase in livestock around population centres has led to serious overgrazing and erosion in many areas (Mlay 1982). Planting of Jatropha hedges might help decrease erosion and protect certain areas from grazing, although this should be done with care to avoid simply moving the problem to another area. Kakute has tried planting Jatropha hedges on the Masai Plain between Arusha and Lake Manyara (see picture), which suffers from serious overgrazing and erosion due to the establishment of a permanent water basin for cattle. However, the Jatropha hedges did not help, as the causes of the problem (the basin and the cattle) were still present. (Henning 2003b)

As in Mali, the collection of firewood is one of the causes of deforestation in Tanzania as well. However, the limited availability and relatively high price of Jatropha oil make that it is currently not a viable alternative to firewood. (Ngoo 2006)

With regard to the establishment of Jatropha plantations and hedgerows, Kakute has noted that especially in more arid regions it is important to use seedlings instead of cuttings, because seedlings develop a tap-root and therefore have better access to groundwater. Jatropha trees grown from cuttings only develop four lateral roots, but no tap root, and will therefore not survive periods of extended drought. (Manyanga 2006)

6.4 Food security

Hedgerows and small-scale plantations of Jatropha curcas grown for local production of biofuel are unlikely to have a negative effect on food security. Moreover, if the plants are cultivated in such a way as to reduce erosion and grazing, and increase groundwater infiltration, they might contribute to soil restoration and thus have a positive effect on long-term local food security. This is especially the case for hedgerows and Jatropha live-fences around existing fields or on wastelands suffering from erosion.

If the yield of Jatropha seeds is sufficient to be used as fuel or for soap production, this may further contribute to rural food security. This may be because additional income is generated by selling seeds, oil, soap or energy services. Or it may be due to the substitution of firewood, thereby reducing deforestation, soil degradation, the time needed by women and girls to collect firewood and the negative health effects of smoke. Finally, significant benefits to food security, gender equity and the Millennium Development Goals in general may be obtained through the provision of rural energy services by a Multifunctional Platform For Village Power which is operated on Jatropha oil (see also: Havet 2003 and UNDP 2004).

A case study by Henning (2003) concluded that many of the African Jatropha projects were not yet sufficiently successful to have a significant positive impact on food security, although there have been some moderate successes.

6.5 Conclusion

Community-scale production of Jatropha based biofuels provides interesting opportunities for income generation, empowerment of women, sustainable rural energy production and protection and restoration of soils. Especially small-scale mixed cropping of Jatropha curcas with food- or cash-crops, and Jatropha hedges around fields may provide the added benefits of Jatropha-derived products without negatively impacting existing production systems and local ecology.

The current potential for Jatropha for income generation and as energy source is somewhat limited by the high price of Jatropha oil relative to petrol-based fuel and firewood. However, this balance may change with rising oil prices and an increased scarcity of suitable firewood. Breaking the vicious circle of low production and low demand will be important if Jatropha oil is to become more widely used as fuel. Better (commercial) availability of plant-oil stoves and lamps, as well as Jatropha Energy Platforms may help in breaking this circle by increasing the demand. Awareness programmes and stimulating measures for small-scale cultivation of Jatropha curcas as hedges or in (community) gardens or small plantations may help to increase the potential supply op Jatropha seeds.

In setting up community-scale Jatropha-related projects, it is important to adopt a participative approach and clearly define the roles and responsibilities of all actors. Cultural preferences, gender-issues and the creation of local expertise are very important for the success of such projects, and should not be overlooked.

Over the years MFC in Mali and Kakute in Tanzania have built up considerable experience with planting and processing Jatropha curcas in semi-arid African climates. This experience may prove valuable if Jatropha were to become a more economically interesting source of energy. It would be useful if their experience in cultivation and application of Jatropha and their lessons learnt in project management would be more widely disseminated.

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/or roles and responsibilities of the various actors are unclear; 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, and/or equipment for filtering the oil. 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. Several organisations and companies have designed equipment suitable for use with pure Jatropha oil, including cooking stoves (BSH Group), oil lamps (Kakute Ltd. Tanzania) and oil expellers and filtering equipment (Mali Folkecenter). These designs should be more widely used.

Production of biodiesel from pure 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 biofuel 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_2 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-based biofuel 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 biofuel 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.
- Provision of new energy services in rural communities, e.g. using the Multifunctional Platform for Village Energy.
- 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.

