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Food Security and Biofuels: A Case Study of Jatropha Curcas in Bolivia

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Abstract

The paper analyzes a Bolivian region for possible cultivation of the oil plant Jatropha curcas for sustainable biodiesel production in order to replace in part Bolivia's diesel imports. The specific site for this study is located in the dry region of Gran Chaco in Santa Cruz. The aim of this work is to analyse the potential of useable land and resources for sustainable biodiesel production from Jatropha without competition with edibles production using economic, environmental and social criteria. In addition the article introduces Jatropha as one of the preferred oil plants for biodiesel production in several countries and indicates its different uses. The recommendation to cultivate Jatropha for biodiesel production is based on an exploration of the possibility of land use in the selected region and the benefits Jatropha production could offer. In this manner a *sustainable* cultivation of Jatropha in the region of Gran Chaco is recommended to produce biodiesel and to improve some of the environmental problems facing the region.

Keywords: *Biofuels, Bolivia, Food security, Jatropha curcas, toxicity*

1. Introduction

One of the renewable energy alternatives today is biofuels. Its production as an alternative energy source could contribute to cover *in part* our increased energy demand worldwide [1]. The topic of biofuels production is becoming a very controversial issue, however, because its production relies on using other resources such as water and soil and thus competes with food production, leading people to fret about food security. The demand for food production and the demand for biofuels are both increasing annually as the worldwide population is also increasing. There is a general misconception that the global food deficit is a result of biofuels production, but the relationship between food security and biofuels production must be more closely analyzed to include other variables such as climate change. Global food security will depend on *accelerating* the rate of gain in crop yields and food production capacity on both the local and global scales [2]. Human activities that damage the environment, like water pollution, high emission of carbon dioxide, deforestation, excessive non-degradable waste production, and accidental nuclear catastrophe (e.g. the catastrophe of Fukushima in Japan on 11th March 2011 and Tschernobyl in Russia on 26th April 1986), also *contribute* to climate change. Climate change is also affected by natural phenomena such as earthquakes, volcanic eruption, flooding, and tidal waves. At present, the main environmental problems facing developing countries are the degradation of soils, the pollution of fresh water and air – caused by human activity – leading to reduced development of farming activity. E.g. by the 2080s crop yields will reduce by 3-16 percent [3].

This article explores the potential of the Gran Chaco region in Santa Cruz, Bolivia – under specific climatic and environmental conditions – for a sustainable biodiesel production from Jatropha curcas to cover *in part* its local energy demand (towards independence to be self-sufficient in supplying its own energy demand by producing an environmentally-sound energy source) and to support a more effective use of land and other resources as an integral development plan.

Bolivia is an importer of diesel fuel because it faces a continuously increasing diesel demand (more than half of Bolivia's diesel has to be imported). It needs to quickly develop a strategy in order to reduce its increased importation of diesel fuel. In addition, Bolivia has not been able to develop good strategies for effectively using its land and resources, due to a lack of political, financial, and technological support. Until now Bolivia's agricultural industry remains underdeveloped. Therefore, even though Bolivia is rich in diverse natural landscapes and climatic regions, it relies on importing essential

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food commodities. Approximately 38% percent of the Bolivian land area is agricultural land (defined as the share of land area that is arable, under permanent crops, and under permanent pastures) [4]. Of the 3.74 million hectares of agricultural land in Bolivia, 1.83 million are located in the region Santa Cruz [5], [6]. Despite this amount of agricultural land, Bolivia still imports approximately 20 products, of which sugar, corn and wheat are the main products [7].

Deforestation in the lowlands of Bolivia remains a critical environmental problem and is largely the result of economic development policies, such as structural adjustment for the production of oil plant soybeans and the conversion of forest into pastures for cattle ranching. (The total amount of deforestation that occurred from the mid-1970s to 2000 is 3.60 million hectares [8]).

Given this precarious economic and environmental situation in Bolivia, this study considers the production of biofuels from Jatropha curcas plant.

2. Jatropha Curcas

Jatropha curcas is an oil plant that is native to the region. It is a small toxic tree. Its seeds are rich in protein and in oil; the oil content of Jatropha curcas (1,825 liter oil per ha) is higher than the oil content of Palm (215 liter oil per ha) [9]. A main advantage this plant offers is that its cultivation has no direct competition with the cultivation of edibles.

This hardy wild oil plant can grow under adverse climatic conditions such as low rainfall (200 mm per year) and can survive long periods of drought, as its water demand is low. Jatropha curcas can grow not only in tropic climates but also in dry climates. The plant needs drained soils and sunlight. Its indigenous habitat is the most suitable place for it to grow.

2.1. Toxicity of Jatropha curcas

The leaves and nuts of Jatropha curcas are toxic [10]. Therefore it is imperative to assess the potential danger for the people who would have prolonged contact with the oil plant in considering the wide-scale cultivation of the plant for biodiesel production.

