Theoretical and Practical Evaluation of Jatropha as Energy Source Biofuel in Tanzania

Stelyus L. Mkoma and Faith P. Mabiki
Faculty of Science, Sokoine University of Agriculture
Tanzania

1. Introduction

Sustainable energy production and supply are strategic objectives for developed as well as developing countries. The energy sector plays a crucial role in attaining the United Nations Millennium Development Goals (Short, 2002), and the sustainability of modern economics is based in part on the capacity of countries to ensure their energy supplies. This is especially true for the transport sector, which consumes 30% of the world energy production, 99% of which is petrol-based (IEA, 2008). Global energy supply is currently mainly based on fossil fuels, which have many disadvantages. It is now widely agreed that more sustainable alternative energy sources will need to be developed. One potentially promising option consists of biofuels, since these are derived from biomass, have a closed carbon-cycle and do not contribute to the greenhouse effect. The biomass necessary for the production of biofuels can be derived from several sources; oil-producing crops are prominent among these. Due to relatively faster crop growth in the tropics, as well as the substantial land requirements for large-scale production, developing countries could potentially play a substantial role in the cultivation of oil-producing crops to yield major potential economic and environmental benefits for these countries. Notably, they could help to create additional income for the rural poor, and alleviate countries' balance of payments constraints by lessening oil import dependency or even by yielding export revenue. A gradual transition of the dominant energy regime in these countries from fossil fuels towards biofuels could thus have many advantages.

Current biofuels are actually based on traditional food crops such as maize, rapeseed or sunflower. A wide range of energy and global greenhouse gas budgets has been reported for them, although they are generally favourable compared with conventional fossil fuels like gasoline and diesel (Hill et al., 2006). However, these types of feedstock raise concerns because they are directly linked to food security issues? Also their cultivation is fuel-fertilizer and pesticide-intensive, with significant impacts on ecosystems. People living in the large part of the African, Asian and Latin America continents often lack access to energy sources in general. One approach to provide people with energy to increase living standards is to enable them to produce energy from local resources. The use of *Jatropha curcas* (Linnaeus), an inedible crop appears to be the promising alternative of local renewable energy source for people living in tropical and subtropical regions. When people use the term Jatropha, usually they refer to *Jatropha curcas* L. which is one of the 170 known species of this plant. Jatropha is a small wild plant belongs to the family Euphorbiaceae and is indigenous to Latin America and now found in all the tropical and subtropical zones (30°N; 35°S) of Africa and Asia. All parts of the plant, including seeds, leaves and bark, fresh or as a decoction, are toxic to humans and animals due to the presence of phorbol esters (Jongschaap et al., 2007).

Jatropha can be utilized for various purposes of which the application as fuel is probably the most interesting one from both an economical and ecological point of view. Nevertheless the other uses are worth mentioning as they provide insight in the total value chain of Jatropha products. Jatropha can be used for biogas production from its press cake formed during oil production. However, the press cake also has a wide variety of applications depending on local circumstances e.g. as a fertilizer (Kaushik et al., 2007). Jatropha can also be used to prevent and/or control soil erosion, to reclaim exhausted land (Benge, 2006), as a medicinal plant, be planted as a commercial crop, grown as a natural fence, especially to contain or exclude farm animals. In Tanzania the Swahili name for Jatropha is "Mbono Kaburi" (graveyard tree). It is known so because it was traditionally planted to mark a grave whenever someone dies. However, different domestic and traditional belief on the plant is excised in different parts of Africa and the world; these include guard against misfortunes reported in Brazil (Augustus et al., 2002).

Although Jatropha grows naturally in Africa, its cultivation on an economic scale is a recent venture for which little reliable scientific data exists either for environmental assessment or management. At present, the main agro-environmental impact studies in East African countries are largely qualitative, this include countries like Kenya (Kalua, 2008) and Tanzania (Eijck & Romijn, 2008). The Kenya biodiesel association created in 2008 to regulate and promote the production of Jatropha methyl ester in the country proposed to allow a 3% blending of biodiesel in conventional diesel fuel (Kalua, 2008). In Tanzania, the development of Jatropha biofuels is still in an early phase, and that its future is still unclear. Despite the favourable constellation of many contextual 'landscape' factors, there remain prominent barriers within Tanzania's existing energy regime (Eijck & Romijn, 2008).

This chapter reports on some important recent results from the Jatropha research in Tanzania. The chapter examines the *Jatropha curcas* L. as energy source biofuel in Tanzania. It also analyses the theory and practical evaluation of biofuel as renewable source of energy and Jatropha production, use and its application which have pronounced effects on the environment and economic aspects. Further, the chapter will concentrate on the production and energy potential of biogas from Jatropha press cake and provide an overview of the critical aspects, issues and best practice for sustainable exploitation of Jatropha in Tanzania.

2. Biofuel as renewable source of energy

An alternative to the oil-based energy production is provided by the biofuel, which can be produced from any biological material like plants, in contrast with fossil fuel like carbon, which is derived from long dead biological material. In developing countries, biofuel energy production could be a better alternative to solar energy system. Initial investment in respect to a solar installation and the cost of maintenance are limited. Moreover the solar-based energy production is not always suitable for rural regions and generally not easily reachable. Advantages of biofuels are mainly related to the fact that they are renewable sources of energy and can recover the use of diesel generators without further investments in new technologies. Also, biofuels are "carbon neutral" which means that the carbon released during the use of the fuel is reabsorbed and thus balanced by the carbon used by new plant growth if environmental conservation principles are observed.

Among different biofuels; the most important can be divided in ethanol based and oil based. The ethanol-based methods use sugar crops (sugar cane or sugar beet) and starch (corn or maize) to produce gas-fuel. Bioethanol fuel is mainly produced by the fermentation process, although it can also be manufactured by the chemical process of reacting ethylene with steam. There is also ongoing research and development into the use of municipal solid wastes to produce ethanol fuel. Globally renewable energy policies have promoted rapid growth in the biofuel economy. Currently, Brazil, Europe, and United States account for roughly 90% of total ethanol and biodiesel production (Coyle, 2007). Brazil is the first country where bio-ethanol is a real alternative to oil-based fuel (Brown, 2008). Since 1977 the Brazilian government made mandatory to blend 20% of bio-ethanol with gasoline, requiring just a minor adjustment on regular gasoline engines. Today the mandatory blend is allowed to vary nationwide between 20% to 25% bio-ethanol and it is used by all regular gasoline vehicles, plus three million cars running on 100% anhydrous bio-ethanol and five million of dual vehicles. The oil-based biofuels use oil plants are oil palm, soybean, algae or Jatropha. However, in United State of America the most common crop used for ethanol production is maize and for biodiesel feedstocks is soybean (as in Brazil) while in Europe rapeseed is the most common crop used for biodiesel all of which with large differences in energy efficiency between the production lines (Brown, 2008). In Brazil, soybean oil is a source that is already scaled up for biodiesel production. Nevertheless, other sources such as palm oil, algae, Jatropha, coconut, sunflower, peanut, cotton, and castor oil may be used in the near future once their cultivation achieve an economic up-scaling (Pinto et al., 2005). Oil plants-based biofuels can be a solution to the controversial question of "food vs fuel". In fact prices on a number of food types used for biofuel have doubled in the last couple of years even though biofuel is not the only cause. However, the impact of food price's increase is greater in poorer countries since demand for fuel in rich countries is now competing against demand for food in poor countries (Henning, 2003). For the mentioned reasons this chapter consider the suitability of the biofuel production using Jatropha plants.