Food security is determined by a number of factors, which will differ between regions and population groups. For marginal groups, access to food is often limited by income. This may even be the case for subsistence farmers in rural areas. In some regions (especially in arid or very wet environments) availability of food may also be seasonally limited. Proper attention should be given to identify the main factors limiting food security in a given region, whenever the production of biofuels is considered. It should also be noted that food sovereignty plays an important role in ensuring food security in the long-term. Switching from subsistence farming to cash crops (including biofuel-crops) may increase income (and therefore food security) in the short term. However, it will also increase dependence on imported food and market prices, which may threaten food security in the long term.

7.3 Sustainability

In order to make production of Jatropha biofuel 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 biofuel 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, water pumps and agricultural equipment. 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.
- Better use of existing knowledge and experience, and decentralised development of new 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, cooking stoves and filtering equipment 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 over-all benefits than the small-scale scenario described above, although it may lead to a much wider adoption of CO_2-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 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 (micro)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

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.
http://dx.doi.org/10.1016/S0196-8904(00)00080-7

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 now becomes national project.
http://www.arushatimes.co.tz/2006/14/local_news_12.htm

Avery, D. (2006), 'Biofuels, food or wildlife? The massive landcost of U.S. ethanol', Competive 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. http://dx.doi.org/10.1098/rstb.1997.0068

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.
http://arjournals.annualreviews.org/doi/abs/10.1146/annurev.energy.21.1.497

van Bastelaar, K. (2004), 'Cookstoves', Working Group for Development Techniques (WOT), Twente, Netherlands. http://www.wot.utwente.nl/documents/description/2004_cookstoves/index_nl.html

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

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 Nuijsenburg, 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

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

BSH Bosch und Siemens Hausgeräte GmbH (2006), 'BSH presents ecological plant oil stove for developing countries'. Website. http://www.bsh-group.com/dynamic/content/unternehmen/gesellschaft_protos_en.htm

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

Cisse, D. (2006), 'Energy and Gender for Sustainable Development: The Case of Mali. National Paper prepared for the UN Commission on Sustainable Development (CSD 14 and 15)'. ENERGIA – International Network on Gender and Sustainable Energy.
http://www.google.com/search?q=cache:xo6m9k7-2SoJ:www.energia.org/resources/reports/2006_csd_mali.pdf

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/14506IIED.pdf

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

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

Diagana, M. (2001), 'Impact study of the multi functional platform on the living conditions of women', Multifunctional Platform for Poverty Alleviation. http://www.ptfm.net/old/diaganareport.pdf

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.
http://www.ingentaconnect.com/content/aibs/bio/2005/00000055/00000007/art00010

Dooley, E. E. (2005), 'Brazilian Biodiesel Blasts Off', Environmental Health Perspectives 113(8), A517. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1280380

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

EIE (2006), 'Energy for Poverty Alleviation in Sahel (IE4Sahel). Deliverable 4: Assessment of potential energy sources.', Intelligent Energy Europe (EIE), in participation with Instituto Superior Técnico (IST) Portugal, Energy for Sustainable Development Ltd. (ESD) UK, Centre for Renewable Energy Sources (CRES) Greece and AGRHYMET Regional Center (ARC) Niger. http://ie4sahel.energyprojects.net/links/IE4Sahel_D4.pdf

Euler, H. & Gorriz, 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

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

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. http://dx.doi.org/10.1016/S0960-8524(96)00111-3

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. http://dx.doi.org/10.1016/j.renene.2003.11.002

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. http://dx.doi.org/10.1111/j.1477-8947.2005.00109.x

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

Govereh, J. & Jayne, T. (2003), 'Cash cropping and food crop productivity: synergies or trade-offs?', Agricultural Economics 28(1), 39-50. http://dx.doi.org/10.1111/j.1574-0862.2003.tb00133.x

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

Havet, I. (2003), 'Linking women and energy at the local level to global goals and targets', United Nations Development Programme (UNDP). http://www.energyandenvironment.undp.org/undp/indexAction.cfm?module=Library&action=GetFile&DocumentAttachmentID=1745

Heller, J. (1996), Physic nut, Jatropha curcas L., Vol. 1, International Plant Genetic Resources Institute (IPGRI). 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

