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EVALUATION OF *JATROPHA CURCAS* AS FUTURE ENERGY CROP IN SOME AFRICAN COUNTRIES

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SUMMARY

This report describes *Jatropha Curcas* as a source of biofuel in some African countries mainly: Sudan, Ethiopia, Kenya and Tanzania. Nowadays, there are several exaggerations about *Jatropha Curcas* such as: its tolerance to drought, survival in marginal lands and it is not competing with food crops. Therefore, the main objectives of my research were: to check if all these exaggerations are true and to verify if biofuel from *Jatropha Curcas* might be the next energy crops for Africa as a substitute for fossil fuel and secure their national energy demands.

The study consists of five sections, each section deals with different aspects. The first part is introductory and gives general overview of the study area, goals and objectives of the study and its limitations.

Section two describes the main methods used in this study. The methdolog is based on literatures review, desktop analysis and consultations with experts in the field of biofuels such as Swedish Bioenergy Association, Chemical Engineering & LWR Departments at KTH and World Bioenergy Association.

Section three deals with the conceptual and theoretical frame work of the study. It defines the basic terminology and theories about biofuels and *Jatropha Curcas*. Chemical aspects and the main processes of Jatropha oil are also discussed in this part. Moreover, the future of Jatropha as a sustainable energy source is also evaluated in this part in relation to sustainability criteria, environmental impact assessment (EIA) and strategic environmental assessment (SEA).

Section four concentrates on the results and discussion. This section shows the main driving forces for cultivation of biofuels in the studied areas such as: securing national energy demands, international perspectives to achieve EUs goals, cut down in the imported oil bills, and reduce the pressure on the environment and national resources. The advantages of biodiesel from Jatropha are also described including all the environmental and social impacts of Jatropha cultivation such as: impacts on biodiversity, impacts on water resources, soil erosion, increase carbon emissions, impacts on food security & cultural heritage.

The last section is the summary, conclusion and recommendations.The main conclusion shows that:

- Biofuel from Jatropha can be a blessing for Africa when cultivation is carried out in small-scale projects due to their significant socio - economic benefits. However, the major large – scale projects in marginal lands are risky and often have been collapsed as a result of insufficient profits.

- Biofuels from Jatropha will be the future for Africa if biofuels projects avoid any related environmental, economic and social impacts.

- If the local government improves the marginal lands and develop appropriate policies for biofuel, the implementation of any large-scale Jatropha projects will lead to a significant benefits regarding energy security.

SUMMARY IN SWEDISH

Denna rapport beskriver *Jatropha Curcas* som en källa för biodrivmedel i vissa afrikanska länder främst: Sudan, Etiopien, Kenya och Tanzania. Numera finns det flera överdrifter om Jatropha curcas såsom: dess tolerans mot torka, överlevnad i marginella marker och att inte konkurrera med livsmedelsgrödor. Därför har de viktigaste motiven för min forskning varit: att kontrollera om alla dessa överdrifter är sanna och om forskningen om biobränsle bekräftar *Jatropha Curcas* som en framtida energigröda för Afrika som ersätter fossila bränslen.

Rapporten består av fem delar, var och en av dem behandlar olika aspekter. Den första delen är inledande och ger en allmän översikt över studieområdet, mål och syften med rapporten samt dess begränsningar.

Del två beskriver de huvudsakliga metoder som använts, vilka är baserade på analys av litteratur, skrivbordsanalys och samråd med experter på området för biobränslen som Svenska Bioenergiföreningen, Kemit eknik & LWR Institutioner vid KTH och World Bioenergi Association.

Del tre är den konceptuella och teoretiska ramen för studien, som definierar grundläggande terminologi och teorier: från en allmän översikt om biobränslen och Jatropha curcas. Kemiska aspekter och de viktigaste processerna för Jatropha olja diskuteras också i denna del. Dessutom utvärderas framtidsutsikterna för Jatropha som en hållbar energikälla i relation till hållbarhetskriterier och miljökonsekvensbeskrivning (MKB) och strategisk miljöbedömning (SMB).

Del fyra koncentrerar sig på resultaten och diskussionen. Denna del visar de främsta drivkrafterna för odling av biobränslen i de studerade områdena såsom: att säkra nationella energikrav, internationella perspektiv för att uppnå EUs mål, skära ned på importerade oljeräkningar, och minska trycket på miljö och nationella resurser. Fördelarna med biodiesel från Jatropha beskrivs inklusive de miljömässiga och sociala effekterna av Jatropha odling såsom: påverkan på biologisk mångfald, påverkan på vatten, jorderosion, koldioxidutsläpp, konsekvenser för livsmedelssäkerhet och kulturarvet.

Det sista delen är en sammanfattningar med slutsatser och rekommendat ioner. Den viktigaste slutsatsen av min forskning är att:

- Biobränsle från Jatropha kan vara en välsignelse för Afrika när odlingen genomförs i småskaliga projekt på grund av deras betydande socio - ekonomiska fördelar. Men stora projekt i marginella marker är riskabla och har ofta kollapsat på grund av otillräckliga vinster.

– Biobränslen från Jatropha kommer att vara framtiden för Afrika om biobränsleprojekten undviker negativa miljömässiga, ekonomiska och sociala effekter.

– Om den lokala regeringen förbättrar marginella marker och utvecklar en anpassad politik för biobränsle kan genomförandet av någon storskaliga Jatropha projekt komma att leda till betydande fördelar när det gäller nationell energisäkerhet.

DEDICATION

I dedicate this work with love to: Royal Institute of Technology (KTH), my parents, my wife, my daughter and my beloved country Sudan.

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First of all I want to express my deepest thanks to my supervisor Mr. Jan-Erik Gustafsson for his patient and diligent supervision. It would have been extremely difficult without his support and genuine knowledg e in biofuels that we gained through advanced, comprehensive and well organized environmental project engineering course under the title Bio-fuels for Transport.

I would like very much to express my respects and appreciation to Swedish Bioenergy Association (SEVBIO) and particularly Mr. Kjell Andersson for his suggestion for the research topic and useful information.

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Last but never least, a very special thanks goes to my family members, I thank for many things, for always being there, for their support, their patience and prayers, their unconditional love, I wish I find a way to repay all this.

My beloved friends for their smiles lighten up the darkest moments of despair.

My wife for his believing in me, for supporting me, for standing with me, I cannot thank enough.

ABBREVIATIONS AND SYMBOLS

ABN	African Biodiversity Network
AFC	Agricultural Famers Co-operative
ARC	Aeronautical Research Centre
ASTM	American Society for Testing and Materials
BCR	Benefit Cost Ratio
BOD	Biological Oxygen Demands
CHP	Combined Heat and Power
COD	Chemical Oxygen Demands
DIN	Detuches Institute für Normung (German Institute for Standardization)
EIA	Environmental Impact Assessment
EU	European Union
FEP	The Flora Eco-power company
FFAs	Free Fatty Acids
GEXSI	Global Exchange for Social Investment
GHG	Greenhouse Gases
GWhr	Gigawatt-hour
GWP	Global warming potential
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
Ksh	Kenyan Shilling
KTH	Royal Institute of Technology
LWR	Land Water Resources
MFP	Multi-Functional Platforms
MW	Megawatts
NGOs	Non-Governmental Organizations
NPV	Net Present Value
PASDEP	Plan of Accelerated and Sustainable Development to Eradicate Poverty in Ethiopia
SEA	Strategic Environmental Assessment
SPC	Sudanese Petroleum Corporation
SEVBIO	The Swedish Bioenergy Association
UNDP	United Nations Development Programme
USD	United States Dollar
WBA	World Bioenergy Association

TABLE OF CONTENT

ABSTRACT

Biofuels now days consider as one of the successful alternative to meet the challenges associated with climate change and peak oil, as well as a way for poorer countries to develop an industry in order to enhance social and economic development. In many developing countries and particularly in Africa, this has led to large-scale investments in lands by foreign companies, and as a consequence there has been a debate on whether these actions are environmentally sustainable and whether this kind of activity actually brings economic development. The investments of biofuels in Africa, especially the Jatropha plantations are debatable. Several arguments have been concentrated on development goals, economic issues and environmental concerns. This report evaluates the status of some Jatropha projects in Sudan, Ethiopia, Kenya and Tanzania, the outcomes of the report show that biofuels from Jatropha lead to a significant socio -economic benefits by creating many jobs opportunities and improve the standard of living in Africa. However, inadequate funding's, high investment costs, no clear policies for biodiesel are the most challenging for Jatropha in Africa which need further mechanisms and ideology by African scientists, leaders, NGOs, farmers and decision makers. In the studied countries, it was reported that the Jatropha produce low yields of oil seeds especially in the marginal lands with no enough water supplies. In Kenya the productivity of Jatropha is very low for large scale- project. Moreover some social and environmental impacts are also seen for Jatropha cultivations in Ethiopia, Kenya and Tanzania. Some Jatropha projects have impacted the food security negatively; nevertheless some biofuels experts believe that Jatropha has no any adverse impacts on food security since it is inedible and grown on marginal lands. In Ethiopia, the main environmental impacts of Jatropha are related to biodiversity, water quality and quantity. In Kenya, the environmental impacts are related to biodiversity, carbon emissions, water withdrawal, pollution of agro- chemicals usage, deforestation and soil erosion, whereas in Tanzania, the main environmental issues are connected to the change of land use system, impacts on biodiversity and impacts on water resources.

Key words: Biofuels; Jatropha Curcas; Africa; policies; environments and food security.

1. THE SCOPE OF THE STUDY

1.1. General overview of the study area

Africa is the second biggest continent in the world, it consists of 56 countries and it has an area of 30.2 M Km^2 and it has approximately 1 billion citizens (Sayre, 1999). As shown in (Fig. 1) the climate varies along the continent which makes Africa a suitable place for biofuels especially from Jatropha plant and it consists of different regions ranging from tropic, dry, hot and some cool climate particularly in the highest altitude and mountains such as Kilimanjaro (Allali et al., 2001). Natural vegetation is also varying in Africa; dessert and semi desert in the north part, the central and southern parts are cover with both savannah and tropical rain forests. Due to all these variations in the climate, Africa is believed to be the origin of biodiversity, wild animals, minerals, fossil fuels and biomass, nevertheless and due to extreme poverty from bad resources management and corruption, Africa is measured as the poorest and underdeveloped continent living on less than 1.25 $ per day (World Bank, 2008). In due to the availability of lands in Africa and good climate, biodiesels from Jatropha is seen as one of the alternatives to replace the fossil fuels.

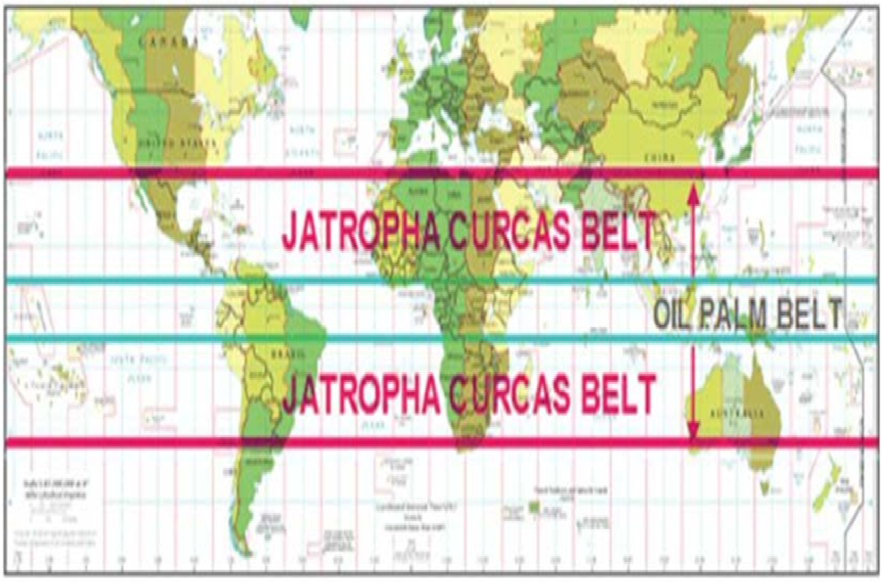

Figure 1. Most suitable climate conditions for the growth of Jatropha (Putten et al., 2010).