3. Jatropha production, use and its application

Tanzania is globally placed to be the leader in biofuel production because of having ideal geographic and climatic conditions for growing a wide range of bio-fuel crops such as: sugar cane, palm oil, Jatropha, soy bean, and cotton. Of the 94 Mha total area of Tanzania 44.4 Mha is potential land available for agricultural investments. Jatropha is well promoted in Tanzania and investments have been reported to increase with strong political support. Currently, estimation for planted Jatropha in Tanzania is 17,000 ha which is 1.9% of the global cultivation and 14.4% of the total cultivation in Africa. Tanzania is considered very important for Jatropha cultivation sector with an estimate of up to 69,870 ha in 2010 to 620,110 ha in 2015 (GEXSi, 2008).

The plant *Jatropha curcas* (Linnaeus) belongs to the family Euphorbiaceae and is indigenous to Latin America and naturalized throughout tropical and subtropical parts of Asia and Africa. When people use the term Jatropha, usually they refer to this species which is one of the 170 known species of this wild plant (Figure 1) (Augustus et al., 2002; Akintayo, 2004; Jongschaap et al., 2007). Jatropha is a bush tree that is able to survive on marginal lands and can get up to 6 or 8 meters high. This perennial bush starts to grow fruits from the 2nd or

3rd year and can live up to 50 years. Under favourable conditions it can grow to a thick bushy fence of approximately one meter high in 6-9 months (Augustus et al., 2002). Jatropha grow under a wide range of rainfall between 200 and 1500 mm and specifically at 600 mm in moderate climates and 1200 mm in hot climates. In addition to water the plant needs nutrients which increase seed development and yield which varies significantly, with higher yields in fertile lands than marginal lands (Openshaw, 2000; Benge, 2006). Seeds from the Jatropha tree are known by many different names but "physic nut" is the most common and in Tanzania it is known as "Mbono". Studies have been conducted on the composition and properties of Jatropha seeds which also provide insight in the possibilities of using Jatropha oil for fuel purposes (Openshaw, 2000; Henning, 2003).

Fig. 1. Left: *The flowering Jatropha plant*. Right: *Representation of close-up of Jatropha fruits* (Photo taken at Sokoine University of Agriculture)

Jatropha being a woody plant can be used for a number of purposes as reported to in different parts of the world. In Tanzania the common uses of Jatropha include hedging, solid fuel, medicines, marking grave yards, supernatural beliefs, soap making, fertilizer and biogas production. These uses have been discussed in various sections in this chapter. Like in most rural areas in Africa, Jatropha plant in Tanzania is commonly used as a natural fence or live protection. The Swahili name for Jatropha in Tanzania is known so "Mbono Kaburi" (graveyard tree), because it was traditionally planted on graves. The reason behind this could be that Jatropha cuttings can be established in any season hence be used to mark a grave whenever someone dies. The Haya a tribe in Kagera region in Lake Victoria zone they call Jatropha "Mwitankoba" meaning a thunder killer tree. Traditionally every house was supposed to have at least one Jatropha tree near it to prevent the house from being destroyed during a thunder storm. In Tanga region (North eastern Tanzania) the Jatropha was used in supernaturally guided ordeals by the Sambaa community in Usambara mountains to determine the guilt or innocence of the accused. Accused persons had to consume the poison; the innocent vomited whereas the guilty died (Fleuret, 1980). Different traditional belief on the plant is excised in different parts of Africa and the world.

Jatropha plant can be used for medicinal purposes due to the medicinal properties of the bark and leaves which contain dye and latex. However, seeds, fresh or as a decoction are also used as traditional medicine and for veterinary purposes (Heller, 1996). Researches show that extracts from all parts of the Jatropha tree show different biological activities and pesticidal properties such as antibacterial, antifungal, insecticidal, fungicidal, molluscidal, blood coagulation and pain control (Heller, 1996; Jongschaap et al., 2007). The presence of the phorbol esters and a combination of lots of other compounds allow synergy of activity that have a broad and strong biological activity. The reported medicinal use of Jatropha in Tanzania include; the soap or oil used as skin antifungal applied external on infected part, the decoction of stem/root bark or leaves used to control hernia for boys, cough treatment and pain relief agents. The milky sap from Jatropha is used as a blood-clotting agent, in all these no scientific doses are seriously considered and it is prepared at locally through experience (Jongschaap et al., 2007).

Jatropha can be utilized for various purposes of which application as transport fuel is probably the most promising for the Jatropha seeds from both an economical and ecological point of view. Nevertheless the other uses as discussed earlier are worth mentioning as they provide insight in the total value chain of Jatropha products. The potential work that a fuel can do is determined by its energy content (Singh et al., 2008). The calorific values of solid and liquid Jatropha fuels as compared to those of conventional fuels are shown in Table 1. Most Jatropha related activities as well as this chapter are centred on liquid fuel (pure plant oil and biodiesel). Vegetable oil that has not been treated apart from filtering is often referred to as pure plant oil or straight vegetable oil. Jatropha oil is just one of a wide variety of pure plant oils. The main reason to use pure plant oil instead of converting it to biodiesel is the costs involved in the transesterification process. Compared to conventional diesel the use of pure plant oil in a diesel engine reduces the emission of sulphur oxides, carbon monoxides, poly-aromatic hydrocarbons, smoke, particle matter and noise. The main disadvantage of pure plant oil on the other hand is its high viscosity than normal diesel or biodiesel that leads to unsuitable pumping and fuel spray characteristics. The Jatropha oil is a potential material for fuel production with viscosity of 34-36 cST as compared to other plant oils such as soybean (31 cST), cottonseed (36 cST) and sunflower (43 cST) (Akintayo, 2004; Knothe & Steidley, 2005; Agarwal & Agarwal, 2007).

Parameter	Gross** calorific value (MJ/Kg)
[a]Jatropha seed	20.852 ± 0.08
[a]Jatropha press cake	18-25.1*
[a]Jatropha oil	37.832 ± 0.08
[a]Gasoline	47.127
[a]Crude oil	44.091
[b]Diesel fuel	46
[b]Kerosene	47
[b]Wood (15% water)	16
[b]Cooking coal (1-4% water)	35-37
[b]Coal (general purpose and 5-10% water)	32-42

Source: [a]Augustus et al., 2002 and [b]www.kayelaby.npl.co.uk
*depends on residue oil content in the press cake
**water formed and liberated during combustion is in the liquid phase

Table 1. Comparison of calorific value of Jatropha oil and seeds to conventional fuels

Biodiesel is a fuel obtained from mixtures, in different proportions, of fossil diesel and alkyl esters of vegetable oils or animal fats. Biodiesel is the fatty acids alkyl ester made by the transesterification of seed oils or fats, from plants or animals, with short chain aliphatic alcohols such as methanol and ethanol (Figure 2). Jatropha biodiesel have been pointed out to be among the twenty-six best suited fatty acid methyl ester mixtures (from a 75 species comparison) (Mohibbe et al., 2005). The important values for selection of fatty acid methyl esters for biodiesel are the cetane number (the ability of a fuel to ignite quickly after injection), iodine value (which indicates the degree of unsaturation) and other variables like linolenic acid value, boiling point and carbon chain length (Krisnangkura et al., 2006).