There are different varieties of Jatropha curcas plants, some of which are toxic and some of which are non-toxic. In an experimental investigation on the toxic substance of Jatropha curcas, phorbol esters were found in high amounts in the toxic variety of the plant, but in the non-toxic variety they do not appear. Phorbol esters are the main toxic substances in Jatropha curcas [11]; the amount of phorbol esters content determines the level of toxicity of the plant. In Mexico there are studies on the toxicity of Jatropha curcas plants from different Mexican provenances of which some do not show toxicity. The studies concluded that the toxicity of the plant depends on its provenance (its genetic and environmental conditions) [12].

Phytic acid, hydrocyanic acid, lectin or curcin are other toxic substances found in Jatropha curcas, some of which are heat-stable and some of which are heat-unstable under high temperatures. For example Phorbol esters are unstable (volatile) not only under high temperatures, but also with exposure to light and oxygen in the air [13], [10].

2.2. Utilization of Jatropha curcas

Jatropha curcas offers a variety of different uses. As Figure 1 illustrates, it can be used not only for biodiesel production, but also for food for fish, for medical use, and for agricultural use (as a fertilizer), among others.

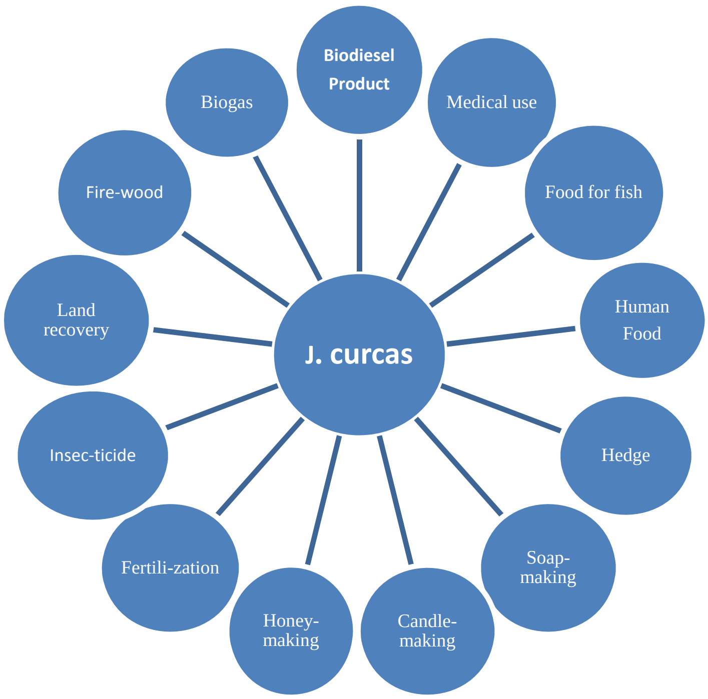

Fig. 1. Several uses of Jatropha curcas - Source: [14]

Table 1 shows in detail the several medical uses of the different parts of the Jatropha curcas plant. Although Jatropha curcas contains toxic substances, it can be used to treat some diseases by traditional medicine. For example, Jatropha curcas has been used medicinally by indigenous ethnic Chiquitanos in Bolivia for a long time [16]. The oil from Jatropha curcas seeds is used not only to produce biodiesel (the next section will be about biodiesel production form Jatropha curcas) but also as varnish [17]. The oil is potentially the most valuable end-product of Jatropha curcas [18]. The plant offers further uses such as in the agriculture industry. Extract from its seeds and leaves can be used as pesticide, insecticide and fungicide [15]. All the toxic parts of the plant can be used as biopesticide [13], [10], [17]. Its fallen leaves, flowers and branches can act as fertilizer by composting the soil [10]. The different parts of its fruit such the shell, seeds, and coat can also be used to benefit the infertile land, like the press cake (the remaining product after the extraction of oil from the seeds) [10], [15], [17]. Latex from Jatropha curcas could be used to inhibit viral plant diseases such watermelon mosaic disease [15]. Jatropha curcas can be planted as a live hedge to protect agricultural cropland and also to recuperate wasteland and eroded soils [10], [15]. Jatropha curcas offers further uses in the field of renewable energies and other industries. Its fruit (shell, press cake from the seeds, and coat) can be utilized as biomass. The flesh of the fruit and press cake can be used to produce biogas by anaerobic fermentation [10]. The stem of the Jatropha curcas tree can be used as firewood [10]. The Jatropha oil can be used to produce soap [15], [17] and candles [10]. Jatropha curcas could be used by the food industry under conditions of detoxification. The detoxified press cake could be used not only for producing food for fish [12], [17], but also for human consumption [11], [12] [19]. In fact, “the defatted meal from Jatrophas seeds was found to contain a high amount of protein. All essential amino acids in Jatropha curcas meal (except for lysine) protein have been reported to be in higher concentrations than those of the FAO reference pattern suggested for the pre-school children” [12], [19]. Bitter substances from the tree bark can be employed to produce honey [17], [14]. In the leather industry, the tannin from the tree bark and from the nut shell can be used as a tanning agent for tanning leather [16], [17]. The leaves can be used as feedstock for the silkworms [17]. Finally, leaves and branches of Jatropha curcas can be used as color pigments [16].