1.2. Aims and Objectives

In the last two decades, Jatropha was seen by many researchers and investors as the upcoming energy crop due to various statements such as: its suitability to African climate, its resistance to drought, its adaptability to various climates conditions and not to compete with food security. However, many projects have been disappointing. Therefore, the aim of this thesis is to form a clear understanding about Jatropha and to investigate if all the above mentioned claims proved to be true or just a glimpse of hope to overcome the lack of the current energy resources in Africa.

The main objectives of this thesis have also been reached to the following research questions and hypothesis:

- Is Jatropha a sustainable source of energy in Africa?
- Is Jatropha - hype or blessing? Or (Is Jatropha grown in arid climate and marginal lands or just exaggerating its benefits?)
- Where does Jatropha stand today and what is a reasonable future role for Jatropha in Africa?
- Are Jatropha profitable in Africa?
- Will biofuel from Jatropha contribute to Africa development to achieve their long-term strategies in terms of energy security and dependently?

1.3. Scope and Limitations

The study is based on literature review, desktop analysis and con-ducted in Sweden. Therefore, this report is lacking questioners which give the actual views of the stakeholders in the biodiesels industry in Africa. Moreover, the study assessed only some projects in particular countries in Africa which are currently taking some steps in producing the biodiesel from the Jatropha and not all the environmental impacts of Jatropha biodiesel were addressed due to the shortage of EIA reports and scientific research in the studied countries.

2. METHODOLOGY

The main method used in this report is based on literatures review, desk top analysis, consultations of experts in the field of biofuels such as Swedish Bioenergy Association (SEVBIO), KTH Chemical Engineering Departments, World Bioenergy Association (WBA) and other NGOs.

Finally, the collected information in this subject was evaluated based on some environmental concepts such as Environmental Impact Assessment (EIA) and EUs sustainability criteria.

2.1. Literature review and desk top analysis

The literature is selected based on the relevant studies that address the current situation of biofuels in Africa in order to provide the readers and interested parties about the current scenario of biodiesel from Jatropha in Africa. Therefore, the main report shows, underlies and identifies the main significances and the gaps of Jatropha biodiesel in Africa.

2.2. Consultations of experts in the field of biofuels

During this research some personal communication and meetings are made with interested parties in the field of bioenergy such as Swedish Bioenergy Association (SEVBIO), Chemical Engineering and LWR Departments at KTH, World Bioenergy Association (WBA) and NGOs. The main objectives of consultation of experts are: to share their experiences, collect relevant information and literature about biofuels.

2.3. Evaluation of the findings against some environmental criteria

Finally, the collected information and literature in the subject were evaluated based on some environmental concepts such as Environmental Impact Assessment (EIA) and EUs sustainability criteria in order to achieve the main research questions as well as drawing conclusion about the current status of Jatropha in the studied countries.

3. THEORETHICAL FRAMEWORK OF THE STUDY

3.1. Biofuels definitions

Biofuel is a gaseous, liquid and solid fuel which is mainly produced from biomass and used according to the current global energy demands to substitute the fossil fuels (Knothe, 2010).

There are different types of biomass and basically four types are defined as a source of biofuels such as: lignocelluloses which are derived from cellulose or plant dry matters, crops rich of sugar and starch, plants containing vegetable oils and fats and wet biofuels (i.e. sewage wastes and municipal wastes) (Walimwipi et al., 2012).

Based on the biomass and the type of technology that was used to extract the biofuels, it can also be known as first generation or second generation biofuels, first generation biofuels is produced from crops and wastes feedstock, while the second generation ones are shaped from the lingo-cellulosic biomass feedstock, according to the process and the conversion technology the first generation is related to a bio-chemical transformation pathway, whereas the second generations are created through thermo-chemical pathways (Walimwipi et al., 2012).

Biodiesel from Jatropha fatty acid or methyl ester of vegetable oil is a type of biofuel that is synthesized when the seeds oil react with methanol or ethanol in the presence of alkaline or basic catalyst.

Current researches are seeking higher productivity of biodiesel. Therefore, efforts are made to develop enzymes as catalysts to overcome the drawback of the alkaline or the basic catalysts, and according to Bacovsky et al. (2007) using enzymes as catalysts is more favorable due to the fact that enzyme catalysts can produce biodiesel under mild temperature, pressure and pH conditions, it also produces pure biodiesel and glycerol that does not require any further purification. The enzyme catalysts will improve the environmental standard related to the alkaline waste water and both the transesterfication of triglycerides and the esterification of the free fatty acid are performed in one step process (Bacovsky et al., 2007).

3.2. Routes for converting biomass to Energy

There are two main routes that have been used in large- scale to convert biomass into useful energy sources, the first rout is the thermo-chemical process and the second rout is bio-chemical process, and through both technologies three products of energy are obtained: heat, power and transport fuels (McKendry, 2002). Figure 2 summarizes the main routes of converting biomass into energy (EEA, 2013).

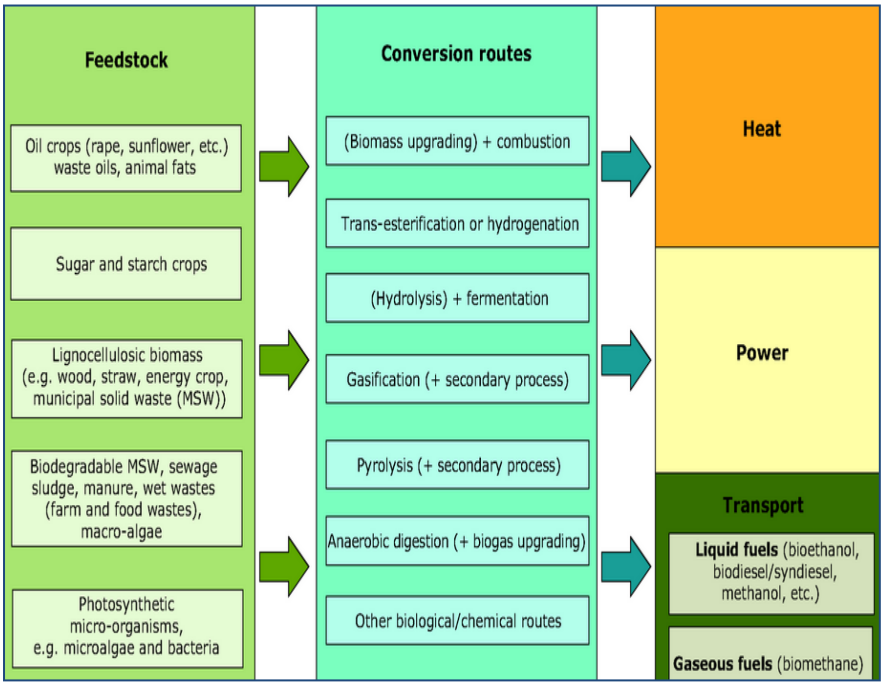

Figure 2. Main routes for converting biomass (EEA, 2013).

3.3. Jatropha Curcas

Jatropha Curcas L. is the Latin name which is always known as "Jatropha", the genus contains 14 species and it belongs to the family Euphorbiaceaa-Spurge and has various local names, in English it is known as physic nut, in French as pourghère, in Dutch as purgeernoot, Mmbono in Tanzanian, *Jatropha Curcas* is a plant which yields seeds with higher oil contents, it can be grown under severe climate conditions such as tropical climate and land with little soil fertility, Jatropha has a toxic seeds which make it as a non-edible crop (Putten et al., 2010).

Jatropha seeds are non-edible and produced oil from 30 to 40%. Therefore, it is likely to be a noble source of energy to produce biodiesel (Kandpal & Madan, 1995). Moreover, the seeds cake can be exploited as organic fertilizer because it is rich of protein, nitrogen and pesticide and the plant remains useful for 35-50 years (Bio Zio, 2012).

Jatropha Curcas is a large grainy annual shrub which is grown up to 5 m high (Heller, 1996). Under normal condition from seedlings five roots are formed, one is central and the others are peripheral (Kobilke, 1989) as cited by Heller (1996). It has green to pale green colored leaves with a length and width of 6-15 cm and the leaves arrange themselves alternately, the plant is always monoecious, consequently the male and female flowers are shaped on the same inflorescence and usually there are 20 male flowers in respect to each female flower and sometimes 10 male to each female flower where the inflorescence form in the leaf axil (Sachdeva et al., 2011). However, sometimes hermaphrodic flowers are present infrequently and self-pollinating occurred (Staubmann et al., 2010).

Ewurum et al. (2010) study as cited by Kamal et. al (2011) shows that the mature plant usually produces capsule shape fruits in winter or during the year if the soil moisture is good and temperature is appropriately high (Fig. 3). The seeds are black and range from 10 mm long and 10 mm wide and become matured when the seeds color changes from green to yellow, this usually takes 3 to 4 months after the flowering and there are 1375 seeds/kg in average (Li et al., 2010). List & Horhammer (1969-1979) as cited by Nahar & Hampton (2011) show that Jatropha leaves contain different chemical compounds such as saccharose, raffinose, stachyose, glucose, fructose, galactose, and protein. Fatty acid such as oleic, linoleic acids, palmatic and others acids are also reported (Perry & Metzger, 1980).

3.4. The potential of Jatropha Curcas as biodiesel feed stock

Several studies show positive energy balances for the *Jatropha Curcas* when it is used as feedstock for biodiesel production especially as fence plantations (Feto, 2011; Energy, 2009) due to the fact that it produces viable biodiesel and each hectare can provide about 1900 liters of biodiesel per year in addition to 3400 kilograms of waste biomass (Muok & Källbäck, 2008). According to several estimates made by experts, (Table 1) represents the yield of Jatropha seeds/hectare in different years (Bio Zio, 2012).

Jatropha Curcas can tolerate severe weather conditions and survives in different sort of soils such as marginal, low fertility, degraded, fallow and wasteland. *Jatropha Curcas* can be also be grown along canals, roads, railway lines, fence boarder between farms, areas with low rainfall (200 mm/y) and alkaline soils with temperature above 20 C^0. *Jatropha Curcas* is considered as a sustainable biofuels feedstock since it does not compete

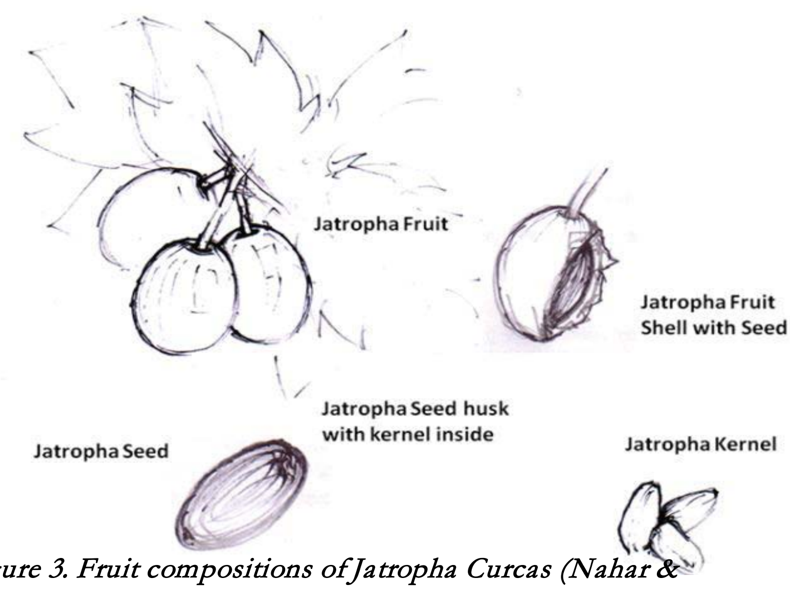

Figure 3. Fruit compositions of Jatropha Curcas (Nahar & Sunny, 2011).

Table 1. Yields of Jatropha seeds (BioZio, 2012).

Year	Range of reported yields per hectare (tone)	Most likely average yield per hectare
1	0.250–1.25	0.50
2	1-2.5	1.5
3	2.5–5.0	3.0
4	5 – 6.25	5.0
5	6.25 – 7.5	6.5

with food productions, non-edible oils, control soil erosion, and help in poverty reduction (Kumar & Sharma, 2005).

3.5. Uses of Jatropha

Different parts of *Jatropha Curcas* have useful applications and uses. Jatropha have gained its importance due to the higher oil contents, in addition to its useful medical uses, some records show that Jatropha was used by Indians a long time ago for medical purposes in traditional ways, the main use of Jatropha is as fences around agricultural fields or to control erosion on marginal soils (Peter et al., 2010). Moreover, it is used as fire wood, fuel for lamps & cooking stoves and direct engine fuel, the oil is also considered as alternative for soap production, on the other hand there are a lot of medical uses for Jatropha oil such as: the seed oil can be used to treat eczema, skin diseases and rheumatic, the seed cake are used as soil fertilizers, input for biogas production, input for combustion and production of charcoal (Peter et al., 2010). Jatropha liquid is used to inhibit watermelon mosaic virus (Tewari & Shukla, 1982). Figure 4 summarizes the foremost uses of *Jatropha Curcas* (Nahar & Hampton, 2011).