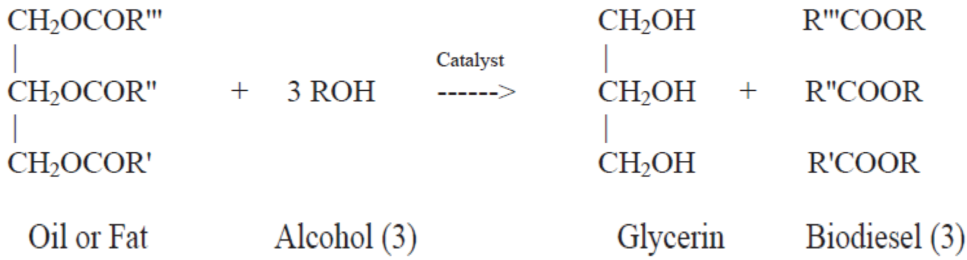


Fig. 2. The chemical reaction equation for catalyzed biodiesel production (Transesterification)

4. Jatropha biofuel by-products

The by-products of fresh Jatropha fruits include the shell, the hull, and the press cake. The fresh Jatropha fruit contains about 35–40% shell and 60–65% seed (by weight) of which 40–42% husk/hull and 58–60% kernels which consists of about 50% oil. The fruit shell is reported to contain about 34% cellulose, 10% hemi cellulose and 12% lignin and is good in minerals (Singh et al., 2008). In Tanzania is common to press the oil from peeled fruits and the shells are obtained after peeling the fruits leaving the seed with 100% hull to be pressed. Scientific investigation on the shell reveals its potentials for biological conversion and energy source as powdered briquettes and it high ash content (14.88%) a potential for fertilization of the soil. Using an up flow anaerobic digester filter, biological conversion of the shells after pre-treatment to remove fibres was possible producing biogas with 70% methane. Despite all that the shell briquettes still offers a more green energy opportunity for domestic and industrial fuel (Singh et al., 2008).

The Jatropha seed hull/husk is known to contain 3.97% ash, 71.04% volatile matter and 24.99% fixed carbon on dry weight basis, 10% moisture and the calorific value of 4044 $kcalKg^{-1}$. Laboratory gasification of the husks reached a maximum efficiency of 68.31% at a gas flow rate of 5.5 m^3h^{-1} and specific gasification rate of 270 $Kgh^{-1}m^{-2}$, at this point the calorific value of the gas is 1105 $kcalm^{-3}$. Biological conversion can be possible as well due to its high content of organic matter and this one contributes much to the Jatropha press cake organic matter because husks is left with the seed for pressing. Currently, the seed hull can not be counted separately as a source of energy since it part of the press cake.

The Jatropha press cake is obtained after separating the oil from the other seed contents chemically or mechanically. In Tanzania oil is obtained mechanically using a ram press or a screw press. Jatropha press cake in Tanzania is used as fertilizer, animal feed, source of biochemical and biogas production for energy source. Jatropha press cake can be used as organic manure, it nutrient content is richer than cow dung and neem cake and comparable to chicken manure. It contains macroelements nitrogen, phosphorus, potassium, sulphur and micronutrients Fe, Mn, Zn and Cu in a range from 800 to1000, 300 to 500, 30 to 50 and 18 to 25 $mgKg^{-1}$ of respectively. Jatropha press cake has also a nitrogen content of up to 6%, similar to that of castor beans and chicken manure. These increase the yield of Jatropha seeds up to 120% over the control without manure treatment. In Tanzania the Jatropha press cake is used as fertilizer without any scientific standards, research is needed in the area. The great hope behind many growers of Jatropha in Tanzania was to utilize the press cake for animal feed and selling to gain income. This has been a declined hope due to the fact that the Jatropha species grown in the country as of many parts of the world is toxic and yet the detoxification of cake is not of economically achievable and profitable at least at large scale. Therefore, the cake is only used as fertilizer and for energy source as briquettes or biogas production raw material (Janssen et al., 2005). Jatropha seed cake a source biochemicals and considered a best carbon sources among various carbohydrates, because it is pure, inexpensive and can be available in a mass supply. It has also been reported as good feed stock for production enzymes used by food industry (Muralidhara Rao et al., 2007).

5. Production and energy potential of biogas from jatropha press cake in Tanzania

Jatropha press cake is a good feedstock for biogas production because it is rich in organic matter; containing between 56%-64% crude protein (Benge, 2006). Biogas production from Jatropha press cake is about 60% higher as compared to the biogas generated from cow dung and had better calorific value as it had more methane (Lopez et al., 1997). More scientific investigations for anaerobic digestions of Jatropha press cake is required in order to draw a conclusion on its potentials to contribute as energy source.

5.1 Basics of the biogas process

Fermentation of organic matter by Microorganisms, allows the decomposition of organic matter aerobically or anaerobically. In aerobic decomposition the end products are carbon dioxide, heat and humus, during which most of the energy is lost as heat and production of new biomass. In anaerobic decomposition the main products are methane, carbon dioxide and peat or manure or sludge depending on the nature of process and the raw materials. When methane is produced under natural fossil conditions the gas produced is called natural gas. Biogas is normally produced through the process known as anaerobic digestion in swamps, marshes and intestinal tract of ruminant animals. Anaerobic digestion can be defined as the symbiotically stepwise process by which organic matter is digested to mainly methane (CH_4) and carbon dioxide (CO_2). It is a process due to concerted action of several metabolic groups of micro-organisms (Figure 3).

Biogas composed of a mixture of different gases including methane (50-75 Vol.%), carbon dioxide (25-50 Vol.%), hydrogen sulphide (50-6000 ppmv), Nitrogen (0-5 Vol.%), Ammonia (0-1 Vol.%), Oxygen (0-2 Vol.%), hydrogen peroxide (1-10 Vol. %) and water vapour (0-1 Vol.%) (Singh et al., 2008). The contents of the gases will depend on the type of the material composition of the organic matter used as feedstock and the process parameters and conditions during fermentation. The major difference between natural gas and biogas is the

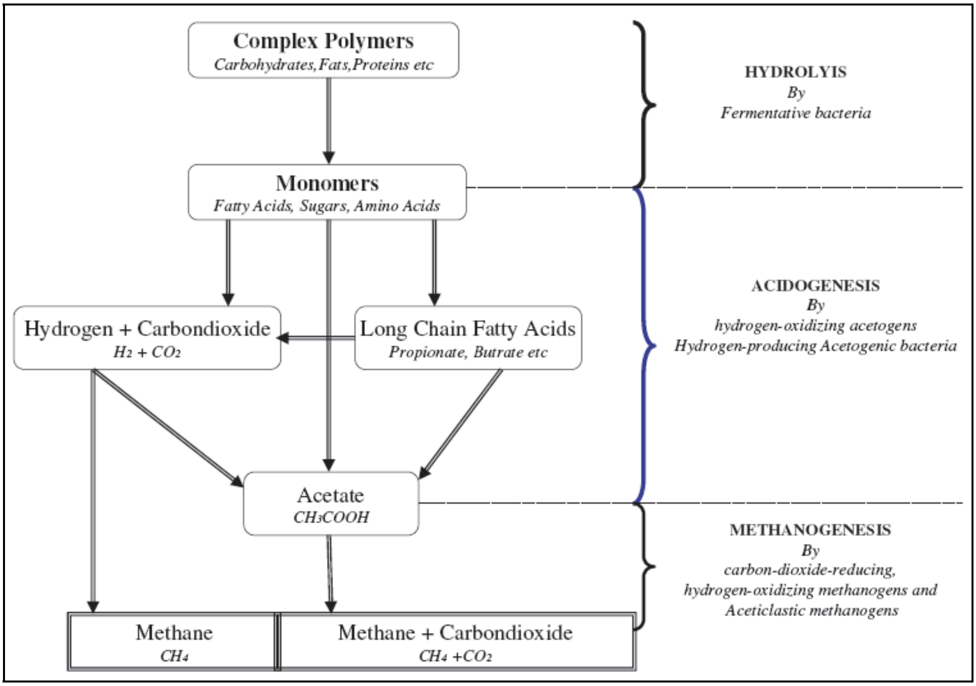


Fig. 3. Anaerobic digestion process

methane content and so it implies to their energy quality. The methane content is giving the energy quality of the gas and hence determines its application. The methane content of the biogas is usually measured at 50% to 80% by volume of the produced gas.