Table 1: Medical uses of Jatropha curcas

Part of the plant	By-product	Mode of use	Use for/ Effect of
Seed	Oil		Laxative [15]
Seed, leaves, bark	Decoction	Watery extract	Laxative [15]
Seed	Oil		Skin disease [15]
Seed	Oil	Analgesic	Pain caused by rheumatism [15]
Leaves		Boiled leaves for external use	Rheumatism and inflammation [15]
Seed			Anthelminthic [15]
Leaves			Haemostatic [15]
Leaves		Boiled leaves	Cough [15]
Leaves		Boiled leaves	Antiseptic after the birth [16], [15]
Branches		Chewed chopsticks	[15]
Was not specified	Substance		Wound healing [16], [15]
Was not specified	Substance		Anti-inflammatory effect [15]
Root	Decoction	To drink	Pneumonia, syphilis, [15]
Root	Decoction	To drink	Abortive. anthelminthic, laxative [15]
Seeds/fruit			Abortive. Contraceptive [15]
Seed			Ascites, Gout, Paralysis [15]
Latex			Fungi inflammation in the mouth, bee sting, insect sting and digestion troubles of the children [15]
Offspring	Tea		Diarrhea [16]
Offspring	Tea	Taking a teaspoon of the tea plus decoction of guayacan, (its heartwood), chamomile flower and anis fruit. In addition rub the body with bovine fat.	Intumescences, paralysis by sick babies [16]
Resin		Rub on the infected area	Skin infection (e.g. scabies and similar skin diseases) [16]
Resin		Plus decoction of the leaves	Wounds or similar lesions [16]
Leaves & twig	Ethanolic extract	From defatted leaves and twig	Contra P-388 lymphocytic leukemia [15]
Latex			Healing for wound, hard-wearing abscess, septic adhesive [15]
Seeds			Molluscicidal activity contra host of liver fluke [15]

As illustrated above, Jatropha curcas is a versatile oil plant and has a large variety of different uses for industry. Therefore farmers cultivating Jatropha curcas could benefit from its various uses and benefits.

2.3. Biodiesel production from Jatropha curcas

Although the oil from Jatropha curcas is more viscous and its quality of ignition (cetane number: 16-18 carbon atoms per molecule) is lower than fossil diesel (cetane number: 8-10 carbon atoms per molecule), it can be used directly in the diesel engine as it was in Madagascar, Cape Verde and Benin during the Second World War – or it can be used as biodiesel, which is the result of a transterefication reaction involving methanol. Thus, the oil from Jatropha curcas can serve as a potential substitute for fossil diesel [15], [17]. According to several scientific reports, *transesterification* is the preferred method for production of biodiesel from vegetable oil. Transesterification, also called alcoholysis, is the reaction of triglycerides with alcohols to produce for example methyl or ethyl esters and glycerol as a by-product [18]. But this chemical reaction requires excess alcohol in order to increase its efficiency. In the process, a catalyst is usually used to improve the time of the reaction and the yield [18], [20], [21] This method of *base-catalyzed transesterification* is used to produce biodiesel fuel in the markets of North America, South America (such as in Brazil) and Europe (such as in Germany and France) [18].

Figure 2 illustrates the general process chain for biodiesel production from Jatropha curcas. The first part of the process is the cultivation and harvest of the Jatropha curcas plant. In this process a large number of manual workers are necessary in particular for the pruning and harvesting of the plant. I.e. it is important to improve the number of branches, because the blossoms develop only at the tips of the branches [22] and each plant can have at the same time flower, green and mature fruits as it was told to me at a field trip to the Center of Research for Tropical Agricultural (CIAT) in Santa Cruz on 18 of August 2010). The cultivation and harvest of the plant is followed by transportation and storage of the seeds (the seeds can be stored for up to three months). The next step is the pressing of the seed to extract the oil. The Jatropha oil can be used directly as fuel or undergo further chemical processing through *transesterification* to produce biodiesel. This process plays a very important role in obtaining Jatropha biodiesel with similar characteristics to the conventional diesel and established biodiesel fuels. After the pressing, the press cake, if previously detoxified, can be used as fertilizer or as food for fish, as described above.