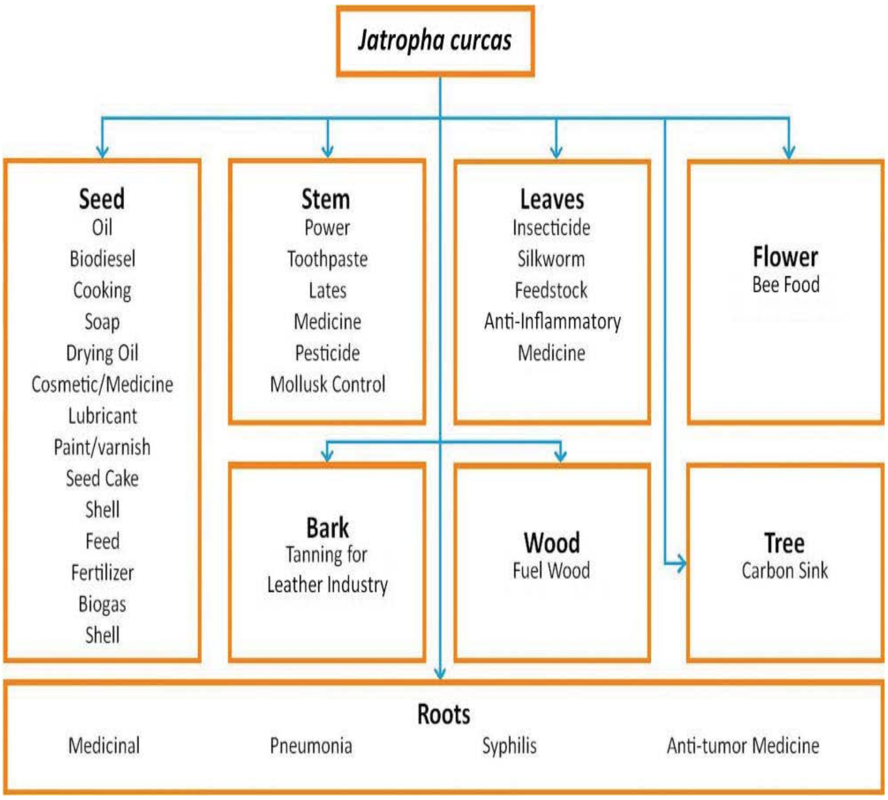

Figure 4. Uses of Jatropha (Nahar & Hampton, 2011).

3.6. Physical and chemical characteristics of Jatropha Curcas oil

Jatropha Curcas oil contains considerable amount of free fatty acids (FFAs) such as palmitic, stearic, arachidic, oleic and linoleic, these contents are higher in Jatropha oil relative to other non-edible biofuel plants such as Caster and Linseed (Martin et al., 2011).

Biodiesel from Jatropha is better than fossil fuel diesel in terms of ash contents, carbon residue, sulfur contents and acid value according to Singh et al. (2006). Table 2 illustrates the main characteristics of Jatropha oil, Jatropha methyl ester and petroleum diesel relative to international standards such as American Society for Testing and Materials (ASTM) and Detuches Institute für Normung (German Institute for Standardization) DIN.

Table 2. Comparisons of physical and chemical characteristics of Jatropha oil and Methyl ester with fossil fuel diesel (Singh & Saroj, 2009).

Property	Unit	Jatropha Oil	Jatropha oil Methyl ester	Diesel	ASTM (D 6751- 02)	DIN 14214
Density at 15 0C	Km/m3	918	880	850	875-900	860-900
Viscosity at 40 0C	Mm2/S	35.4	4.84	2.60	1.9-6.0	3.5-5.0
Pour point	0C	-6	-6	-20	-	-
Water content	%	5	Nil	0.02	<0.03	<0.05
Ash content	%	0.7	Nil	0.01	<0.02	<0.02
Carbon residue	%	0.3	0.025	0.17	-	<0.3
Sulphur content	%	0.02	Nil	-	0.05	-
Acid value	Mg KOH/g	11.0	0.24	0.35	<0.8	<0.50
Iodine value	-	101	104	-	-	-
Saponification value	-	194	190	-	-	-
Calorific value	MJ/kg	33	37.2	42	-	-
Cetane number	-	23	51.6	46	-	-

3.7. Main process of converting Jatropha oil into biodiesels

In order to produce biodiesel from Jatropha there are different processes involved to turn the raw materials (fats and oils) into ester while separating the glycerin.

The well-known process through which glycerin is separated from the biodiesel is known as transesterfication (Fig. 5). In this process, chemical ex-change takes place between (OR) of the ester compounds (R COOR) and alcohol such as Methanol (CH3OH) or Ethanol (CH3CH2OH) in the presence of a catalyst such as Sodium hydroxide (NaOH) or Potassium hydroxide (KOH) and finally the methyl or ethyl ester which is known as biodiesel is formed (Riemenschneider, 2005).

As seen in (Fig. 6) after crushing Jatropha seeds to produce fats and oils, a filtration (pre-treatment) process is used in order to get rid of impurities and suspended particles which are not part of the oil such as: barks, FFAs, phosphorus, access water, and bits of the cakes (Nahar & Sunny, 2011). After filtration, the transesterfication process is going to be started by adding methanol or ethanol in the presence of catalyst to produce methyl ester (biodiesel). By-products such as: Glycerin, unchanged FFAs and water are sent to a separate tank to recover the glycerin from impurities and the methanol that is not consumed during the transesterfication process goes to the recovery tank to be used again in the system.

3.8. Future of Jatropha as energy crop in Africa

Due to scarcity of fossil fuel reserves in most African countries, in addition to the fact that Jatropha can withstand the harsh climate conditions and has no impacts on food security when it cultivated in the marginal lands, it is therefore seen by some experts as one of the suitable energy crops in the developing countries for large-scale biodiesel production. However, these assumptions and it's characteristics are still not understood nor validated (Ouwens et al., 2007), all these statements regarding Jatropha can be true and false at the same time; true if clear policies about Jatropha biodiesel have been made, otherwise instead of seeing Jatropha as a future crop it will be as one of the coming disasters in nearest future in Africa, due to the fact that Jatropha without compre-

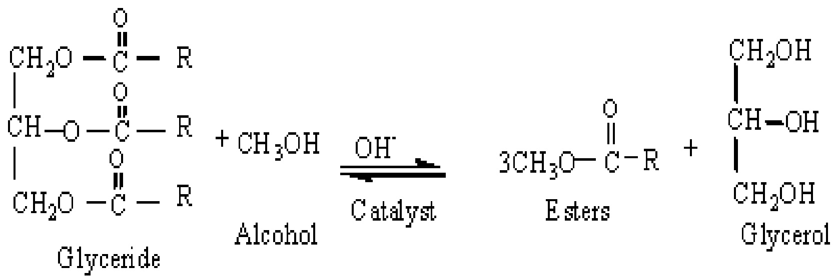

Figure 5. Transesterfication Reactions.

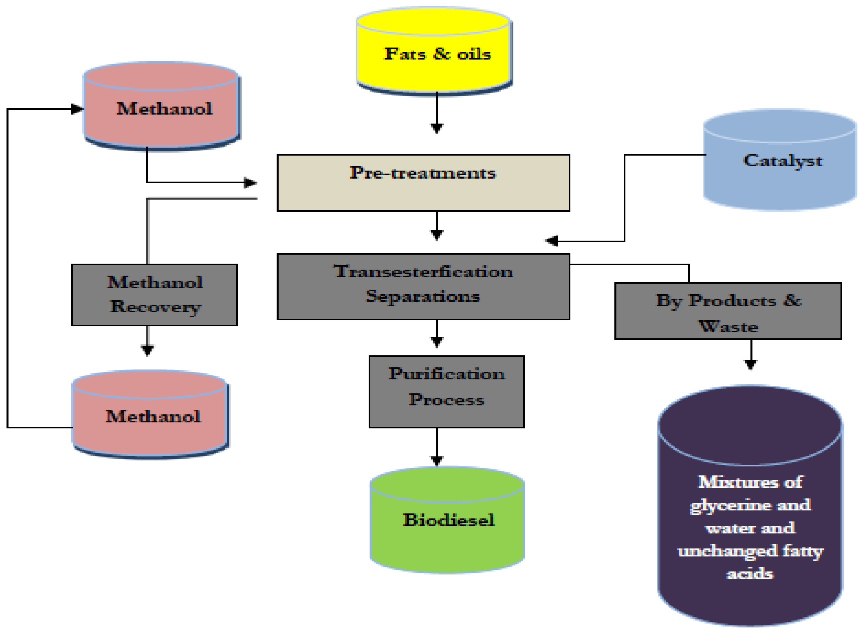

Figure 6. Main process of converting Jatropha oil into biodiesels (Nahar & Sunny, 2011).

hensive studies and good planning might contribute to many negative impacts economically, socially and environmentally.

Nowadays, Jatropha oil plays a crucial role in small-scale decentralized systems to generate electricity in small villages and remote areas where there are no accesses to central power generation. In both Mali and Tanzania biodiesel from Jatropha is being used to operate Multi-Functional platforms (MFP) to provide different energy services and thus improved the livelihoods in these areas (United Nation, 2007).

Jatropha will be the future energy crops, if the current gaps and challenges facing the Jatropha have been identified and carefully considered such as funding's, high investment costs, no clear policies, improvement of the marginal lands, R & D on plant agronomy to produce high seeds etc.

3.9. **Why National Policy on Biofuels in Africa**

The main drivers of stimulation policies regarding bioenergy are: to increase the energy security; economic development and decrease CO_2 emissions (Moller et al., 2011). Therefore, several governments and policy makers started to establish new policies and regulations targeted at increasing biofuels to achieve EU policy objective of 20% reduction in GHGs by 2020. Furthermore, in 2007 the outcomes of the 4th assessment report of Intergovernmental Panel on Climate Change (IPCC) show the significant role of biofuels in the reduction of CO_2 emission to achieve the future target of limiting the global warming (IPCC, 2007).

Other factors for stimulation biofuels policies in Africa are due to the scarcity, depletion of liquid fossil fuels and most of the fossil fuel coming from a small number of countries which are politically unstable (Goldemberg, 2007). Similarly, the developing countries started to produce biofuels locally in order to cut down in the annual cost of the imported fossil fuel (Siwa & Martin, 2013) .About forty two countries in Africa are net energy importers while fewer countries are oil exporters because Africa has only 9.5% of world's oil reserve which counts for 12% to the global oil production (Amigun et al., 2011).

Africa climate is seen as additional reason for stimulation of biofuel rules and Xlmlng et al., (2011) writes that, most of global biomass potential lies in the tropical areas where there is access to sunlight and irrigation. For all the above mentioned reasons, European countries started to establish and regulate biofuels policies very early. However, fewer developing countries have clear biofuel policies at the moment.

3.10. **Feasibility of Jatropha oil for Biodiesel production**

There are three key factors which can determine the profitability of the Jatropha seeds and its economic value. The first factor is the yield of the mature plant per hectare, the second one is the production cost and the last factor is the market price. From policy point of view, the Jatropha is economically viable when the oil barrel of Jatropha is 60-70 USD relative to fossil fuel (Soto et al., 2013a). Furthermore, the system of the production and the production cost are significant factors for Jatropha profitability since they will stimulate and improve the gross margin and return to the labors. On the other hand the biofuel productions will became more competitive when taking into account the externality and biofuels by products (Soto et al., 2013a). For most large-scale projects to become economically viable, several literatures review suggested that the optimization of production cost, energy yield per hectare, adaptability to natural condition, storage potential, appropriate climate, labors availability, infrastructure and logistics are the most important factors that will enhance the feasibility of the Jatropha oil for biodiesel production.

The study carried out in Ethiopia by Feto (2011) shows that "of all production systems, cultivation of Jatropha in live - fence hedge is the most feasible from economic viewpoint" and also in Mali the low seeds prices and higher labors cost influenced the profitability of Jatropha biodiesel. Therefore, by -products might be exploited in order to improve the profitability of the Jatropha system (Soto et al, 2013b).