5.2 Process parameters and conditions

During the anaerobic digestion process parameters like pH, temperature and content of secondary gases in the digester must be controlled (Lopez et al., 1997; Wulf, 2005). Higher pH, value of the medium will allow gases such carbon dioxide and hydrogen sulphide to remain dissolved in the median and so methane yield is higher in the biogas produced. However, too high medium pH will again lead to accumulation of organic acids which can lower the pH of the medium. Because the methanogenic bacteria are pH sensitive, pH less than 6 and above 8 will limit the functioning and hence lower the production of methane most of the time, the buffer system is used to make the system stable throughout the process. Biogas producing can work at either psychrophilic (below 20 °C), or mesophilic (room temperatures/above 20 °C to 42 °C) or thermophilic conditions with temperatures between 42 °C -55 °C. However most of the bacteria work best at mesophilic conditions. At very low temperatures the microorganisms are very slow and the residence time can go up to 3 months. At thermophilic conditions the digestion is very fast (15-20 days) but the process becomes very temperature sensitive and promotes the volatile fatty acids formation. Sulphide content and ammonia gases content during digestion differs depending on substrate used, proteins high sources always can give higher sulphide and ammonia gases due to decomposition of protein, these can be controlled by pH stability and then the gas is purified or can be removed by additives, example sulphide can be removed by addition of iron salts in the medium.

The amount of biogas yield from anaerobic digester will depend on:

1. *The substrate composition*: Simplicity for degradation by type of microorganisms depends on structure components of the substrate ingredients, the values given in Table 3 are maximum values assuming that the substrate is fully converted usually 3% to 10% of the substrate is not available for biogas formation, these figures can realistically rise up to 30%-50% for proteins and fats respectively. Theoretically samples containing more fat/lipid contents will yield more gas and with high quality for different application (Table 2) relative to others under the conditions. These samples may include waste fat, grease and oils. The rate of digestion always depends on the structure complexity of the substrate and it should not be confused with the yield. Carbohydrates such as sugars are easily degradable than starch or protein so the protein will take more time to digest. On the other hand substrate like cellulose and hemicelluloses are even harder to degrade while the lignin is even not degradable.

Application	Energy type	Gas quality requirement
Heating/cooking	Heat	Low
Combustion in combined heat and power	Electric heat	
Compression and use in vehicles	Fuel	
Fuel cells	Electricity	
Compression and feeding in grid	Any	High

Source: Wulf, 2005.

Table 2. Showing biogas quality needed for different application

2. *Organic Total Solids (oTS)*: The amount of degradable material will determine the amount of biogas produced. In continuous process organic loading rate (KgoTS/m^3day) determines the yield. When the process can accommodate a high organic loading rate then this can imply higher yields. However on the other hand if the concentration of the organic total solids is too high, microoganisms can have a problem of adaptation and hence affects the yield and/or the retention time. Depending on the process and type of substrate, organic loading rate differs (Table 3).

Substrate	Theoretical biogas yield (N/kgoTS)	Theoretical biogas quality	
		Vol.% CH_4	Vol.% CO_2
Carbohydrates	746	50	50
Fats	1300	72	28
Proteins	800	60	40

Source: Wulf, 2005..

Table 3. Theoretical biogas yield and quality for different substrates

Biomass serves as the major source of energy in Tanzania providing about 90% of the total energy consumed, energy from oil and gas provides about 7% of the consumed energy (ProFOREST, 2008). Tanzania consumed as estimate of 25000 barrel of oil/day in the year 2005.

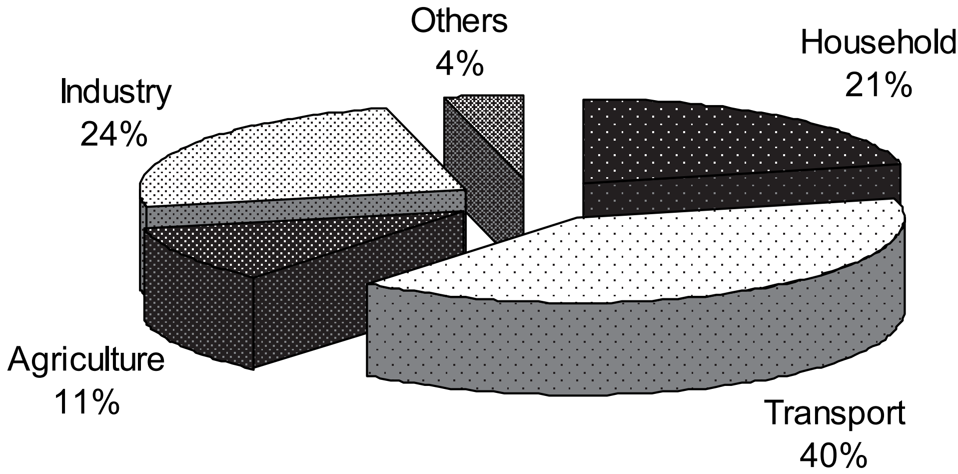


Fig. 4. Tanzania petroleum use pattern (Modified from Mgodo, 2008)

Two scenarios of Jatropha press cake availability are considered depending on the GXSI report on Jatropha Cultivation in Tanzania; experts' scenario as scenario 1 and GXSI scenario as scenario 2 (Table 4). In the scenario 1 the area estimated to be under cultivation is 11700, 34300 and 116000 for 2008, 2010 and 2015 respectively. For the scenario 2 the area identified under Jatropha cultivation is 17000, 69870, 620110 ha for 2008, 2010 and 2015 year respectively. Assuming that 6 T/ha constant yield of seeds per ha to 2015, 75% of the seed remain as press cake after pressing the oil, 4kg of seed gives 1L of oil and the 3Kg remains as press cake. The press cake is 100% available for biogas production, characterized by 92% oTS and 92% TS, biogas production is at 350 L/KgoTS with 65% methane. The proper technology is used resulting to efficient production and power losses during transmission are negligible.

Value added to 1L of oil pressed: One litre of oil is obtained by pressing 4 kg of Jatropha seed, leaving 3kg of press cake as a by-product. Biogas production from this cake will produce 578 L of biogas which is worthy 20.8 MJ of energy. Comparing to the energy value of 1 L of Jatropha oil which is 40.7 MJ, the value added is 51%. This will improve the Jatropha bioenergy system and contribute significantly in sustainability of Jatropha bioenergy system exploitation in Tanzania.