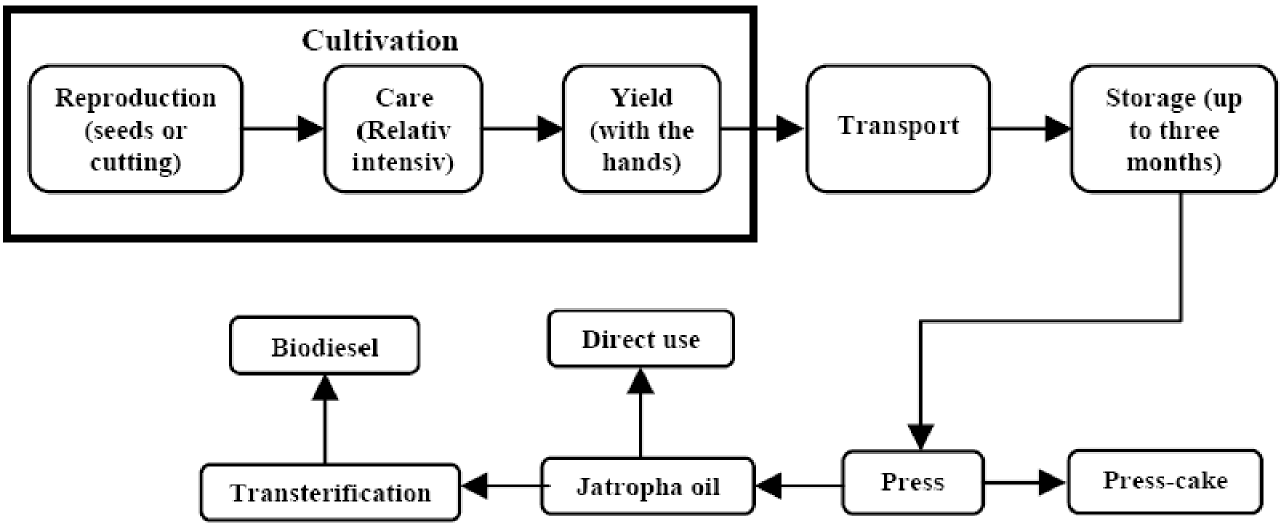

Fig. 2. General process chain for the biodiesel production from Jatropha curcas

The common methods used to extract oil from Jatropha curcas are cold pressing and solvents. The first method is more viable economically, as it doesn't require high-cost investment. But the solvent extraction method is more effective (producing a higher extraction of oil: 48-98%) than the cold pressing [14], [23]. While the best solvent for oil extraction from Jatropha curcas is hexane, it can contaminate the air and cause nerve damage to people with prolonged exposure to the solvent [24].
An experimental study in Mali was conducted to evaluate fuel conversion efficiency and emissions with direct and indirect fuel injection of oil from different plants into an engine. The oil from Jatropha curcas had the lowest emission of the oils tested. Another study in Thailand showed that engines functioned with Jatropha oil with satisfactory efficiency [15].

It is important to note that the ambient air temperature plays an important role in the storage stability and in the flow point and cloud point quality of the biodiesel to ensure an optimal running by the engines. Thus it could be a disadvantage to use biodiesel from Jatropha curcas in countries with low temperatures.

The oil from Jatrophas seed has low acidity, good oxidation stability in comparison to the oil from soybean, lower viscosity than the oil from castor, and better cold properties in comparison to palm oil. The viscosity, free fatty acid (FFA), and density of the oil and biodiesel are stable during the period of storage [18]. The oil from Jatropha curcas requires proper handling and storage conditions to preserve the stability of its qualities [25]. Exposure to humidity and light in the air, for example, can lead to the degradation of the biodiesel. Therefore, the choice of plant for biodiesel production is very important. Biodiesel from Jatropha curcas must have the similar physical and chemical qualities of fossil diesel in order to ensure the use of biodiesel from Jatropha curcas by diesel engines without modification [20]. Therefore production of biodiesel from Jatropha curcas through transesterification is more recommendable than the direct use of the Jatropha oil by adapted engines [15]. Table 2 displays a comparison between the physical and chemical properties of Jatropha oil, Jatropha biodiesel, conventional diesel and established biodiesel standards.

Table 2: Fuel Properties of Jatropha Biodiesel - Source: [24]

Property	Unit	Jatropha oil	Jatropha biodiesel	Diesel	Biodiesel standards	
					ASTM D 6751-02	DIN EN 14214
Density at 15 °C	kg m^3	940	880	850	-	860-900
Viscosity at 15 °C	$mm^2\ s^{-1}$	24,5	4,8	2,6	1,9-6,0	3,5-5,0
Flash point	°C	225	135	68	>130	>120
Pour point	°C	4	2	-20	-	-
Water content	%	1,4	0,025	0,02	<0,03	<0,05
Ash content	%	0,8	0,012	0,01	<0,02	<0,02
Carbon residue	%	1	0,2	0,17	-	<0,30
Acid value	Mg KOH g^{-1}	28	0,4	-	<0,8	<0,50
Calorific value	MJ kg^{-1}	38,65	39,23	42	-	-