In Kenya according to a study based on farmer's interview which was performed in 2009 to assess the agronomic and economic viability of Jatropha, most Jatropha farms in the country revealed very low yields and the cost of production was very high which make it economically unfeasible for smallholder projects when Jatropha grown within a monoculture or intercrop plantation model. However, the most economic approach for small-holders according to field experiences is when the Jatropha is naturally growing as a fence plantation and this approach is conforming to Ethiopian model (Energy, 2009).

For the above mentioned reasons, the Jatropha value chain is a key indicator for the probability and feasibility of Jatropha production. Figure 7 illustrates the Jatropha value chain from plantation stage to the supply of the final products to the end users in forms of biodiesel or utilization of the seeds cakes as fertilizers (Faso Gaz, 2013).

Soto, et al. (2013a) show that the Jatropha value-chain can leads to considerable reductions in the greenhouse gas emissions when all the adverse impacts during the biodiesel life cycle are analyzed using sensitivity analysis in order to assess any related risks by identifying the variables that have great influence in the projects net profits using different techniques such as Benefit Cost Ratio (BCR), Internal Rate of Return (IRR), Net Present Value (NPV) or other indicators.

3.11. Sustainability criteria for biofuels (Jatropha)

According to 2005 World Summit on Social Development, the objectives of sustainable development are: to identify the economic, social and environmental issues related to any developments (Shah, 2005).

Sustainability criteria should consider all the predicted impacts at the stage of initiating the Environmental Impact Assessment (EIA) and the Strategic Environmental Assessment (SEA), because the whole picture of sustainability can be seen in the context of these two processes.

EIA can be defined as a process for identifying and evaluation of the likely consequences (impacts) of any particular activities. Therefore, EIA

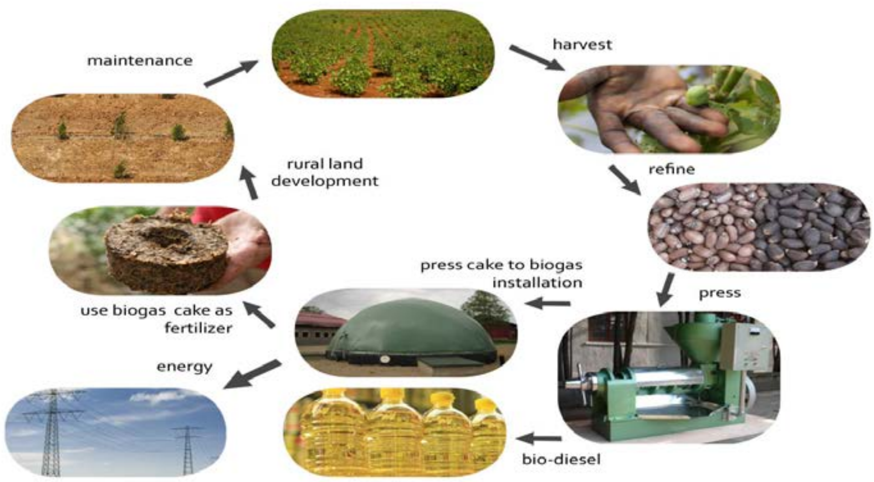

Figure 7. Jatropha Value chain (Faso Gaz, 2013).

play a fundamental role as one of the instruments to achieve sustainable development and the economic development and social development must be placed in their environmental contexts (Glasson et al., 2013).

SEA is defined as a strategic tool towards sustainability by linking different issues such as social, institutional and economic in strategic manner to help in driving the development into sustainability pathways (Partidário, 2012).

Energy security is a central issue for socio-development and could provide all the services towards better life (Singh & Sooch, 2004). For bioenergy, a number of studies have been performed to classify the most significant factors that might contribute to the sustainability of bioenergy and they have all demonstrated that any bioenergy project should give a positive energy balance as well as environmental benefits (Mangoyana, 2007).

The most environmental impacts are related to: Reduction of GHGs, soil conservation & erosion, land use changes, loss of biodiversity, over-exploitation of water resources and contamination due to application of fertilizers (environmental impacts are discussed in section 4 of this report).

Social impacts are associated with:

Poverty alleviation: Biofuels can help in poverty alleviation due to creation of jobs and increasing the income per capita (Prasad & Visagie, 2005).

Food versus fuel: when agricultural lands are planted by energy crops.

Land tenure and cultural heritage: Most of the lands granted for biofuels projects are belong to villagers whom are economically and socially vulnerable and their land tenure is not formal (Amigun et al., 2011). Lands for these communities is not only a source of economy and income, it is also a matter of pride and spirituality and people always struggle to maintain this precious wealth that have been given to them by their ancestors and they should maintain and keep it for both themselves and future generations (Young, 2000).

Health impacts: The production of biofuels is believed to have both positive and negative health impacts; sustainable biofuel will improve the air quality due to the reduction of CO_2 pollution. On the other side, some biofuels projects might lead to some health impacts such as water contamination due to the release of some toxic materials (Jatropha seeds are highly toxic) when are discharged from the effluent of biofuels processing plants (TERI, 2008).

The economic issues are related to biofuels value chain such as: investment costs, Jatropha productivity, energy yields, reduction in fuel usage, market prices and etc. (as discussed in section 3.10).

3.12. The current status of some projects of Jatropha in Africa

According to survey conducted by Dr. Guy Midgley from South African National Biodiversity Institute, there are over 1,660 million hectares of lands in Africa are appropriate for Jatropha plantations (Bio Zio, 2007).

Currently, there are several Jatropha projects in Africa and Africa is the second biggest area for Jatropha cultivations after Asia. However, there are no operational commercial (Large-scale) biodiesel projects and biodiesel is mainly characterized by small - and medium –scale producers (Amigun et al., 2011). The large-scale projects concerning Jatropha cultivations have often been collapsed in most African countries as a result of insufficient profits.

Based on data conducted by global market study on Jatropha in 2008, there are rapid increases in the concern of some African countries to increase the plantations of Jatropha by 2015. Table 3 describes the scale of Jatropha projects in 2008 as well as the forecasted biofuels projects by 2015, the strong commercial activities refer to; when biofuels plantations are > 5000 ha, whereas raising commercial activities refer to the current biofuel plantations in range of 100-5000 ha and low commercial activities refer to when the current plantations is just starting or < 100 ha. (GEXSI, 2008).

As seen in Table 3 the experts are so optimistic about Jatropha cultivation in Africa and by 2015 Madagascar will become the leading Jatropha producer due to the favorable climate for Jatropha cultivation in addition to government programs that have been drafted to encourage biodiesel industry in this country, the strong commercial activities by 2015 are similarly going to be implemented by Ghana, Tanzania, Zambia and Mozambique, however raising commercial activities and low activities is seen for Malawi, Cameron, Ethiopia, Sudan and the remaining of African countries due to climate struggle and absent of governmental legislations for Jatropha plantations (GEXSI, 2008).

There are many challenges and opportunities associated with biofuels industry in Africa based on some experts views which are presented on Nairobi conference of 2010 under the title: "*Jatropha Curcas* - Derived Biofuel Industry in Africa". Table 4 shows some examples of these opportunities and challenges.

Table 3. Scale and development of Biofuels in some African countries. Modified from GEXSI (2008).

Country	ha of biofuel in project identified in 2008	ha of biofuel in project estimated by expert in 2015	Number of project identified	Current Status
Madagascar	35,700	500,000	13	Strong Commercial Activities
Mozambique	7,900	170,000	12	Strong Commercial Activities
Tanzania	17,600	166,000	9	Strong Commercial Activities
Ghana	2	600,000	3	Strong Commercial Activities
Zambia	35,200	134,000	6	Strong Commercial Activities
Malawi	4,500	226,000	12	Raising Commercial Activities
Cameroon	3,000	135,500	4	Raising Commercial Activities
Ethiopia	200	125,000	6	Raising Commercial Activities
Sudan	-	125,000	-	Raising Commercial Activities
Other countries	-	-	-	Low or no commercial activities reported

As shown in Table 4 the lands availabilities and climate are the main opportunities for African countries to go towards Jatropha plantations. However, inadequate funding's, high investment costs associated with large-scale plantations, needs for policies on biofuels and the lack of extraction and processing technology to process the finished products are the most challenges for Jatropha biodiesel which need further mechanisms and ideology by African scientists, leaders, NGOs, farmers and decision makers to overcome these obstacles (AAS, 2010).

Table 4. Opportunities and Challenges of Biofuel in some African Countries. Modified from AAS (2010).

Country	Opportunities	Challenges
Kenya	- Land availability in the semi-arid areas that own virtuous climate for Jatropha cultivation. - Availability of labors to meet the market demands	- The choice of crop between agro-forestry trees and food crops. - High investment cost associated to large-scale plantation - Lack of extraction and processing technology to process the finished products. - No clear polices and guidelines for biofuels production.
Tanzania	- Proper climate for Jatropha cultivations.	- Low awareness among farmers - Inadequate funding. - Negative views about Jatropha by some people. - Needs for strategies and policies on biofuels.
Ghana	- Good climate in terms of soil and rainfall for biofuel. - Jatropha can be grown on marginal lands that are not suited for food crops	- Some projects run into some problems such as funding , lack of rules and regulations in biofuel and scarce of scientific data on biofuel

4. RESULTS AND DISCUSSIONS

4.1. Case study of Sudan

4.1.1. *Biofuels development in Sudan*

Sudan has a total area of 1,882,000 sq. km and it has a population of about 33.5 million and measured as one of the biggest African countries in terms of area and populations (Ministry of Information, 2011). At the present time, the main source of energy is oil produced from fossil fuel and the charcoal from wood biomass. According to data from Sudanese Petroleum Corporation, Sudan's energy demand has considerably grown-up through the past two decades from 6.8 Mtoe to beyond 11.2 Mtoe and most of its petroleum exists in the South part of Sudan and due to the separation of 2011; the North part has lost more than 70 % of its energy sources (SPC, 2012).

The latest study carried out in 2013 by Sudan Aeronautical Research Centre (ARC- Sudan) in collaboration with Andrew Lang from world bioenergy association (WBA), showed that Sudan has many opportunities to undertake biofuels. The key factors for Sudan are related to water availability, sunlight, biomass and land tenure system. The water availability is due to the flow of the River Nile along the whole country as well as several hydroelectric dams which could support the irrigation systems. Sudan has a very hot solar radiation which could be exploited in order to generate electricity for biofuel project using solar system. Biomass from agricultural residue and by-products can be used as feedstock for energy production. Sudan has a land tenure system that offers good chances without any risk to investors (Farouk & Lang, 2013), because the majority of the lands are owns by the government. On the contrary, the main expected adverse impacts related to biofuels in Sudan could be due to supply of services to regions, drought, desertification, deforestation and bad perceptions about Sudan by many international firms and community due to political instability, civil wars and USA sanctions (Ministry of Information, 2011).

4.1.2. *Current situation of Jatropha in Sudan*

An alternative source to substitute the oil losses due to separation of Sudan is much needed and Jatropha is seen as one option, due to its suitability for Sudan climate. Consequently, in March 2013 Sudan government with the help of Sudan Aeronautic Research Centre and Andrew Lang from World Bioenergy Association issued a comprehensive report about Sudan potential and the roadmap to produce biodiesel from Jatropha at large- scale. The report discussed different issues in order to establish a genuine scenario about the current situation to produce biodiesel from Jatropha. There are many issues underlined in this study for the production of Jatropha at large- scale in Sudan such as: the estimated cost of sites, establishment and initial infrastructure in (year 1) for 125,000 ha = $ 375 million, the estimated annual operations costs (year 2-3) for 125,000 ha = $ 110 million, the estimated operating costs from year 4 onwards when all 125.000 ha are in full production = $ 160 million, the estimated gross revenue in (year 5) for 125,000 ha= $ 306 million and the total cost will be recovered by the year 10.

In summary the project is optimistic over rather longer time epoch (Farouk & Lang, 2013). Figure 8 shows the Technology milestones for Sudan's Biofuel for Transportation roadmap - Jatropha Base (Farouk et al., 2013).