Contribution to National Energy Sector: The annual per capita electricity consumption in Tanzania was estimated to be about 80 kWh in 2005 while the annual energy consumption per capita was 29,300 MJ. Having these data as constant base values, with efficient exploitation of Jatropha press cake and use of the gas as energy source would contribute significantly to the energy sector in the country especially in rural areas with decentralization of the electricity distribution system. With scenario 1, there is a potential of 3.7×10^5 GJ existing currently which is mainly utilized as fertilizer and little biogas substrate in households, this potential is to be expected to increases up to 3.6×10^6 GJ in 2015. In scenario 2, the current potential is which 5.3×10^5 GJ which is 43% higher compared to the first Scenario. This as well is expected to increases up to 5.4×10^8 GJ in 2015 which is 500 times higher compared to the same in scenario 1. This energy amount can be used as source of heat for cooking at household level, or to generate electricity. The contribution of the energy in terms of Barrel of Oil Equivalent (BEO) in both scenarios ranges from 0.06 to 3.2 Million BEO per year which is equivalent to foreign exchange saving of 2-128 days due to importation of crude oil barrels. These energy potentials will therefore contribute to environmental conservation due deforestation, accelerate national development by increasing the number of Tanzanians with access to electricity; allowing small scale investments and business projects, these are directly linked to the millennium development goals and available national development strategies. However still this will need more research input in order to efficiently exploit the potentials.

Scenario	Year	Area under Jatropha cultivation (ha)	Amount of press cake (Tx10^3)	Methane produced (m^3)	Equivalent energy potentials		
					GJ	MWh	BEO
Scenario 1	2008	11,700	52	1.0×10^7	3.7×10^5	1.0×10^5	6.0×10^4
	2010	34,300	154	3.0×10^7	1.0×10^6	3.0×10^5	1.7×10^5
	2015	116,000	522	1.0×10^8	3.6×10^6	1.0×10^6	6.0×10^5
Scenario 2	2008	17,000	77	1.5×10^7	5.3×10^5	1.5×10^5	8.7×10^4
	2010	69,870	314	6.1×10^7	2.1×10^6	6.1×10^5	3.6×10^5
	2015	620,110	2790	5.4×10^8	1.9×10^7	5.4×10^6	3.2×10^6

Table 4. Energy potentials of the Jatropha press cake in two scenarios

For scenario 1, the potential for contribution to national annual electricity per capita is 134%, which is equivalent to 1.65% of the national total annual energy per capita in 2015. The corresponding values were 4% and 0.05% in 2008 and 15% and 0.19% in 2010. The energy can be exploited more efficiently at local levels to avoid power loss due to long distances and lack of capacity. In scenario 2, if the biomethane potentially produced is converted to electricity and fed in to the national electricity grid. It has a potential to contribute up to 25% in 2015 in the annual national electricity per capita, this contribute 0.31% of the total national annual energy per capita**.** The corresponding values were 3% and 0.003% in 2008 and 7% and 0.09% in 2010.

6. Critical aspects and issues on jatropha cultivation in Tanzania

The Government of Tanzania and international donors have identified biofuel as a priority growth sector and aimed at providing extensive support for investments in this sector. The hesitation is well revealed in the areas of land provision for biofuel crop cultivation though the country is politically stable and has favourable environment for business. On the other hand as the biofuel policy is not in place, government deferred new biofuel projects registration as it prepares a national policy on biofuels (Sawe, 2007). Though the biofuel issues are discussed very generally, it is worth noting that the pros and cons of the oil crops differ in many ways. The more focused biofuels crops in Tanzania include Jatropha, sugar cane, sisal and palm oil, this section focuses on the Jatropha. Billed as wonder crop, the establishment of Jatropha plantations on the ground in Tanzania has been far from successful, or, in some cases, ethical. Biofuel investment and production in Tanzania is a highly contentious issue. Biofuel investors have been doing business in Tanzania since 2000,

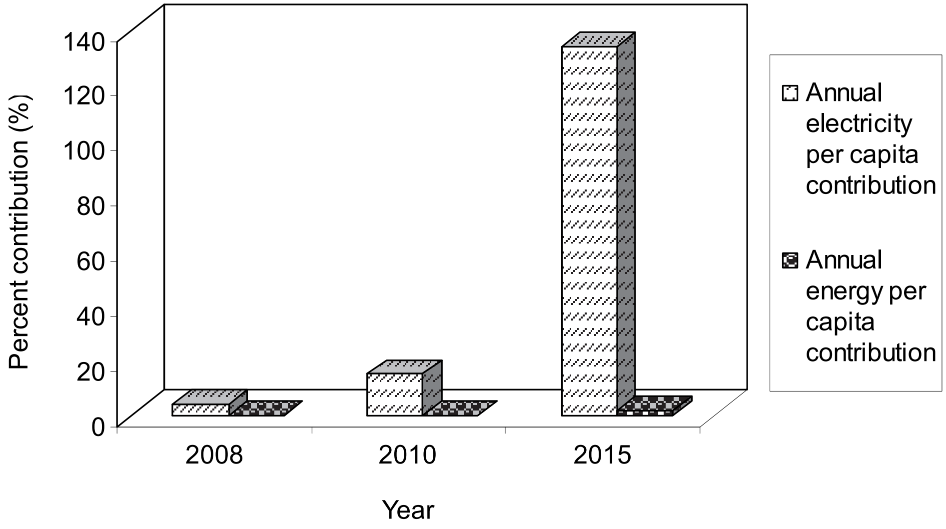


Fig. 5. Potential biogas contribution to Tanzania annual energy and electricity per capita in scenario 1

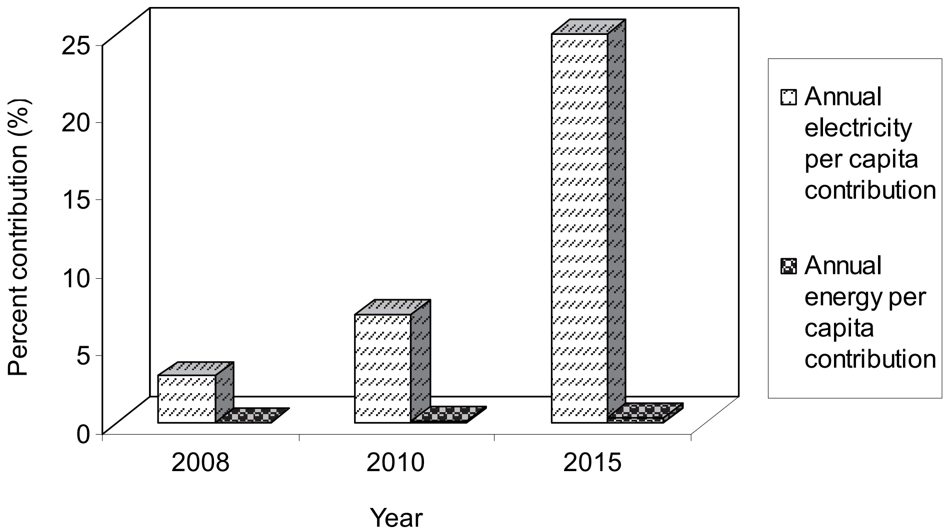


Fig. 6. Potential biogas contribution to Tanzania annual energy and electricity per capita in scenario 2