2.4. Experience of Jatropha Curcas Cultivation

In the last decade the interest in cultivating Jatropha curcas for biodiesel production has been growing because Jatropha curcas plant shows potential to produce a large amount of oil with relatively small input. By 2008, Jatropha had already been planted on over an estimated 900,000 ha globally, of which an overwhelming 85% was in Asia, 13% in Africa and 2% in Latin America. By 2015 Jatropha curcas is expected to cover 12.8 million ha worldwide [26]. Jatropha curcas has high oil and protein content. It is hardy and can survive for long periods of time without water. Its water demand is low and requires between 300 and 1000 mm of rainfall per year only [27]. Its propagation is by seeds and cutting. It can grow in infertile soils. Due its toxicity it has few insect pests [15]. Its cultivation does not have *direct* competition with edibles. All these natural attributes have led to ambitious programs for the cultivation of Jatropha curcas to produce biodiesel.

So far, the experiences of cultivating Jatropha curcas for biodiesel production have not been satisfactory because the cost for its cultivation has been greater than its yield. The cultivation of Jatropha curcas requires a large source of manual labor to care for and maintain the plant as well as to harvest the crop. The experience of Jatropha curcas cultivation in some countries has also been unsuccessful due to unsuitable climatic conditions and other factors.

The qualities of Jatropha curcas depend on the provenance of the plant. The Jatropha curcas plant in Mexico can have different qualities from Jatropha curcas plants in Kenya or Bolivia (there are more than one hundred varieties of Jatropha curcas). In this respect it is not easy to extrapolate conclusions from pilot studies. In one experimental study, the yield of Jatropha curcas was assessed using three different forms of cultivation: cultivation as monoculture, as mixed cultivation and as hedge in Kenya. The most profitable case was the cultivation as hedge. This interesting study can serve as a helpful example for further studies [28]. There are several other important reports with scientific information about Jatropha curcas and its cultivation in China, Mali, Cambodia, Indonesia, Thailand, Nicaragua, Costa Rica, Belize, El Salvador, Guatemala, Honduras, Mexico, Egypt, Tanzania, Ghana and India. The latter ventured the largest project to cultivate Jatropha on 400,000 hectares within the period 2003–2007. The Indian government's goal is to replace 20% of diesel consumption with biodiesel produced from Jatropha curcas by 2011–2012, cultivated on around 10 million hectares of wasteland and generating year-round employment for 5 million people [27], [29]. From their experiences other counties can learn and improve for a successful cultivation of Jatropha curcas. The cultivation of Jatropha curcas requires a large source of manual labor and its cultivation has the potential to produce much-needed job opportunities in the region.

3. Bolivia case study

Bolivia (the Plurinational State of, since 2009) extends from the Andes Mountain to Amazon rainforest and therefore encompasses three natural regions: highland, valley and lowlands, and hosts a variety of climatic regions. It has an area of one million square kilometers (1,083,300 sq. km) and has a low population density (8.2 people per square kilometer [30]). The most populated region of Bolivia is the city of Santa Cruz. The Department of Santa Cruz is also the most important city in Bolivia in terms of economic production.

3.1. Energy resources in Bolivia

In Bolivia, the consumption of diesel oil was 3,422,952 liters per day in 2010, of which the Department of Santa Cruz consumed 1,383,141 liters diesel oil per day (40% of Bolivia's total diesel fuel consumption). Bolivian diesel oil production amounts to 1,623,549 liters per day. This results in a daily deficit of 1,799,403 liters of diesel oil (the deficit between diesel supply and diesel consumption amounted to approximately 54% in 2010, which Bolivia must import from Venezuela and Argentina [31]). The main fuel source used in Bolivia is diesel fuel. Automobiles and agricultural machines in Bolivia run on diesel fuel. Therefore, Bolivia relies on diesel for its economic development.

Bolivia owns the second largest reserve of natural gas in South America after Venezuela (Bolivia exports natural gas to Brazil and to Argentina). However, Bolivia is dependent on South America's diesel-supplying countries such as Venezuela and Argentina for diesel fuel [32]. It is currently not possible to transform the natural gas into fuels (gasoline or diesel) because there is not yet enough applicable experiences world-wide with the liquefaction process of natural gas – such as the Fisher Trop method. In addition, it would not be feasible in Bolivia, because the price of the feedstock (natural gas) in the internal market is very high due the price of the exportation of the natural gas: US$ 7.0 per million British thermal units (MMBtu), and the consumer price of diesel including taxes is approximately US$ 0.52 [33].

Fifty-nine percent of Bolivia's electricity is generated from traditional fossil fuels. Other forms of electricity production (renewable energy) in Bolivia are hydropower (38%) and biomass and waste (3%) [32]. There is no official information about energy generated by biofuels, solar or wind power.