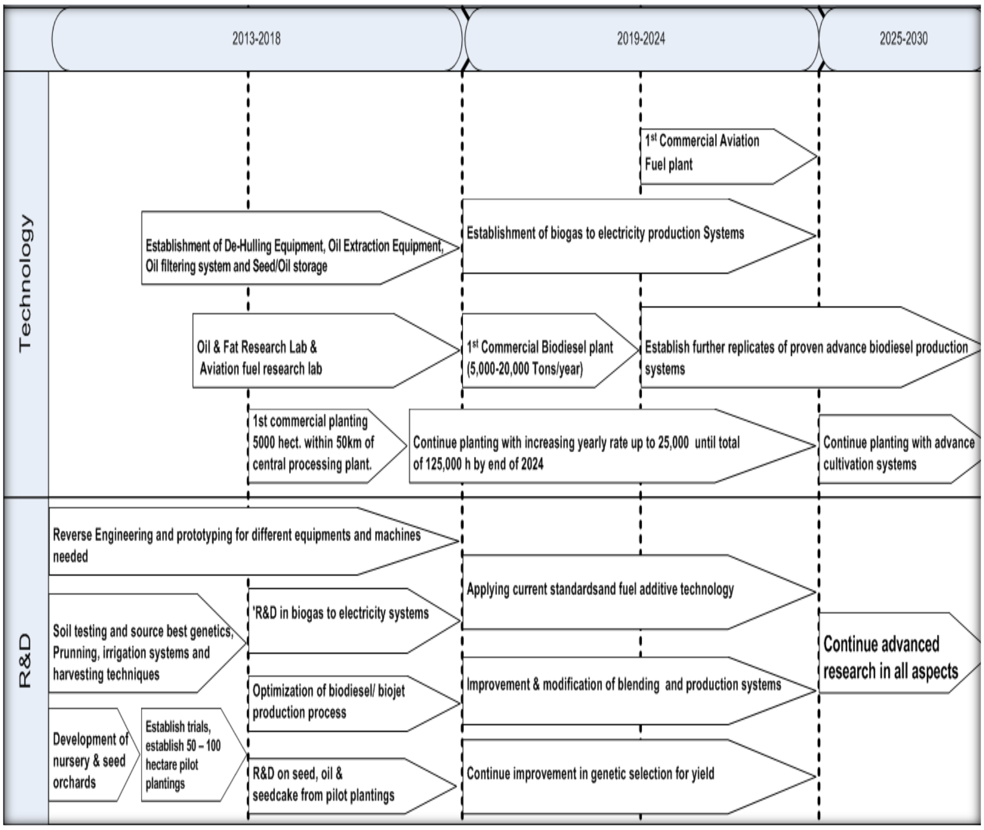

Figure 8. Technology milestones for Sudan's Biofuel for transportation roadmap: Jatropha Base (Farouk et al., 2013).

4.1.3. *Potentials of Jatropha in Sudan*

Currently, there are no any Jatropha projects that are operating, the only project for Jatropha in Sudan is now under the initiating phases, and the study carried out by Hazir Farouk and Andrew Lang seems to be optimistic for the following perspectives which are addressed in their report (Farouk & Lang, 2013):

- Jatropha cultivations can substitute the losses of the fossil fuel due to separation of the South Sudan by replacing 5% of fossil fuel demands and this amount will definitely enhance the country economic growth.
- Sudan biofuels road map aiming at the reduction of the traditional energy sources such as the dependency on wood and charcoal particularly in the country sites.
- The project is considered as re-vegetation program.
- Jatropha seedcakes besides the production of biogas can be used for the production of Combined Heat and Power (CHP), because the cultivations of 625,000 tons of Jatropha seeds will produced 150,000 tons of diesel as well as 432,000 tons of the seed cakes and this amount of the seed cakes has approximately 2,185 gigawatt-hour (GWhr) energy values. If this energy values will be used in an efficient CHP this might produce about 87 Megawatts (MW) electricity annually.
- Production of biodiesel from Jatropha will improve the rural areas.
- Regarding sustainability, the proposed Jatropha project will be sustainable since the recommended sites are not currently in used which will result in low land- use change and will be positive for the greenhouse gas balance. The project will not affect the use of water from aquifer or result in salinity or competing with food crops.

4.1.4. *Related Risks of Jatropha in Sudan*

There are no any operational Jatropha projects in Sudan at the moment, consequently there are no any data available regarding any environmental assessments (i.e. EIA and SEA documents). The current study on Jatropha predicted some related risks such as: "inadequate quantity and quality of water, insufficient labors at harvest or for other time-critical operations, mishandling of seeds and oil resulting in rise in free fatty acids, mismanagement at sites during harvesting, fertilizers, weed control, irrigation, pests & disease, lack of pollinating insects, climate extremes at flowering, lack of trained personnel for pressing plant or other system, a fall in international prices of Jatropha oil or biodiesel, or other adverse international and/or internal political problems" (Farouk & Lang, 2013).

4.2. Case study of Ethiopia

4.2.1. *Reasons and policy for the increase of biofuel in Ethiopia*

There are two reasons and driving forces for the increase of biofuels in Ethiopia, the first one is the intention of the government to secure its national energy from their own local feedstock to cut down in the high amount of currency that is spending in the importing of oil from outside due to the dramatic increase in the transport sector as well as economic growth in the country (Feto, 2011).

The second reason is the international perspective to achieve EUs goals to increase the renewable sources by 20% particularly from biofuels.

In 2009, the government of Ethiopia made two policies to support biofuel, the first policy is the blending of 5% ethanol with 9 5% gasoline and the blending increased to 10% in 2011 and 25% will be applied by

2014, the second policy is the revision of many agricultural and taxation policies particularly in the large-scale agricultural projects in order to attract the investors to come and take part in this business (MoME, 2007).

4.2.2. *Some Scenarios of biofuel projects in Ethiopia*

In recent years many interest are seen by foreign investors to develop a biofuel business in Ethiopia in order to improve the standard of living by adding extra sources for hard currency for the sake of the economic growth. One target of "Ethiopian Biofuel Development and Utilization Strategy" is to produce biofuel locally from Jatropha without conflicting with food security and environmental criteria, the strategy also set out rules and estimated that about 106,997 million tons of ethanol will be produced from sugar cane by the year 2016 and 1.25 million farmers will be involved in the production of the Jatropha (Feto, 2011). This initiative could help in the replacement of one billion liters of the annually imported petroleum diesel (MoME, 2007) and according to data cited by GRAIN (2007), there are about 196,000 hectares of land approved by the government for Jatropha cultivation and the numbers of projects are fast growing. Therefore, Ethiopia is seen as one of the largest African countries in relation to areas planted with Jatropha (Nepomuk et al., 2012).

Currently, there are 25 biodiesel projects that have been granted by Ethiopian government; 20 projects are planned for Jatropha. Nevertheless, very few of these projects are continued. This is due to several reasons regarding economic viability (Locke & Henley, 2013). There are a number of studies and assessments ongoing to make positive business because most of the projects have not been started yet. Currently, there are fewer companies working in Ethiopia such as Emami Bio-tech and Flora Eco-Power, these two companies are working in: Bati, Fedis and Mieso districts of Oromia National Regional State. (Feto, 2011). The Emami Bio-tech is an Indian firm which was started in 2008 and the main purpose of this project is to produce different sort of oil seeds and non- edible oil including Jatropha, in the future Emami company is going to build its own processing facilities, the Flora Eco-Power (FEP) was established by Germany in 2007 in four districts in Ethiopia (Feto, 2011). Referred to the Environmental Impact Assessment report of FEP (2007) as cited by Feto (2011), Flora Eco Power has set up its own processing facilities with capacity to extract about 220 tons of oil per day. (Table 5) shows three examples of ongoing Jatropha projects and some climate condition in Ethiopia.

From the previous data, it has been noticed that although there is high governmental support for Jatropha in Ethiopia, but still there is no obvious outcomes regarding these investments and this could be due to unfavorable conditions in the granted areas (marginal lands), in addition to the risk avoidance by the sponsors & investors in order to have a successful outcomes and revenues. According to a revision done by Gebremehdine et al., (2010) from African Biodiversity Network to understand the performance of the current projects in Ethiopia, the findings of this report came with the same previous conclusion indicated that, the Jatropha has poor performance in low rainfall areas with low soil nutrients. The second observed reason for of the failing Jatropha in Ethiopia, is the absent of the governmental regulations that will avoid the undesirable socio-economic and environmental impacts.

Table 5. Status of Jatropha and Climate Condition in Ethiopia. Modified from Feto (2011) and Gebremeskel & Tesfaye (2008).

Investors	Area of the projects	Climate conditions	Results
a. Emami Bio-tech (Indian) b. The Flora Eco-Power Germany c. Sun Biofuels (UK)	40,000 ha 5,000 ha	1. High evapotranspiration. 2. Less rainfall that improved with irrigation for the cultivation of Jatropha and sometimes the annual rainfall reach 500-1000 mm. 3. The annual average temperature 18 0C-360C 4. Soil is very shallow and contains highly weathered and fractured volcanic rocks	Jatropha producing very low yield, therefore Emami & Flora Eco investors focus in Castor instead. Sun Biofuels (UK) closed the operation in 2009

4.2.3. ***Potentials of Jatropha in Ethiopia***

Jatropha might be a potential for Ethiopia for the following reasons; it will secure the national energy demands, it will cut down in the annual spending for the imported oil, substitution of kerosene for lighting, improve the health and increase the productivity by supplying universal access to acceptable energy service (UNDP, 2004).

The local biofuel projects in Ethiopia lead to a significant socio - economic benefits by creating many jobs opportunities and improve the standard of living of the local people. In case of the Flora EO Power, more than 7,000 jobs have been created with the ability to be increased up to 2,000 jobs in the future, whereas in the case of Sun Biofuel more than 1,000 jobs were also created (Gebremeskel & Tesfaye, 2008).

Jatropha plantations as fencing is demonstrated to be of high potential for soil erosion control in Ethiopia and Reubens et al. (2011) claimed that Jatropha is a potential factor against soil erosion, Jatropha plantations is one of the approaches for soil & water conservations and Jatropha plantations will reduce the dependency of rural people in the traditional biomass such as firewood and charcoal (reducing the pressure on natural resources).

4.2.4. ***Some Drawbacks of Jatropha in Ethiopia***

It was noticed that despite the potentials of the Jatropha as biodiesel source, still there are many issues which can be regarded as draw backs of some Jatropha projects in Ethiopia, these issues are summarized in the below points :

Jatropha producing low yields and failing on the Marginal Lands

The current worldwide Jatropha projects show several variations in yields due to different factors such as: poor growing methodology, seed quality, water sources, soil and topographic conditions, fertilizers and pesticides usage (GFE Global, 2009). Jatropha in Ethiopia showed the same trend of this productivity and even much lower productivity was observed. Therefore, in the villages of Mancha and Wolaita, which are considered as marginal lands due to dry and low fertile lands, the Jatropha projects performed very poorly and produced low yields. Therefore, the Sun Biofuel in 2009 closed their Mancha operation and said that “accompany can’t make money from a plant in a place without adequate rain” (Gebremehdine et al., 2010).

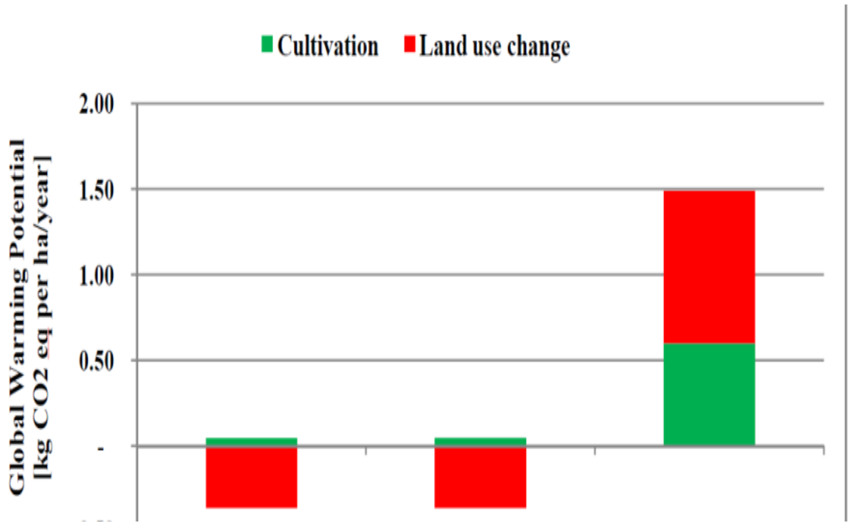

Figure 9. GWP of Jatropha cultivation system and land use change (Feto, 2011).