but business stepped up a gear after 2006. To date there are 17 investor companies, from UK, cane, sisal and palm oil, this section focuses on the Jatropha. Billed as wonder crop, the establishment of Jatropha plantations on the ground in Tanzania has been far from Germany, Sweden, the Nederland and America. This is a small number of investors compared to those in Brazil and Indonesia, but a number with clear motives. With over four million hectares requested by investors for biofuels only 650,000 hectares currently allocated, this is a sizeable potential earner for Tanzania (Sawe, 2007; Alweny, 2008).
Cultivation of Jatropha is going on and more investors and local farmers have shown interest of acquiring land for Jatropha cultivation. The Dutch based company Diligent Tanzania which has contracted about 5000 farmers for 10 years giving them support and advice on how to grow the Jatropha (Alweny, 2008). Another company the Sun Biofuels, a UK-based company, acquired 8,000 ha to grow Jatropha, part of a plan to expand capacity to 85,000 ha in the long-term. The company promises to pay workers $1095 per year for farming and harvesting and would devote an additional five percent of its budget towards "social infrastructure". PROKON Renewable Energy Ltd. Tanzania a German company in origin working in western Tanzania, with farmers cultivating more than 10,000ha of Jatropha supplied with Jatropha seed and extension services. Other Local institution and NGOs promoting Jatropha use in Tanzania include Tanzania Traditional Energy Development and Environmental Organization (TaTEDO), The Company For Technology Dissemination and Training (KAKUTE Limited-"Kampuni ya Kusambaza Teknolojia") and Tanzania Industrial Research and Development Organisation (TIRDO) (Sawe, 2007).

6.1 Water distribution and usage

Tanzania is surrounded by water bodies including the Indian ocean in the eastern part and great lakes, namely lake Victoria in the north, Nyasa in the south east and Tanganyika in the west of the country. There are rivers flowing throughout the year with many medium and small seasonal rivers. With this context Tanzania has good potential for irrigation of about 29.4 Mha, of which, currently only about 1% of the total potential have been developed. To date, Tanzania Jatropha cultivation is reported in areas with enough rainfall such as Arusha and Rukwa, and so no practical example from dry area such as those in central Tanzania. Large-scale systematic studies of the impact of Jatropha plantations on hydrological cycles is still lacking, however it is well documented that water use of Jatropha generally is low and that it is unlikely to have a negative effect on annual stream flow (ProFOREST, 2008; Jongschaap et al., 2007).

6.2 Food security

The decline of world food stocks particularly cereals and the rocketing of food prices in recent years have alarmed a threat to expansion of biofuels production (Janssen et al., 2005). Tanzania has currently not achieved food security, and therefore it is anticipated that converting main sites identified as suitable for growing food crops to produce biofuels crops is a threat to both accessibility and affordability of food. It has to be noted that food insecurity is not only caused by biofuel crops cultivation but poor farming practices and other factors which are not discussed in this chapter (FNT, 2008). To ensure food security the exclusive plantations cultivation should be avoided especially where it has to shift farmers and intercropping biofuel with food crops should be encouraged whenever possible. About 75% of Tanzanians are rural based and mostly engaged in crop production.

6.3 Environmental conservation and biodiversity issues

In order to suffice the external market during export production large scale biofuels production, monocultures cropping may be preferred over crop rotations or mixed farming. This can well be associated with deforestation and decrease in crop and farm biodiversity. Though the Biofuel policy is not in place the National Environmental Management Act is in place, under National Environmental Management Council (NEMC) ensures that all the investors in biofuels crop production carry out Environmental Impact Assessment (EIA) and adhere to recommended production practices. A number of research reports on the ability of Jatropha to conserve the environment in many ways including binding the soil, fertilizing, carbon conservation and air quality improvement However, these ability are subjected to more research to understand fully their effects if any (Soares Severion et al., 2007). The Massai plain near Arusha is very much endangered by erosion due to overgrazing. KAKUTE plants Jatropha trees to control erosion at Engaruka area in Arusha but failed because the field was near a water source for cattle and so they were destroyed. It is expected that other areas could also be affected hence research is needed.

6.4 Social impacts

Gender issues are imports to be looked on in Jatropha cultivation in Tanzania, who does the work, who gets the money, changes of the distribution of the workload, and changes of the social status. In Tanzania land is owned by the government which gives lease and permission to people owning it legally. Most of the Tanzanians especially those in rural areas do not have legal entitlement to their land, they own it by historical inheritance. The most people involved in production activities at lower levels are women, however their work is classifies as unpaid labour and so not counted in connection to the economic development of the nation. Women are the possible and cheap labour in many developing countries. It is reported that owners tend to prefer women workers, as they are able to pay them less than their male counterparts and find them a docile and dependent workforce, and are therefore more exploitable (Hurst et al., 2007). People without own farm land should have accessibility of seed, Jatropha in public forests for free collection. In Most part of Tanzania, there are wild and farm Jatropha trees. Jatropha trees planted as protection hedges, there is always an ownership of a family and only members of the family can allow collecting seeds. Other social issues include cultural and religious traditions or indigenous knowledge. In Tanzania, women are not allowed to own farm land and trees. But in both cases the responsible for the distribution of the land gave some plots to women groups to grow Jatropha there. Concerning indigenous knowledge the soap making with oil from different oil fruits is well known in Tanzania and has an old tradition.

6.5 Economic issues

In Tanzania the following economic evaluation of activities of the use of the Jatropha plant is based on experience of KAKUTE in its Jatropha project ARI-Monduli (Alternative Resources of Income for Monduli women). It is ascertained by KAKUTE that the collection of seeds and its sale gives the least added value as compared to oil extraction which also is not as good as soap making. This explains very clearly that the Massai women of Engaruka are not very much interested to sell seeds or oil, they want to gain the added value of the whole production chain and sell only soap.

7. Best practice for sustainable exploitation of Jatropha in Tanzania

Biorefineries are facilities that integrate biomass conversion processes that produce fuels, power, and chemicals from biomass. Biorefineries involves producing multiple products, taking advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock. Using the concept of biorefinery therefore, it is possible to reduce amount of and increase safety of waste products, increase economic effectiveness of biomass source and valorisation of all plant material to useful and high value products (see Figure 7) (Zinoviev et al., 2007). There is clear indication that the Jatropha system in Tanzania can adopt the biorefinery concept as the industry is growing very fast with full support from investors, government and local people. The biorefinery concept could significantly reduce production costs of plant-based chemicals and facilitate their substitution into existing markets.