3.1.1. Biofuels production in Bolivia

In the year 2005 legislation was passed promoting biofuels production in Bolivia (law N° 3207), and one year later law N° 3546 was promulgated to create the Complejo Agroindustrial of San Buenaventura in the Department of La Paz (Highland region) to promote the cultivation of cane sugar to produce sugar and ethanol and to cultivate Palma Africana to produce biodiesel [34]). Currently, however, hardly any biofuels production is taking place. The main reason is the lack of political willingness to define more specific rules on the biofuel sector, long term strategies as well as subsidies for fossil fuels. The price of fossil diesel in Bolivia is subsidized (approximately US$ 0.52 per liter of diesel, equivalent to 3.74 Bs.) and therefore the price of production of biodiesel could not be profitable and competitive [35]). For example, the cost of producing a liter Jatropha biodiesel excluding taxes was US$ 0.74 in Tanzania in October 2008 [36]. However, in Santa Cruz, the region of Bolivia which has the greatest amount of economic and agricultural activity, the local government has started a pilot project for the production of biodiesel from native oil plants such macororó (Ricinus), palms (cusi and totaí) and including piñón (Jatropha curcas). The research project is executed by the Center of Research for Tropical Agricultural (CIAT) and it scheduled to take five years from 2008 to 2012 [34].

In 2007-2008, there were some experiences with occasional production of biodiesel from degummed soy oil to use as an additive compound for agrarian fumigation and not as biofuel, like the small plant of biodiesel of Agroinco S.A. (agrarian Company) in Santa Cruz [35].

Given the set of circumstances described above, Bolivia must work in the field of diesel production to meet its needs. With its natural resources, Bolivia can benefit from today's worldwide boom in biofuels production in order for Bolivia to achieve better economic development and growth and meet its diesel demand.

3.2. El Gran Chaco Boliviano: Site of Study

El Gran Chaco Sudamericano is the second largest rainforest area in South America, after the Amazon. It extends through four countries and encompasses approximately one million square kilometers of land, 13% of which belongs to Bolivia [37]. Therefore this area offers a diverse array of natural climatic and geographical regions, such as humid lands, dry lands, and mountain forest. El Gran Chaco Sudamericano hosts a unique ecosystem with a great diversity of fauna and flora. But this region is facing several environmental problems such as deforestation and pollution of fresh water. The Gran Chaco Boliviano is in southeast Bolivia and accounts for 12% of Bolivia's land area. Of this area (127,675 sq. km), 18% belongs to the Department of Tarija, 15% to Chuquisaca and 67% to Santa Cruz. Its 16 rural municipalities constitute the Mancomunidad of the Chaco Boliviano (MANCHABOL) [37], of which seven municipalities (Camiri, Lagunillas, Cabezas, Gutierrez, Cuevo, Charagua, Boyuibe) belong to *Santa Cruz* and are the chosen site of this study.

3.2.1. Environmental problems

The region chosen for this study is home to diverse and at times severely contrasting natural landscapes. For example, Kaa-Iya del Gran Chaco National Park and Integrated Management Natural Area are among the most important not only Bolivian but also South American protected areas. In contrast with this beautiful park, there is a vast dry area. The latter is the specific area chosen for the study.

The selected area does not have natural favorable conditions for cultivating edibles. The majority of the soils are saline and fresh water is scarce. In addition, the pollution of fresh water sources, deforestation, inapropriate use of the soil and destruction of the scarce resources are major problems affecting the region. Another critical environmental problem is the forest fire *Chaqueo*. Chaqueo is a traditional method for improving soil quality for agricultural activity and cattle ranching, which is now a form of deforestation that results in other problems such as air pollution. The Chaqueo fire cannot be controlled because the land is dry and the fire spreads rapidly, resulting in highly damaging wild fires.

An ecological study conducted on the region revealed that the sources of ecological destruction in the region are the following: uncontrolled expansion of agricultural activity such as making farms for cattle-raising; the building of infrastructure for the fossil oil industry; uncontrolled hunting of fauna; and forest fires. Therefore, young people are forced to emigrate in order to find work and seek better educational opportunities. The inhabitants of the region have trouble due lack of fresh water and food [38].

Despite its many environmental problems, this region could offer great potential for sustainable use of renewable energy such as the production of biodiesel from the Jatropha curcas plant, if its resources are used reasonably for sustainable development. Therefore the biggest challenge facing this area is effective use of its resources.