If Jatropha grows in marginal lands, the productivity will be also very low, because studies on marginal lands in India showed that applying fertilizer improved the marginal lands and increased the oil seeds by 70% (Ratolia et al., 2007) and another study demonstrates that when the nutrient is not sufficient this could lead to the decrease of the Jatropha seeds (Kumari & Kumar, 2007).

Impact on Biodiversity

Jatropha plantations were negatively impacts the biodiversity in Ethiopia, due to the fact that some of the projects were established in valuable ecosystem and several natural forests have been destroyed, for instance about 50 ha of forest were cleared in order to make way for the Sun Biofuel Jatropha Plantations (Gebremeskel & Tesfaye, 2008).

Impact on water

The study of Gebremeskel & Tesfaye (2008) shows that Jatropha projects in Ethiopia impacts the water resources negatively because most of the ongoing projects are mainly rain fed and this practice resulted in higher water consumption and contamination, during the peak growing period the plant needs sufficient quantity of water to meet the evapotranspiration, also the effluents coming out from biofuel processing plants emit considerable amount of contaminants with high biological and chemical oxygen demands (COD and BOD) and toxic substances. All these practices threaten the ecosystems in different ways (i.e. water pollution, killing aquatic life and causing eutrophication) furthermore; the greater water consumption of biofuels projects might disturb the regional hydrology due to reduction in rainfall infiltration which will negatively impact the aquifer (Gebremeskel & Tesfaye, 2008).

Impact on Soil

As reported by Gebremeskel & Tesfaye, (2008) some of the lands that have been granted by the governments to the biofuels firms are fertile and covered by vegetation. Therefore, Large –Scale projects will lead to sever soil problems such as: erosion, poor soil organic matter, reduce soil biodiversity and soil contaminations due to the release of nutrients which are rich with waste products. There are not any actions in use by the bio-

Figure 10. Degraded land in arid condition in Kenya (Muok & Källbäck, 2008).

fuel developers in order to overcome the negative impacts of chemicals whether as fertilizers or pesticides (Gebremeskel & Tesfaye, 2008).

Air pollutions and increase carbon emissions

Although, there are no data available regarding the likely impacts of biofuels production on air quality, many researchers believe that air pollutions will be resulted from these activities. Most of biofuel investors and supporters claimed that biofuels will reduce carbon emissions and lead to greenhouse gases (GHG) saving of up to 66% (Volckaert, 2009). In Ethiopia the only model that is totally agreed with this fact is when the Jatropha is cultivated as a fence plantation because the Global warming potential (GWP) of Large- scale Jatropha cultivation is higher by many folds than when Jatropha cultivation as a fence.

As seen in Fig. 9 Mieso Large –Scale Jatropha Plantation emit more CO_2 and this is due to different factors such as application of fertilizers, irrigation, pesticides and the use of fossil fuels during biofuels production process (Feto, 2011). Figure 9 compares the GWP of Jatropha cultivations as a fence in Bati and Mieso projects and large – scale Cultivations in Mieso as inter-crop (IC) plantations.

Food Security

Referring to the Plan of Accelerated and Sustainable Development to Eradicate Poverty in Ethiopia (PASDEP) towards achieving the Millennium Development Goals the current large-scale biofuel projects resulted in making approximately 6.71 million people facing food insecurity and the current biofuel activities are likely to have adverse impacts in the food security because the plantations of Jatropha or Castor for biofuels might let the farmers to left the food crops and shift to biofuel crops as a result of motivation by the investors (Gebremeskel & Tesfaye, 2008).

4.3. Case study of Kenya

Kenya lies in the East of Africa and it has borders with five countries: South Sudan, Ethiopia, Uganda, Tanzania and Somalia. It has a total area of 582,650 square kilometers. According to Kenya National Bureau of Statistic (2007) Kenya's population was estimated at 37 million and most of the populations are concentrated in the Capital and agricultural areas. The climate is varies along the country from tropical to arid and less than 15% of the country receives 760 mm per year rainfall which make the

Jatropha cultivations very attractive due to its tolerance to such wet and dry seasons, Fig. 10 shows example of degraded land in Kenya (Muok & Källbäck, 2008).

4.3.1. *Jatropha Development in Kenya*

There are many motives for Kenya government to develop business in the area of biofuel mainly for the Jatropha. The poverty and environmental problems are the vital reasons for this because 60% of the populations live below the poverty line (Muok & Källbäck, 2008). Drought and overexploitation of natural vegetation's for fuel wood had put additional pressure on the environment and sustainability. Moreover, biofuels will supply Kenya with clean energy source and reduce the high cost of fossil fuel and providing good alternative of energy to replace the traditional sources such as charcoal and fire wood in the disadvantaged location, in addition to adding more valuable socio-economic benefits (Muok & Källbäck, 2008).

From my point of view, the most socio-economic value for the rural communities is the creation of employment in the rural areas and thus cut down in the numbers of immigrants to the urban areas in search of work, this will lead to a dual advantages to both rural and urban areas; it will improve the rural economy as well as improving the services in the urban areas since there are not much people going to be concentrated in the same region.

4.3.2. *Status of production of Jatropha in Kenya*

Jatropha in Kenya was naturally grown as a wild plant in the different part of the country since 50 years ago and some farmers started to plant Jatropha as a fence to protect their crops, Jatropha naturally grown in Kenya mainly in the high land regions where the climate conditions are favorable (fertile soils and proper temperature) and also Jatropha is found in the southern coastal region (GEXSI, 2008).

Miyuki et al. (2012) indicated that, Jatropha yield in different agro-ecological zones is very low under Kenyan farm conditions. However, there are many small- scales Jatropha projects currently in Kenya due to the inspiration of the non–governmental organizations and private firms, small-scale projects are mainly found in Kitui, Thika, Namanga, Kajiado, Nyanza, Nakuru, Marakwet, Naivasha and Meru that covered an area of 3,860 acres and most of the projects have started (Muok & Källbäck, 2008).

There are several funds which are available for Jatropha cultivations, these funds are coming from different sources: Locally, the key sponsors are Agricultural Famers Co-operative (AFC) through introducing of loan programs to farmers in order to encourage them to plant Jatropha, internationally, there are different programs and companies such as World Bank, European Commission, World Wide Fund For Nature, Hydronet Energy Company Ltd., and Biwako Bio-Laboratory Inc. (Muok & Källbäck, 2008).

According to Nepomuk et al. (2012) the numbers of the Jatropha projects are 4 – 6 projects in areas of 1463 ha, however the assessment made by GEXSI (2008) as seen in Table 6 shows different estimates in terms of areas and projects numbers in both 2008 and 2015.

Table 6. Estimates in terms of area and projects numbers in both 2008 and 2015 in Kenya (GEXSI, 2008).

Projects	source	Type	Project Location	ha 2008	ha 2015
Green Africa Foundation	3	Commercial Project	Kitui District	400	-
Green Power	3	Non-commercial Project	Isenya & neighbouring districts	200	6,000
Africa Energy Ltd.	1	Non-commercial Project	Not specified	100	10,000
UNDP GEF	1	Non-commercial Project	Mawindi and Kwane District	70	240
Nyumbani Village	3	Commercial project	Kitui District	10	-
Biwako Bio Laboratory, Hydronet Energy Company Ltd. And Green Africa Foundation	3	Non-commercial Project	Not specified	0	75,000
World Agroforestry Centre Research	1	Non-commercial Project	Not specified	-	-
	Acreage non-disclosed projects			0	325,410
	Total			780	416,650

Note: *(1) in the source column indicates: The interview done through questionnaire with project representative and (3) means from public sources.*

4.3.3. *Policies supporting biofuel development in Kenya*

Recently, there are many policies and regulations that play a vital role in promoting biofuels and Jatropha cultivations in Kenya in addition to the role of Kenya Energy Act 2006, Forest Act 2005 and Agricultural Act 2006 (Muok & Källbäck, 2008). However, there are many efforts enduring by some private organizations and societies to let the government to mandate and improve the current policies. For instance, The East Africa Natural History Society is looking for the development of an appropriate guidance on sustainable biofuels production before commencement and approval of any biofuel project.

According to the National Biofuel Policy Draft of (2011), the government of Kenya is going to reduce its dependency of imported petroleum by 25 % by 2030, this will be a achieved through increasing both biodiesel and bio-ethanol production, even so there are many challenges such as insufficient biofuel feedstock, limited research data, insufficient legal frame work to support sustainable biofuel and threat to food security. Therefore, in the third draft of national energy policy (2012), the Republic of Kenya drafted new polices to overcome the current challenges related to biofuel production such as supporting R & D for cultivation of high yield feed stocks, revising the current legislations to enhance sustainable biofuel, introducing new incentives to meet existing energy demand, induce the public participation and the awareness via biofuel programs and the encouragement of small- scale biofuel projects through a three term agenda.

Table 7. Biofuel projects in Kenya based on three terms agenda (National Energy Policy, 2012).

Short term (2012 -2016)	Medium term 2012 - 2022	Long Term 2012-2030
- Access to high yielding biofuel feed stock - Map out the appropriate location and potential biofuel through the country - Regulations to enhance sustainable biofuels - Three year tax holiday for biofuel project - Government to facilitate on biofuel plant and equipment - Selection of potential pilot location for biofuel feedstock production - Pilot 10% ethanol-gasoline blend in governmental vehicles and in public transport vehicle - Pilot 1% biodiesel in government vehicles - Develop blueprint road map for national biofuel implementation program - Public awareness through seminars and workshops about growing biofuel feedstock.	- Government and county government to allocate land for biofuel feed stock - Government and county government to enter into PPP with private sector to accelerate the development of biofuels - All vehicles in the country to use at least 10% ethanol-gasoline blend - Government vehicles to use 5% biodiesel blend and to use 100% biodiesel at all isolated power generation	- All vehicles in the country to use at least 30% ethanol-gasoline blend - All vehicles in the country to use at least 5% biodiesel blend

Despite the target of the three terms agenda which is mentioned in Table 7, there are some issues that need careful consideration by Kenyan government in order to pave the way towards a successful business. Muok & Källbäck (2008) underline some of these issues such as: the new policies need to be unified into one comprehensive guideline and the absolute need to build a detailed institutional agenda to address such biofuel development in Kenya and also the current public land tenure management system need to be revised to guarantee operative use of public lands.

It is clear that Jatropha is not a wasteland crop, it needs fertilizers, water and good management that is why some of the project are collapsed in Kenya due to ignoring such factors and most of the farmers are disappointed due to low yields and some of biofuels investors have not fulfilled their promises to provide the farmers with financial support. Therefore most of the farmers are forced to abandon the crop (Energy, 2009).

4.3.4. *Potentials of Jatropha in Kenya*

Clean energy source, and reduce the dependency and high cost of fossil fuel

Biofuels from Jatropha oil could be one of the clean energy sources that help in cutting down the Greenhouse gases, increase the percentage of the renewable sources as well as replacing the high costs of fossil fuel.

According to economic survey 2007, the cost of the imported petroleum products in 2005 was about 95.7 billion Kenyan shilling (Ksh), whereas in 2006 about 113.7 Ksh (National Bureau of Statistic, 2007) and if Kenya substitute 12% of imported fossil fuels with biofuel this will leads to 71 million USD annually saving (Energy, 2009).

Improve the local livelihood

Biofuels from Jatropha could lead to poverty alleviation and also will improve the local livelihood by creating employment and increase the income especially in rural areas, Heller (1996) said that Jatropha can be used to replace the kerosene for lamps and stoves since the cost of the Jatropha oil is less than the kerosene. According to a survey carried out by Kenya Ministry of Energy in 2000, the consumption of kerosene was reported very high and more than 2,300 households in 15 rural and 5 urban areas in Kenya used more than 88% of kerosene for domestic households (Tomomatsu & Swallow, 2007).

On contrary, in some districts such as Dakatcha woodlands, the Jatropha project led to negative social impacts because 20,000 people who are living in the forest for hundreds of years are requested to evacuate the area (North Energy, 2011), by so doing their livelihoods are going to be violated because such community are depend mainly on Dakatcha forest for growing crops to feed their family and the community relies on woodlands for drinking water, fire supply, some plants & trees use as source of herbal medicine and the forest represents cultural and heritage values to them because their ancestors and some leaders are buried in the grave which is found in the forest (North Energy, 2011).