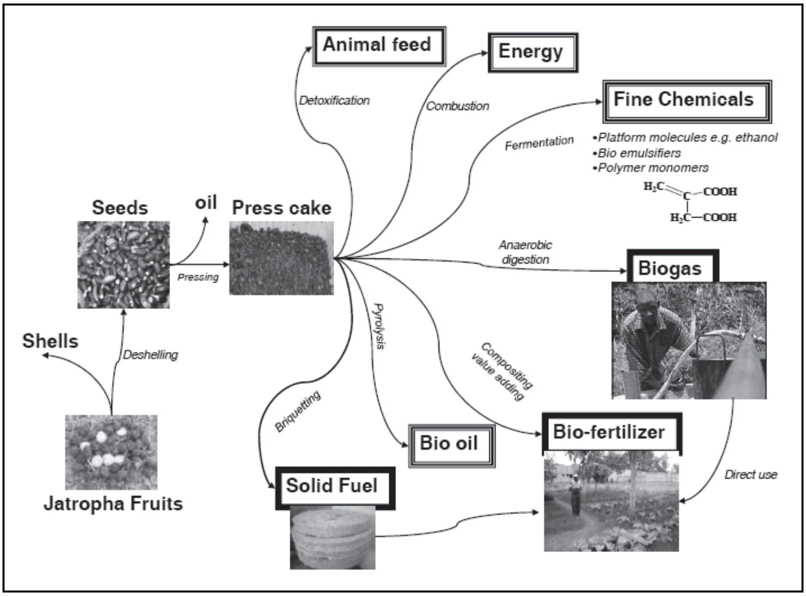


Fig. 7. The valorisation of Jatropha press cake for biorefinery potentials

Possible more use of the Jatropha by-products includes the utilization for biodiesel, production of chemicals, soap and lubricants and also utilization of Jatropha shells as an energy source, biogas production residues as fertilizers and biogas as fuel in engines, Jatropha press as substrate for enzyme production and platform chemicals (Figure 7). The biggest challenge in the exploiting the biorefinery concept are lack of experience and knowledge (best practices) on the Jatropha system i.e. still a young industry, lack of research to avail proper technologies and processes proper in the context of Tanzania, lack of capital, lack of biofuel policy and lack of local expertise.

The concept of people, planet and profit is very important to a country like Tanzania which still strives for the wellbeing of the people. The concept tries to guide the investor sand country governments to ensure the projects are sustainable for the middle and long term.

There should be no destruction of village or social structures, no infringement of common lands or traditional user rights and no displacement of people. There should be enhancement of local employment or income generation of local people, decent wages to be paid and preferably no dependency of a sole income source of people (risk avoidance). Planet is another criterion which takes care on what is real waste or idle land, minimal and no lasting environmental pollution in production by agro chemicals and fertilizers. There should be careful consideration of the sustainability of cropping. No selection of lands with high biodiversity importance and intercropping preferable, especially in the earlier years. Preparation of clear business plans, based on conservative/proven data, company profits preferably reinvested in the country, Jatropha should in first instance be used to supply internal markets. Local use is more energy efficient and there is always enough internal demand. Company profits sharing with farmers, and farmers decent payment and no excessive company profits.

8. Conclusion

The principle though originally focuses on risks for Jatropha large scale plantations but it fevers poverty reduction and the fulfilment of the millennium development goals (MDGs) in general (World Bank, 2006). Countries like Tanzania also aims to reduce poverty of her people but the environment the element of planet should be conserved and considered when biomass is utilized. On the other hand there is no business without profit then the investors have to be careful before and during investment. It is hereby highly recommended to take the precaution as the industry grows very fast. The ideas mentioned in the people, planet and profit concept are very important for sustainable exploitation of the Jatropha system products in Tanzania. In order to fully exploit the Jatropha products in Tanzania the following areas has to be seriously considered for advance:

- Speeding the formulation of biofuel policy by-products valorisation, oil production and blending. The biofuel policy will determine the investment environment and market for Jatropha but also pave a way for technology expansion and technology transfer.
- Research collaboration in the areas of technology and production with local institutions such Sokoine University of Agriculture (SUA) and other university and NGOs to fever the improvement of the local expertise and sharing of knowledge for the sustainability of the biofuel industry and specifically Jatropha system.
- Improvement of top down information and knowledge flow in order to facilitate the MDGs goals fulfilment and reduce conflict. Also improvement of technical know-how for mainstreaming and multiplication of technology

In Tanzania there are great opportunities for Jatropha biofuel industry and the biofuel industry in general. These include the land availability, supportive climatic conditions, water availability, political and peoples will and the need of the industry and its potentials towards attaining the MDGs. Already the short-term experience in Jatropha investment shows promising potentials in exploiting the products of Jatropha. Scenarios indicated positive contribution of the Jatropha bioenergy system to the energy sector in Tanzania. Jatropha press cake biogas alone has a potential to contribute 25% to 134% of the national annual electricity per capita by the year 2015, while adding more than 50% oil obtained after pressing of Jatropha seeds. Biorefinery of Jatropha products will also offer more energy contribution, wastes reduction and more value to Tanzania biofuel industry, particularly

Jatropha bioenergy system. Biofuel is an inter-sectoral industry; the success and sustainability of the industry in Tanzania will sorely depend on policy to be put in place.

9. Acknowledgement

The authors would like to acknowledge the International Centre for Science and High Technology of the United Nations Industrial Development Organization (ICS UNIDO) for sponsoring this work. The technical support form Faculty of Science, Sokoine University of Agriculture and the German Biomass Research Centre (DBFZ) is heartly appreciated.

10. References

Agarwal, D. & Agarwal, A.K. (2007). Performance and emissions characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine. *Applied Thermal Engineering*, Vol. 27, No. 13, (September 2007), pp. 2314-2323, ISSN: 1359-4311

Akintayo, E.T. (2004). Characteristics and composition of Parkia biglobbossa and *Jatropha curcas* oils and cakes. *Bioresource Technology*, Vol. 92, No. 3, (May 2004), pp. 307-310, ISSN: 09608524

Alweny, S. (2008). Potential boom for biofuels in Tanzania? Feature May 2008, Global facilitation unit for underutilized species, Available from http://www.underutilized-pecies.org/features/jatropha/salomes_jatropha_story.pdf

Augustus, G.D.P.S., Jayabalan, M. & Seiler, G.J. (2002). Evaluation and bioinduction of energy components of *Jatropha curcas*. *Biomass and Bioenergy*, Vol. 23, No. 3, (September 2002), pp. 161-164, ISSN: 0961-9534

Benge, M. (2006). Assessment of the potential of Jatropha curcas, (biodiesel tree) for energy production and other uses in developing countries, Available from http://www.ascension-publishing.com/BIZ/jatropha.pdf

Brown, L.R. (2008). Turning to renewable energy. *Chapter 12 in Plan B 3.0. Mobilizing to Save Civilization*, Elizabeth Doherty, (First Ed): Earth Policy Institute, W.W. Norton & Company, Inc., ISBN: 978-0-393-06589-3, New York, United States of America, Available from http://www.earth-policy.org/images/uploads/book_files/pb3book.pdf

Coyle, W. (2007). The future of biofuels: a global perspective. Amber Waves Nov 2007. USDA Economic Research Service Washington D.C., Available from http://www.ers.usda.gov/AmberWaves/November07/Features/Biofuels.htm

Eijck, J. & Romijn, H. (2008). Prospects for Jatropha biofuels in Tanzania: An analysis with Strategic Niche Management. *Energy Policy*, Vol. 36, No. 1, (January 2008), pp. 311-325, ISSN: 0301-4215

Fews Net Tanzania, FNT. (2008). Tanzania Food Security Update, Famine Early Warning Systems Network, Final report, January 2008, Available from http://www.fews.net/docs/Publications/Tanzania_2008_01_final.pdf

Fleuret, A. (1980). Non-food uses of plants in Usambara. *Economic Bot*any, Vol. 34, No. 4, (June 1980), pp. 320-333, ISSN: 0013-0001

Global exchange for Social investment (GEXSi) (2008). Global Market Study on Jatropha. Final Report 2008. Prepared for, the World Wide Fund for Nature (WWF) London/Berlin.

Heller, J. (1996). Physic nut *Jatropha curcas* L. Promoting the conservation and use of underutilized and neglected crops. Gatersleben: Institute of Plant Genetics and Crop Plant Research, and Rome: International Plant Genetic Resources Institute. Rome, Available from http://www.ipgri.cgiar.org/publications/pdf/161.pdf

Henning, R.K. (2003). *Jatropha curcas* L. in Africa. Baganì, Weissenberg, Germany.