4. Conclusion

This study has shown Bolivian potential to cultivate Jatropha curcas plant for sustainable biodiesel production in the eroded land of the selected region for the study. Considerations such as increasing dependence on diesel-exporting countries for fuel, the natural provenance of Jatropha curcas in the region, the availability of land and resources, infertile or eroded soils, low population density, and excessive unemployment make Bolivia an ideal candidate for the *sustainable* cultivation of Jatropha curcas for biodiesel production and to resolve some of its local environmental, economic, and social problems. The natural attributes of Jatropha curcas as a toxic, hearty and resistant plant, containing high amounts of oil and protein and consuming low amounts of water also make it a good crop to cultivate for biodiesel production in the region without competition with edibles production. Furthermore, the Jatropha biodiesel could be suitable to use in the diesel engines used in the warm regions of Bolivia, due its properties (flow point and cloud point). As experiences in the cultivation of Jatropha curcas for biodiesel production have shown, the cost is one of the most important factors in designing a viable plan to produce biodiesel, and this factor has not been satisfactory for several pilot projects. A large-scale cultivation of Jatropha curcas will require a great amount of care and investment in infrastructure. Governmental support will be necessary in order to achieve a sustainable cultivation of Jatropha curcas to produce biodiesel in Bolivia. The versatility of Jatropha curcas plant is an important advantage in its successful cultivation. It can be exploited in order to alleviate in part the social problems in the region, to alleviate the environmental problems in the region such the reclaiming of waste- or eroded lands and/or to introduce a beneficial use of the land. Farmers cultivating Jatropha curcas could benefit from cultivating Jatropha curcas due its various uses. But biodiesel production is an activity that implicates many different sectors and arenas and therefore it is necessary to undertake studies about the large-scale cultivation of Jatropha curcas (i.e. to see the possibility of cultivating in combination with other local oil plants to avoid monoculture production).

Bolivia shows big potential for producing not only biofuels or biodiesel, but also food. But Bolivia should develop an integrated biofuels strategy, including environmental, agricultural, and economic policies, to regulate the production of biofuels as soon as possible to benefit the growth of the country.

References

[1] Renewable Energy Policy Network for the 21st Century (REN21). Renewables 2011, Global Status Report, 1-116.

[2] Cassman K. Climate change, biofuels, and global food security. IOP Publishing. Environmental Research Letters, 2007; 2: 1-3. http://dx.doi.org/10.1088/1748-9326/2/1/011002.

[3] The World Bank. Working for a World Free of Poverty. Climate Change, Climate-smart Agriculture, 2007.

[4] The World Bank. Working for a World Free of Poverty. Data World Bank. Agriculture & Rural Development, Bolivia, 2010.

[5] Cámara Agropecuaria del Oriente (CAO). Santa Cruz-Bolivia. Evolución de la Superficie Cultivada por Rubro y Campaña, 2006.

[6] Food and Agriculture Organization of the United States (FAO). FAO Country Profiles. Bolivia (Plurinational State Of). Agriculture sector, 2009.

[7] Food and Agriculture Organization of the United States (FAO). FAO Statistical Databases & Data-sets (FAOSTAT). Trade Top Imports- Bolivia (Plurinational State Of), 2009.

[8] Pacheco P. Agricultural expansion and deforestation in lowland Bolivia: The import substitution versus the structural adjustment model. Land Use Policy 2006; 23: 205-225. http://dx.doi.org/10.1016/j.landusepol.2004.09.004.

[9] Kurki A; Hill A, Morris M. Biodiesel: The Sustainability Dimensions, National Center for Appropriate Technology (NCAT) Program Specialists, A Publication of National Sustainable Agriculture Information Service (ATTRA). 2006, pp. 1-12.

[10] Jongschaap R.E.E, Corré W.J, Bindraban P.S, Brandenburg W.A. Claims and Facts on Jatropha curcas L.Global Jatropha curcas evaluation, breeding and propagation programme. Plant Research International, Report 158, October 2007, pp.1-66.

[11] Makkar H. P. S, Becker K, Sporer F, Wink M. Studies on Nutritive Potential and Toxic Constituents of Different Provenances of Jatropha curcas. J. Agric. Food Chem. 1997; 45: 3152-3157.

[12] Martínez-Herrera J, Siddhuraju P, Francis G, Dávila-Ortíz G, Becker K, Chemical composition, toxic/antimetabolic constituents, and effects of different treatments on their levels, in four provenances of Jatropha curcas L. from Mexico. El Servier, Food Chemistry 2006; 96: 80-89. http://dx.doi.org/10.1016/j.foodchem.2005.01.059.

[13] Goel G, Makkar H.P.S, Francis G, Becker K. Phorbol Esters: Structure, Biological Activity, and Toxicity in Animals, Institute for Animal Production in the Tropics and Subtropics. International Journal of Toxicology 2007; 26: 279-288. http://dx.doi.org/10.1080/10915810701464641.

[14] Kumar A, Sharma S. An evaluation of multipurpose oil seed crop for industrial uses (Jatropha curcas L.): A review. Industrial Crops and Products 2008; 28: 1-10. http://dx.doi.org/10.1016/j.indcrop.2008.01.001.

[15] Gübitz G.M, Mittelbach M, Trabi M. Exploitation of the tropical oil seed plant Jatropha curcas L. El Sevier, Bioresource Technology,1999; 67: 73-82.