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

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

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

Kakute Ltd. (2002), 'ARI - MONDULI. Alternative Resources for Income Generating for Women in Monduli', KAKUTE Limited Tanzania. http://www.jatropha.de/tanzania/Kakute/ari-monduli/ari-m-gen-proj-descr.pdf

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

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; Faida MaLi & IIRR (2006), Chain Empowerment: Supporting African farmers to develop markets, Royal Tropical Institute (KIT), Amsterdam; Faida Market Link, Arusha; and International Institute of Rural Reconstruction (IIRR), Nairobi. ISBN 9966754008. http://www.mamud.com/Docs/chains.pdf

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

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

Lal, R. (1997), 'Degradation and resilience of soils', Phil. Trans. R. Soc. B 352(1356), 997-1010. http://dx.doi.org/10.1098/rstb.1997.0078

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.

Abhiskek Maharishi (2006), 'Centre of Excellence for Jatropha Biodiesel Promotion'. Website. November 2006 http://jatrophabiodiesel.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. http://www.uni-hohenheim.de/i3ve/00068900/20405041.htm

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) V52(1), 31-36. http://dx.doi.org/10.1023/A:1008054010079

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. http://dx.doi.org/10.1146/annurev.energy.27.122001.083444

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. http://dx.doi.org/10.1146/annurev.energy.27.122001.083444

Manyanga, L. (2006), 'Jatropha sub-sector evolution in Tanzania', KAKUTE Limited Tanzania. http://www.jatropha.de/Journal/Jatropha%20Developpement%20in%20Tanzania.pdf

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

Mlay, W. (1982), Environmental implications of land-use patterns in the new villages in Tanzania, in J.W. Arntzen; L.D. Ngcongco & S.D. Turner, ed., 'Land Policy and Agriculture in Eastern and Southern Africa', The United Nations University (UNU), 1986. Department of Geography, University of Dar es Salaam, Dar es Salaam, Tanzania. http://www.unu.edu/unupress/unupbooks/80604e/80604E0e.htm

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

Ngoo, G. (2006), 'Improved biomass energy use for reducing biodiversity loss in three districts of Tanzania', Tanzania Traditional Energy Development and Environment Organisation (TaTEDO). http://www.tatedo.org/sedf7.htm

Otto, J. (2006), 'History of the KAKUTE plant oil stove' http://www.bioenergylists.org/en/kakutestove

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

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/PimbertISSLandConference.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. http://dx.doi.org/10.1016/S0960-1481(02)00027-7

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. http://dx.doi.org/10.1016/j.renene.2003.09.008

Roth, C. (2006), 'GTZ Probec Protos Stove Tests Tanzania', GTZ Probec. http://www.bioenergylists.org/en/gtzprotostanz

Sai Petrochemicals (2006), 'Biodiesel in India'. Website. December 2006 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. http://dx.doi.org/10.1111/j.1477-8947.2005.00141.x

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/splang189PDF%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 9-12-2006

Shaine Tyson, K. (2006), 'Biodiesel Technology and Feedstocks', Presentation. http://www.easternct.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

Shiva, V. (2004), 'The future of food: countering globalisation and recolonisation of Indian agriculture', Futures 36, 715-732. http://www.casadelaindia.org/educacion/cursoespecialistaUVA/archivos/Indian%20agriculture.pdf

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

Syers, J. K. (1997), 'Managing soils for long-term productivity', Phil. Trans. R. Soc. B 352(1356), 1011-1021. http://dx.doi.org/10.1098/rstb.1997.0079

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

UN (2006), 'Water a shared responsibility - The United Nations World Water Development Report 2', United Nations Educational, Scientific and Cultural Organization (UNESCO) and others. ISBN 92-3-104006-5. http://www.unesco.org/water/wwap/wwdr2/table_contents.shtml
Section 5 (Sharing Responsibilities), Chapter 14 (Case Studies), p. 489-491 (Mali)
http://www.unesco.org/water/wwap/wwdr2/case_studies/pdf/mali.pdf

UNDP (2000), 'Poverty Report', United Nations Development Program.
http://www.undp.org/povertyreport/countryprofiles/mali1.html

UNDP (2004), 'Gender & Energy For Sustainable Development: A Toolkit And Resource Guide', United Nations Development Programme (UNDP), Bureau for Development Policy, Energy and Environment Group. http://www.undp.org/energy/genenergykit/genderengtoolkit.pdf