4.3.5. *Drawbacks of Jatropha in Kenya*

Most literature reviews revealed that there is a high risk and uncertainty about profits from Jatropha feed stocks. According to Energy (2009) the economic profitability of Jatropha oilseeds in Kenya for Monoculture, Intercrop and Fence models show different variations in the profitability using the Net Margin. The only model that is profitable is the fence plantations because it gave annual profit in the fourth years (Table 8) and the other two models give no profits (Table 9 and 10). Furthermore, (Miyuki et al., 2012) writes that "the productivity of Jatropha under smallholder are still very lower because the growers are using genetically unimproved germplasm, suboptimal management practices and biophysical boundaries of high Jatropha yield are poorly defined."

Similarly, in India the commercial large-scale Jatropha projects of 2003 show low yield and the project originators realized their exaggerations of Jatropha yields and profitability (Singh & Saroj, 2009). However, small-scale Jatropha projects in India are considered sustainable and playing a significant role in rural areas by meeting cooking and lightning fuel needs. As recommended in the report done by Kedar et.al (2009) various environmental, social and economic issues must be controlled effectively while setting up a sustainable Jatropha oil decentralized community based system such as (loss of biodiversity, water usage, application of fertilizers, land use pattern, land tenure, health impacts, exploitation of workers, food security, investment costs, completion with larger plantations and higher expectations on fruit yields).

Table 8. Net Margins over 10 years in One- Acre Fence Jatropha for both low and high Projected Plantations (Energy , 2009).

Years	**Net low (Ksh)**	**Net high (Ksh)**
0	-1,618	-1,618
1	- 545	- 545
2	- 836	- 836
3	373	251
4	574	612
5	783	1,354
6	1,011	1,743
7	1,212	2,104
8	1,441	2,561
9	1,441	2,561
total	3,836	8,187

Table 9. Net Margins over 10 years in One- Acre Monoculture Jatropha for both low and high projected plantations (Energy, 2009).

Years	Net low (Ksh)	Net high (Ksh)
0	-10,314	-10,314
1	- 8,542	- 8,542
2	- 6,653	- 6,653
3	-7,038	- 6,999
4	-7,226	- 6,314
5	- 6,505	- 3,574
6	- 7,217	- 3,422
7	- 6,946	- 2,288
8	- 6,664	- 0,900
9	- 6,664	- 0,900
total	-73,769	- 49,905

Table 10. Net Margins over 10 years in One- Acre Intercrop Jatropha for both low and high Projected Plantations (Energy, 2009).

Years	Net low (Ksh)	Net high (Ksh)
0	- 6,177	- 6,177
1	- 4,400	- 4,400
2	- 4,985	- 4,985
3	- 4,374	- 4,359
4	- 4,722	- 4,390
5	- 4,190	- 3,127
6	- 4,743	- 3,365
7	- 4,660	- 2,968
8	- 4,558	- 2,463
9	- 4,558	- 2,463
total	- 47,366	- 38,699

Biodiversity and Carbon emission

The impact of the Jatropha cultivation on biodiversity in Africa is poorly studied, but still there are debates about its adverse impact which are underlined in some literature review. The establishment of 50,000 ha of Jatropha in Tana Delta region in Kenya led to displacement of some bird's populations and wildlife (Action Aid, 2009). The North Energy report of 2011 conveyed that many bird species such as; southern banded eagle, Fischer's turaco, Sokoke scope owl, Sokoke pipit and Clarke's weaver are now under threat in Dakatcha woodland due to Jatropha project and also the GHGs emission due to land conversion for Jatropha plantation in Dakatcha woodlands were reported to be 2.5 to 6 times the equivalent fossil fuel and this amount is higher than the target level of EU Renewable Energy Directive for 2017 (North Energy, 2011). These emissions are not meet the sustainability criteria (35% GHGs saving) (Kimuyu, et al., 2012).

Water management and wet land degradations

Generally, as shown in different literature review, the main problems of biofuel are coming from irrigations of the Jatropha plants, in addition to the pollution arising from the usage of fertilizers and agrochemicals. However, biofuels in Kenya proved to have no impacts on water usage (Kimuyu et al., 2012) the main issues of water are related to poor water management and high evaporation rate which resulted in low Jatropha yield (Ehrensperger et al., 2012).

In Kenya the main issue of biofuel project related to the degradation of wetlands, which serve as natural regulator for some ecosystem services such as: groundwater recharge, base flow regulation, natural and biodiversity, the conversion of the wetlands in Tana delta in northern Kenya for biofuels has led to arguments and people refused the investment in this sensitive ecosystem (Salé & Dewes, 2009).

Deforestation and Soil erosion

Forest is essential to the environment and ecosystem services for many reasons such as: forests remove carbon from the atmosphere and this will limit the magnitude of GHGs, it provide oxygen via photosynthesis, maintain the biodiversity since it is the habitats of most wildlife species and the forests protect watershed against soil degradation. Therefore, clearing and burning forest influence both local climate and human due to changing temperature, depletion of stratospheric ozone (UV radiation flux) and wind breaks (WHO, 2003). Clearing the forest for biofuels might lead to deforestation and soil erosion. However, increasing *Jatropha Curcas* might lead to improve the soil characteristics, through reclamation, erosion control, protection and improving the microclimate (Openshaw, 2000).

Food security and competition with agricultural land

Jatropha could impact the food security negatively due to the competition with agricultural lands, even though this issue is a controversial among biofuels experts.

In Kenya, some experts believe that Jatropha has no any adverse impacts on food security since it is non-edible and grown on marginal lands and Mogaka et al. (2012) cited that there are no any indication that Jatropha has any influence on food security, because most of the current projects are small-scale projects and grown by food secured farmers. However, Kimuyu et al. (2012) indicated that for poor countries, biofuels may increase the income, but it can also lead to food insecurity, because farmers are going to shift from food crops to energy crops and the large-scale biofuels projects in Kenya are expected to impact the food security negatively due to the completion with food crops.

4.4. Case study of Tanzania

Tanzania is located in the East Africa and has boarder with six countries, Kenya and Uganda on the north, Zambia, Malawi and Mozambique on the south, Republic of Congo on the west and Indian Ocean in the east. In 2012, the population of Tanzania is equal to 44,928,923 according to the population and housing census (PHC, 2012).

The climate varies along the country from tropical in the southern coast to moderate in the highlands and the average annual rain fall is 600 - 800 mm (Rowhani et al., 2011). The central part of the country is arid and moderate temperature in the south-western parts, therefore the climate is suitable for Jatropha cultivation in most Tanzania's regions (GEXSI, 2008).

4.4.1. *Jatropha Development in Tanzania*

In the recent years Tanzania started to increase the number of biofuel investments due to several reasons; the main reason is the high level of economic growth which leads the country to increase the existing energy sources, cut down in the imported oil cost (1.3 – 1. 6) billion US dollar annually and reducing the consumption of the fire wood (Kamanga, 2008).

The availability of arable lands and appropriate climate conditions for the Jatropha cultivation are another factors for the development of Jatropha in Tanzania, the country has 44 million ha of arable lands and only 10.2 million ha are been used, consequently the number of the Jatropha projects started to increase quickly due to the efforts of several NGOs and up to date there are approximately about 20 firms working in the Jatropha according to the government statistics (Sulle & Nelson, 2009). However, Kamanga (2008) cited that "37 companies having sought land in Tanzania for biofuel production. (Table 11) gives an overview of some Jatropha projects in Tanzania according to data adapted from Songela & Maclean, (2008).

Table 11. Existing and proposed biofuel investment in Tanzania. Modified from Sulle & Nelson (2009).

Investor	Crop	Location	Land area acquired (ha)	Land area originally requested(ha)
Bio Shape	Jatropha	Kilwa	34,000	82,000
Sun Biofuel	Jatropha	Kisarawe	8,211	50,000
Diligent Tanzania Ltd	Jatropha	Arusha Babati Handeni Singida Monduli	n/a	n/a
Donesta Ltd &Savannah Biofuels Ltd	Jatropha	Dodoma	2,000	n/a
Trinity Consult-ants/ Bioenergy TZ Ltd	Jatropha	Bagamoyo	16,000	30,000
Shanta Estates Ltd	Jatropha	Bagamoyo	14,500	n/a
ZAGA	Jatropha	Kisarawe	n/a	n/a
Bio Massive	Jatropha & Pagamia	Lindi Region	50,000	n/a
JCJ Co. Ltd	Jatropha	Mwanza Mara Shinyanga Tabora	n/a	n/a
Prokon BV	Jatropha	Mpanda	10,000	n/a
Mitusbishi Corporation	Jatropha	Arusha, Dares Salaam, Coast	n/a	n/a
Kapunga Rice Project	Jatropha	Mbarali District	50,000	n/a
DIOils Tanzania Ltd	Jatropha	Kilimanjaro	n/a	n/a
Kikuletwa Farm	Jatropha & Aloe vera		400	n/a

While there are several companies working in Jatropha in Tanzania, some of them stopped their activities due to different reasons such as long land lease process, lack of governmental support and absence of proper policies and regulations to guide biofuel investments in the country. The study carried out by Sosovele (2010) underlines these challenges in Tanzania which are summarized in the following points:

• *The absence of an integrated policy*: The policies are not collaborate energy development, transportation, agriculture lands, and water issues in accordance with biofuel growth

• *Inadequate research and development*: They are not taking into account the value chain of biofuel development.

• *Conservation and environmental issues*: Are not thoroughly addressed, because most large- scale biofuel schemes are established in such vulnerable ecological zones which lead to deforestation (i.e. the case of Kilwa district, in replacing valuable woodlands by Jatropha plantation).

• *Food security*: Some projects located on fertile land that is appropriate for food crops (i.e. Export Trading Company has intention and planned to grow Jatropha on the Kapunga Rice Farm in southern Tanzania).

• *Biofuel Market*: Most of the projects are targeting the external market due to small local consumptions.

• *Land acquisition and resource-use rights*: No proper land acquisitions are applied in Tanzania since the investors in most cases make the land deal directly with the local people who do not know their rights due to illiteracy, corruption and poverty).

• *The institutional framework*: Is complex and there are no observable coordination mechanisms that have been implemented in order to ad-dress separately all the issues involve avoiding repetition of the ef-forts and involvements.

4.4.2. *Potentials Impacts of Jatropha in Tanzania*

Biofuels from Jatropha if produced sustainably is considered as a good alternative which could reduce the burdens coming from the high bills of the imported fossil fuel (GTZ, 2005). Therefore, biofuels will stimulate and improve the national energy security as well as economic growth, because of the availability of lands which are suitable for biofuels (Dellomonaco, et al., 2010).

4.4.3. *Socio economic issues*

Biofuels from Jatropha is expected to improve the livelihoods of the people in the regions by creating of employment and increase of the income. There are several NGOs and small- scale projects using Jatropha to improve the rural electrification system by using Jatropha oil instead of the kerosene and fire wood, many lamps and stoves are manufactured to suit Jatropha oil. However, interview with some villagers indicated that using Jatropha oil for cooking and electricity is not efficient and not economically viable (Mitchell, 2008).

Moreover, the opponents of biofuels in Tanzania argued that, the creation of jobs from biofuels projects is a fake story made by the investors to make business and most of the currents investors have not fulfilled their promises and the jobs are temporary and only for unskilled labours which are likely to diminish in the future with the development of the agricultural machineries and other factors (Action Aid, 2009).

In the Cakenge Village in Kissarawe District, Sun Biofuel Company promised the dwellers about employment opportunities as well as building of hospitals, roads, and new governmental schools. However, an interviews with one citizen, revealed that there is a shortage of food due to the clearing of the nearby forests and the individuals living close to the forests will not be able to get fish, vegetables, wild fruits from the forests (Action Aid, 2009).

4.4.4. *Drawbacks of Jatropha in Tanzania*

Food security

According to the global environment outlook 4 by United Nations environment programme, Tanzania was classified as one of the developing country that is food insecure. Barashiswa (2007) study as cited by Action Aid (2009) shows that, food insecurity is one of the critical problems facing Tanzania at the moments and about 60% of rural areas are food insecure and 36 % live below poverty line .There are many factors that have contributed to food insecurity and the cultivation of agricultural lands for biofuel according to the experts view will result into worse scenarios and will increase the existing problem and according to Nyberg (2007) energy crops such as Jatropha will affect two dimensions of food security, availability and accessibility. Availability due to decrease of food crops as a result of competition with energy crops in the production resources such as lands, labours and accessibility due to the limited of purchasing power.