Hill, J., Nelson, E., Tilman, D., Polasky, S. & Tiffany, D. (2006). "Environmental, economic and energetic costs and benefits of biodiesel and ethanol biofuels". PNAS Vol. 103 N° 30.

Hurst, P., Termine, P. & Karl, M. (2007). Agricultural workers and their contribution to sustainable agriculture and rural development. ISBN: 978-92-2-118709-7, Geneva, Switzerland, Available from http://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---actrav/documents/publication/wcms_113732.pdf

International Energy Agency, IEA. (2008). World Energy Outlook, executive summary. International Energy Agency/Organisation for Cooperation and Development, Paris, pp. 18.

Janssen, R., Woods, J., Sawe, E.N. & Pförtner, R. (2005). Liquid Biofuels for Transportation in Tanzania. Potential and Implications for Sustainable Agriculture and Energy in the 21st Century, Available from http://tatedo.org/cms/images/researchdocs/biofueltransport.pdf

Jongschaap, R.E.E., Corré, W.J., Bindraban, P.S. & Brandenburg, W.A. (2007). Claims and facts on Jatropha curcas L. Global Jatropha curcas evaluation, breeding and propagation programme. Plant Research International BV, Wageningen. Strichting Het Groene Woudt, Laren. Report 158, pp. 66.

Kalua, I. (2008). Stakes constraints of bio-fuels cultivation in East Africa. *Green Africa Foundation presentation, Vanatrop Workshop Non-food and energetic use of plants from Mediterranean and tropical areas, Agropolis International, Montpellier France*, October 22-24, 2008.

Kaushik, N., Kumar, K., Kumar, S., Kaushik, S. & Roy, S. (2007). Genetic variability and divergence studies in seed traits and oil contents of Jatropha (*Jatropha curcas* L.) accessions. *Biomass and Bioenergy*, Vol. 31, No. 7, (July 2007), pp. 497-502, ISSN: 0961-9534

Kearney, A.T. & van Eijck J. (2008). The Nairobichronicle "Biofuels growing in Tanzania, as Kenya lags behind" by AllAfrica.com, Available from http://nairobichronicle.wordpress.com/2008/08/09

Knothe, G. & Steidley, K.R. (2005). Kinematic viscosity of biodiesel fuel components and related compounds. Influence of compound structure and comparison to petrodiesel fuel components. *Fuel*, Vol. 84, No. 9, (June 2005), pp. 1059-1065, ISSN: 0016-2361

Krisnangkura, K., Yimsuwan, T. & Pairintra, R. (2006). An empirical approach in predicting biodiesel viscosity at various temperatures. *Fuel*, Vol. 85, No. 1, (January 2006), pp. 107-113, 0016-2361

Lopez, O., Foidl, G. & Foidl, N. (1997). Production of Biogas from J. curcas Fruit shells In: *Biofuels And Induslrial products From J. Curcas*, Gobitz, Mitielbach, Train (Ed): 118-122, Dvb-Verlag Für die Technische Universität Graz, ISBN: 3-7041-0242-3, Graz, Austria

Mngodo, J. (2008). Presentation at the Second FAO Technical Consultation on Bioenergy and Food Security (BEFS), Rome, 5-6 February, 2008. TACKLING THE NEXUS - Bioenergy and Food Security in Tanzania.

Mohibbe Azam, M., Waris, A. & Nahar, N.M. (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass and Bioenergy*, Vol. 29, No. 4, (October 2005), pp. 293-302, ISSN: 0961-9534

Muralidhara Rao, D., Jaheer Hussain, S.M.D., Pandu Rangadu, V., Subramanyam, K., Sivarama Krishna G. & Swamy, A.V.N. (2007). Fermentatative production of itaconic acid by Aspergillus terreus using Jatropha seed cake Short Communication. *African Journal of Biotechnology,* Vol. 6, No. 18, (September 2007), pp. 2140-2142, ISSN: 1684–531

Openshaw, K. (2000). A review of Jatropha curcas: an oil plant of unfulfilled promise. *Biomass and Bioenergy*, Vol. 19, No. 1, (July 2000), pp. 1-19, ISSN: 0961-9534

Pinto, A.C., Guarieiro, L.L.N., Rezende, M.J.C., Ribeiro, N.M., Torres, E.A., Lopes, W.A., Pereira, P.A.de P. & de Andrade, J.B. (2005). Biodiesel: An Overview. *Brazilian Journal of Chemical Society*, Vol. 16, No. 6B, (November/December 2005), pp. 1313-1330, ISSN: 0103-5053

ProForest (2008). Jatropha literature and perspectives review: Main potential social and environmental impacts arising from large scale plantings', ProForest Ltd., Oxford.

Sawe, E.N. (2007). Presenation by Director TaTEDO at the Eastern and Southern Africa Regional workshop on Biofuels, 28--29 June 29 June 2007, Nairobi, Kenya. Liquid Biofuels, Small Scale production and use, (issues, challenges and opportunities (UNEP).

Short, C. (2002). Energy for the Poor. Underpinning the Millennium Development Goals. Department for International Development (DFID), government of United Kingdom, London. Produced for DFID by Future Energy Solutions. DFID 1 Palace Street London SW1E 5HE. p. 32.

Singh, R.N., Vyas, D.K., Srivastava, N.S.L. & Narra, M. (2008). SPRERI experience on holistic approach to utilize all parts of Jatropha curcas fruit for energy. *Renewable Energy*, Vol. 33, No. 8, (August 2008), pp. 1868–1873, ISSN: 0960-1481

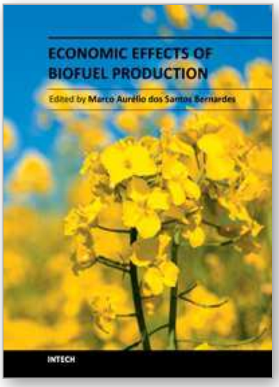
Soares Severion, L., De lourdes Sila de Lima, R., Bezerra Leoao, A. & Esberard de Macedo Betrao, N. (2007). Root system Charachterization of Jatropha curcus Plants propagated through five Methods. Expert Seminar on Jatropha curcus L. Agronomy and genetics. 26 -28 March 2007, Wageningen, Nertherlands.

The PROKON Renewable Energy Tanzania Ltd. Available from http://www.prokon-tanzania.com/tanzania.html

World Bank (2006). Agriculture and Achieving the Millennium Development Goals Washington, D.C.: Agriculture and Rural Development Department of the World Bank, Availbale from http://siteresources.worldbank.org/INTARD/Resources/Ag_MDGs_Complete.pdf

Wulf, S. (2005). Anaerobic digestion and biogas production, a Presentation at First Bonner Summer School on Sustainable Agriculture August 2005. p. 1-44.

Zinoviev, S., Sivasamy Arumugam, S. & Miertus, S. (2007). Background Paper on Biofuel Production Technologies Working document November 2007, Area of Chmeistry-UNIDO, Available from http://www.biofuels-dubrovnik.org/downloads



Economic Effects of Biofuel Production

Edited by Dr. Marco Aurelio Dos Santos Bernardes

ISBN 978-953-307-178-7
Hard cover, 452 pages
Publisher InTech
Published online 29, August, 2011
Published in print edition August, 2011

This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.