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

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. http://dx.doi.org/10.1098/rstb.1997.0076

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

Wallace, J. S. & Batchelor, C. H. (1997), 'Managing water resources for crop production', Phil. Trans. R. Soc. B 352(1356), 937-947. http://dx.doi.org/10.1098/rstb.1997.0073

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 V174(1), 29-49. http://dx.doi.org/10.1007/BF00032240

Wells, T. (1999), 'Land Tenure and the Cadastral System of Mali', University of Maine, Department of Spatial Information Engineering Cadastral and Land Information Systems-SIE526. http://www.spatial.maine.edu/~onsrud/emergingeconomies/country_reports/mali.pdf

Wikipedia (2006), 'Compressed Natural Gas', Website. http://en.wikipedia.org/wiki/Compressed_Natural_Gas

Williamson, A. (2005), 'Initial Business Plan', Khmer Biofuel Enterprise.
http://www.nri.org/biomass/conference_papers/biofuel_in_cambodia.pdf

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. http://dx.doi.org/10.1146/annurev.energy.30.050504.144228

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. http://dx.doi.org/10.2307/2938383

van Eijck, J. & Romijn, H. (2006), 'Prospects for Jatropha Biofuels in Developing Countries: An analysis for Tanzania with Strategic Niche Management', Diligent Tanzania and Eindhoven Centre for Innovation Studies. http://fp.tm.tue.nl/ecis/Working%20Papers/Ecis%20wp151.pdf

El Bassam, N. (2001), 'Renewable energy for rural communities', Renewable Energy 24(3-4), 401--408. http://dx.doi.org/10.1016/S0960-1481(01)00022-2

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. http://dspace.lib.cranfield.ac.uk:8080/bitstream/1826/784/2/Biomass+Resources+for+Energy+in+Nort-Eastern+Brazil.pdf

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

Geuns, L. & Slingerland, S. (2005), 'Drivers for an International Biofuels Market. Discussion paper', Clingendeal Institute. 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. http://dx.doi.org/10.2307/1313165

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. http://dx.doi.org/10.1016/S0306-9192(00)00045-2

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. http://www.ifpri.org/pubs/newsletters/ifpriforum/200606/IF15Biofuel.asp

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

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 creationExperiences of the Jatropha Project in Mali, West Africa, 1987 to 1997'. http://www.jatropha.de/harare98.htm

ICRISAT (2007), 'Pro-Poor Biofuels Outlook for Asia and Africa: ICRISAT's Perspective', International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). http://www.icrisat.org/Investors/Biofuel.pdf

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

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. http://dx.doi.org/10.1111/1467-7660.00139

Niven, R. K. (2005), 'Ethanol in gasoline: environmental impacts and sustainable review article', Renewable & sustainable energy reviews 6, 535. http://dx.doi.org/10.1016/j.rser.2004.06.003

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 V25(1), 91-120. http://dx.doi.org/10.1023/A:1021987920278

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. http://dx.doi.org/10.1590/S0103-50532005000800003

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. http://dx.doi.org/10.1098/rstb.1997.0074

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

Shah, S.; Sharma, S. & Gupta, M. (2004), 'Biodiesel Preparation by Lipase-Catalyzed Transesterification of Jatropha Oil', Energy & Fuels 18(1), 154-159. http://dx.doi.org/10.1021/ef030075z

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

Tinker, P. B. (1997), 'The environmental implications of intensified land use in developing countries', Phil. Trans. R. Soc. B 352(1356), 1023-1033. http://dx.doi.org/10.1098/rstb.1997.0080

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

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 A.

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

Value added for 1 hour work	300 TZS	0,29 USD per hour

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

Input:	**5 kg of seed**	**750 TZS**	**0,71 USD per**
	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
Output:	**Sale of 1 litre of oil**	**2.000 TZS**	**1,90 USD**
Value added for 1 hour of work		**1.145 TZS**	**1,09 USD per**

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
Plasic for wrapping soap = 3.000 TZS
10 hours for miscelenous work (organising purchase of oil, wrapping the soap, etc)

Input:	**20 l oil**	**40.000 TZS**	**38,10 USD**
	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
Output:	**252 bars à 500 TZS**	**126.000 TZS**	**120,00 USD**
Total of revenues		**77.000 TZS**	**73,33 USD**
Value added for 1 hour of work		**2.962 TZS**	**2,82 USD per hour**