Regarding the availability of water for biofuel projects, it was seen that the establishment of some biofuel projects in Rufiji River basin in Tanzania has resulted in negative outcomes in the area, especially in food security, for the reason that the Rufiji River is the main source of irrigation for the agricultural and food crops. Intercropping Jatropha with maize in Mareu village, where Diligent Company is operating has led to low yield of maize because the Jatropha plantations prevent the sunshine to reach the maize crops (Action aid, 2009). Likewise, there are some biofuel projects are planned near to the Wami River basin the main source of irrigation of agricultural crops, the study conducted by Bioenergy and Food Security in 2012, shows that "even in the absence of biofuel projects the water is in stress in the Wami River basin" (BEFS, 2012), this analysis displays that due to bioenergy projects the prices of maize, cassava and rice the main sources of food in Tanzania are increased which resulted in some socio-economic impacts among which the urban poor and rural households female are the most in jeopardy to the rises in the price of the maize.

Environmental Impacts

In the absence of sustainability criteria and regulations, biofuels whether from Jatropha or other crops might be a nightmare, because it was demonstrated among scientist and researchers that biofuel contributes to several environmental and social impacts such as increasing the GHGs emission, atmospheric pollution, overexploitation of water, soil erosion, loss of biodiversity, food security, public health issues, and social impacts. However, Jatropha cultivation demonstrated its ability to have some positive impacts on the environment. In some regions of Tanzania especially in the Engaruka area in Arusha, Jatropha was grown in order to control erosion coming from over grazing (Mkoma et al., 2011). Jatropha also has the ability for the carbon conservation and air quality improvements (Soares et al., 2007).

Figure 11. Land clearing in Mavuji village (Action Aid, 2009).

- **Impact on land**

Cultivation of lands for biofuel leads to the change of land use systems which might result in adverse impacts on the environment and the ecosystem. According to the study of Action Aid (2009), the clearing of forests and vegetation on Mavuji village (Fig. 11) have both environmental and social impacts in the area. Socially, most of the individuals will lack their dominant energy sources (firewood and charcoal). From environmental perspective, the process of clearing the vegetation for cultivation of Jatropha are likely to contribute to the scarcity of the common pool resources (Action Aid, 2009); consequently the GHGs emission will be increase. Land use changes also have negative impacts on the biodiversity in the region (will be discussed in the coming paragraph)

- **Impact on biodiversity**

Biofuel believes to have major impacts on biodiversity and according to the six main causes of the loss of biodiversity evaluated by the Millennium Ecosystem Assessment (2005) four are linked to biofuel activities such as habitat destruction, invasive species, pollution, and climate change (Stromberg et al., 2010).

The replacements of natural vegetation's such as mimbo woodlands and coastal forests in Kilwa District, where BioShape is operating, resulted in undesirable impacts on biodiversity, because mimbo woodlands has great economic value and classified as one of the crucial biodiversity and ecoregions (Action Aid, 2009). Agreeing with FAO (2007) such practices of clearing the natural vegetation would reduce the level of agro-biodiversity such as the availability of foods, fodders, fibbers, fisheries, forest products and biomedicines. Other impacts on biodiversity observed as a result of clearing the forests and mimbo are; the disturbance of some marine organisms and endemic species, in addition to the impacts on the wildlife for example the Svensk Etanolkemi AB project, which is neighboring to the Saadani National Park is likely to have impacts on the wildlife in the area, because the park serve as a home for more than 25 species such as elephants, birds, reptiles, amphibian, fishes and others living organism (Action Aid, 2009).

- **Impacts on water resources**

Most biofuels projects in Tanzania were granted in areas with good supply of water such as forests, woodlands along rivers and flood plains. Therefore, Jatropha projects might impact the water resources, because Jatropha requires high amount of water (i.e. Jatropha project in Kilwa was irrigated through watering from nearby Mavuji River and some boreholes made for the same reason) (Action Aid, 2009).

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary of the findings

As seen in the discussion part, the studied countries show various opportunities and challenges with regards to biofuel from Jatropha:

Opportunities: lands availability and good climate conditions.

Challenges: inadequate funding's, high investment costs for large-scale projects, needs for strategies & policies on biofuels and lack of R &D.

If biofuels is produced sustainably and all the challenges are thoroughly considered, biofuels from Jatropha can be regarded as one of the successful options for Africa to overcome the current problem of the depletion and the scarcity of the fossil fuel in the region.

In summary the main issues regarding the studied countries are underlined in the below points

Sudan:

The investment of biofuels from *Jatropha Curcas* is new for Sudan and the current project by Sudan Aeronautic Research Centre in collaboration with Mr. Andrew Lang from world bioenergy association demonstrated that, biodiesels from Jatropha will be one option for Sudan government to recover the losses of oil due to the separation of South Sudan, especially when all the related risks stated in the report are properly handled and controlled in case of occurrence. The related risks are related to water quality & quantities, insufficient labours at harvest time, plantations issues, process operations & optimization and Market issues (if there will be any fall in the international prices of Jatropha oil in the future).

Ethiopia:

a) Jatropha was failing in the marginal lands (i.e. in the villages of Mancha and Wolaita)

b) Biofuels producing low yields due to poor growing methodology, seeds quality, water supplies, soil and topographic conditions, fertilizers and pesticides usage.

c) Environmental impacts such as: impacts on biodiversity and impacts on water quality & quantity.

d) Socio- economic issues: some biofuels projects led to significant paybacks such as creating many jobs and improve the standard of living in the country. However, some individuals believe that, food security is violated by some biofuels projects.

Kenya:

a) Biofuels from Jatropha is regarded as a clean energy source, and will reduce the dependency and high cost of fossil fuel.

b) The productivity of Jatropha is very low especially for large scale- projects and this could be due to different reasons such as lack of scientific research and also Jatropha was not produced high yields when it was grown in marginal lands (it needs fertilizer, irrigations and good management).

c) Environmental impacts such as: impacts on biodiversity, carbon emissions, water withdrawal and pollution from usage of agro-chemicals, deforestation and soil erosion.

d) Socio-economic issues: improvement of the local livelihoods due to poverty alleviation (creation of jobs and increase the income among the rural people).

e) Food security: Jatropha impacted the food security negatively; nevertheless some biofuels experts believe that Jatropha has no any adverse impacts on food security since it is inedible and grown on marginal lands.

Tanzania:

a) Biofuels from Jatropha will reduce the burdens coming from the bills of the imported fossil fuels.

b) Biofuel projects from Jatropha would result in the economic growth and national energy security.

c) Environmental impacts: change of land use system, impact on biodiversity and impact on water resources.

d) Socio-economic issues: biofuels from Jatropha is expected to improve the livelihoods in the region (by creating of employment, increase of income and improve the infrastructure).

e) Food security: the cultivation of agricultural lands for biofuels according to the experts view will results into worse scenario and might increase the existing problem of food security.

5.2. **Conclusion**

Based on literature review, desk top analysis and consultation of experts in the field of biofuels, this research addressed the status of Jatropha in Africa, particularly in Sudan, Ethiopia, Kenya and Tanzania. The study now turns to the five main research questions that were asked in the beginning in order to draw a good conclusion.

Is Jatropha in Africa a sustainable source of energy?

If all sustainability criteria (environmental, economic and social) have been met, biofuels from *Jatropha Curcas* will have many advantages and probably could be one of the sustainable future energy crops in Africa, especially in small- scale projects. Most of the small-scale projects in Africa were considered successful due to its efforts in electricity generation and poverty eradication in villages and neglected remote rural areas.

Large - scale Jatropha projects in Africa are still facing many obstacles due to the fact that, these investments have not been directed to the benefits of the people, but only to pursue African leader's corruptions and dishonest. Moreover, most of the projects were granted in marginal lands which need efforts and improvement by the local governments.

Large-scale projects can be efficient only when the state is strong, independent and democratic (elected by the people) and not in the hands of foreign companies, so it can work for the benefit of the people.

Large-scale western investments in agricultural lands have also failed in most African countries because most of the lands were originally owned by local people not the state. Most of the large –scale projects and programs which are implemented for the development are actually creating poverty and dividing society into social classes.Therfore, it is essential to study and evaluate the social, economic and political structures, as well as the relationship with the outside world before setting up Jatropha projects.

Is the Jatropha - hype or blessing?

Jatropha oil can be a blessing for Africa when it was implemented in small-scale projects due to their significant socio - economic benefits. Large-sale projects were overestimated than the actual case, because Jatropha needs enough quantity of water in order to produce high seeds and water resources that not compete with food crops should be planned in advance before signing any new project.

Where does Jatropha stand today and what is a reasonable future role for Jatropha in Africa?

In the beginning of the discovery of Jatropha as a source of biodiesel, there was some over exaggeration about its survival in marginal lands and dry climates, but nowadays, experts are totally convince that if Jatropha should produce high yields of oilseeds it needs enough amounts of water and adequate policies to governing biofuels investments in most African countries.

Some of the large- scale Jatropha cultivations in Africa have been collapsed as a result of: insufficient profits, the farmer's expectations to rely on Jatropha have not been met, inadequate funding, high investment costs and no clear governmental policies for biodiesel. Therefore, if the challenges associated with Jatropha are wisely managed, biodiesel from Jatropha can play a considerable role in the nearest future to substitute the fossil fuels.

Are Jatropha profitable in Africa?

Generally, and as discussed earlier large- scale projects in most African countries is not profitable and there is no any positive returns observed due to the failure of some Jatropha projects in Africa. Therefore, costing of biofuels and Jatropha is very difficult to be estimated due to the lack of the main costing components such as: initial cost, plantations cost, operation & maintenance cost and environmental cost.

Jatropha is not profitable in marginal lands as experienced by most western companies granted large-scale projects in marginal lands (i.e. in 2009 Sun Biofuel in Ethiopia stopped their activity). Therefore, western countries will not take future risks by investing in large-scale projects in marginal lands, because their targets are to gain market shares and maximize returns and profits quickly. Biofuels from Jatropha can be target for them only in fertile lands with enough water supplies.

It seems that the major purpose of foreign aid and foreign investment in biofuels in the developing countries is not different from what it was earlier, it is not for the development, but to ensure the donor's profits and domination. Therefore, aid does not necessarily go to the poor or needy countries; contradictory, it goes to the countries that can pay back the loans (Dr. Abdalla Gasimelseed, Personal communication, 16 September 2014). Confirming with this point, the Secretary General of United Nations Mr. Ban Ki-moon, says that "development assistance does not always go where it is most needed and the allocation of aid across the sectors is also cause for concern" (Ki-moon, 2008).

From my opinions, I think developing countries still need the foreign investments, especially in the field of bioenergy to support the development not to exploit the resources. In this sense, international donors should only support small-scale projects and leave large- scale to be the responsibility of the African governments.

Will biofuel from Jatropha contribute to Africa development to achieve their long-term strategies in terms of energy security and dependently?

If biofuels produced sustainably, the answer for this research question is "Yes" and biofuels from Jatropha will contribute to the nation growth. The small-scale projects from Jatropha is already improved the situations in many African countries. What's more, if the local government give high support for biofuels and improve the marginal lands, implementation of any large-scale projects will help in attaining the long-term strategies in terms of energy efficiency and dependently .

5.3. Recommendations

Biofuel from Jatropha will bring about the national growth for Africa and achieving their long-term strategies in terms of energy efficiency, if the following actions which have been recommended in different literature review are carefully considered:

Biofuel policies and regulations

- Development of an appropriate guidance for sustainable biofuels before commencement & approval of any biofuel project and the current biofuels policies need to be revised and modified to include all biofuel sustainability criteria
- Comprehensive governmental policies for Jatropha are needed for all the engaged countries in the field of biofuel.
- The biofuels policies need to be unified into one comprehensive guideline and there is an absolute need to build a detailed institutional agenda to address all biofuel activities and their relevance to resources such as: land and water.
- Biofuel developments need to be viewed within the framework of the overall economy and the policy of the country.

Additional programs

- The current public land tenure management system needs to be revised to guarantee an operative use of public land.
- Water availability that not competes with food crops should be available in advance before signing any new project.
- Appropriate programs to avoid deforestation and soil erosion should be implemented before commencement of any projects.

Studies and R&D

- Cost-benefit analysis, environmental impacts assessment and social impact assessments should carefully and honestly be carried out and should address all the related adverse impacts of any biofuel projects.
- More breeding programs to produce high yielding varieties of Jatropha are needed.
- Good growing practices and good seed quality should be chosen for any Jatropha projects
- Further studies to evaluate the agronomic impact of Jatropha on the soil and other food crops are much needed.
- Environmental & social impacts of Jatropha need further investigations to confirm its impacts on biodiversity, food security and culture heritage.

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