[16] Lachner-Eitzenberger U. M, Medicina tradicional: Ergebnisse einer ethnomedizinieschen Feldstudie bei den Chiquitano in Bolivien, Max-Planck-Institut für Ornithologie Gruppe Schiefenhövel (Humanethologie) und Humanwissenschaftliches Zentrum der Ludwig-Maximilians-Universität München, 2006, pp.1-415.

[17] Openshaw K. A review of Jatropha curcas: An oil plant of unfulfilled promise. Pergamon, Biomass & Bioenergy 2000; 19: 1-15.

[18] Om Tapanes N, Gomes Aranda D, De Mesquita Carneiro J. W, Ceva Antunes O. Transesterification of Jatropha curcas oil glycerides: Theoretical and experimental studies of biodiesel reaction. Fuel 2008; 87: 2286-2295. http://dx.doi.org/10.1016/j.fuel.2007.12.006.

[19] Haas W, Mittelbach M. Detoxification experiments with the seed oil from Jatropha curcas L. El Servier, Industrial Crops and Products 2000; 12: 111-118.

[20] Gui M., Lee K., Bhatia S, Feasibility of edible oil, non-edible vs. waste edible oil as biodiesel feedstock. Energy 2008 ; vol. 33 : pp. 1646 - 1653. http://dx.doi.org/10.1016/j.energy.2008.06.002.

[21] Kumar Tiwari A, Kumar A, Raheman H. Biodiesel production from jatropha oil (Jatropha curcas) with high free fatty acids: An optimized process. Biomass & Bioenergy, 2007; 31: 569-575. http://dx.doi.org/10.1016/j.biombioe.2007.03.003.

[22] Report Expert Meeting Jatropha, Brusels, European Comision Research Directorate – General, (07.12.2007). The Jatropha System. Prepared by Rijssenbeek W, with contribution of Henning R. and Jongschaap R. pp. 1-19.

[23] Adriaans T. Suitability of solvent extraction for Jatropha curcas, Ingenia Consultants & Engineers, for FACT Foundation, November 2006, pp. 1-9.

[24] Buikema B, Gabbadon S, Lee H.-C, Workman M. Biodiesel Production from Seed Oil of the Jatropha Curcas Plant, Final Report: Team 9: Oil from [the] Soil, May 2009, pp. 1-118.

[25] Berchmans H.J, Hirata S. Biodiesel production from crude Jatropha curcas L. Seed oil with a high content of free fatty acids. El Server, Bioresource Technology 2008; 99: 1716-1721. http://dx.doi.org/10.1016/j.biortech.2007.03.051.

[26] Wu S. The Extraordinary Collapse of Jatropha as a Global Biofuel. Int. J. Environmental Science & Technology. 2011, 1-2.

[27] Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture. Rome 2008, pp. 1-138 . 68.

[28] Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Bundesministerium für Wirtschaftlich Zusammenarbeit und Entwicklung (BMZ). GTZ-Studie Jatropha Reality Check. A field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya. Sustainable Management of Resources in Agriculture, 2009, pp. 1-158.

[29] Siddharth J, Sharma M.P. Prospects of biodiesel from Jatropha in India: A review. Renewable and Sustainable Energy Reviews 2010; 14: 763-771. http://dx.doi.org/10.1016/j.rser.2009.10.005.

[30] Instituto Nacional de Estadistica de Bolivia (INE).): Población - Población Total, por Condición Indígena y Área de Residencia, según Departamento, Censo 2001, 2011.

[31] Yacimientos Petrolíferos Fiscales Bolivianos (YPFB). Boletín Estadístico, Yacimientos Petrolíferos Fiscales Bolivianos Januar-Juni 2010. July 2010, pp. 1-39.

[32] Energy Information Administration (EIA). Independent Statistics & Analysis, U.S. Energy Information Administration. Bolivia, Country Analysis Brief Released. April 2010.

[33] Communication by e-mail with Villegas Gonzáles G., deputy director Petrobras Bolivia, on 28 of November 2011.

[34] Foro Boliviano sobre Medio Ambiente y Desarrollo (FOBOMADE). Biocombustibles en Bolivia? 2007, 1-14.

[35] Communication by e-mail with Stambuk J., who is a pioneer in biodiesel production from soya beans in Santa Cruz and expert in Jatropha biodiesel production in El Salvador, Colombia and Guatemala, on 23 of Nov. 2011.

[36] Romijn H. A, Caniels M. C .J. The Jatropha biofuels sector in Tanzania 2005-2009: Evolution towards sustainability? Research Policy, 2011; 40:618-636. http://dx.doi.org/10.1016/j.respol.2011.01.005.

[37] "...donde hay agua hay vida". Plan de ordenamiento territorial Macroregional del Chaco Boliviano. Ministerio de Planificación del Desarrollo. Viceministerio de Planificación Territorial y Medio Ambiente. Dirección General de Planificación Territorial. Unidad de Ordenamiento Territorial. Mancomunidad de Municipios del Chaco Boliviano (MANCHABOL). Programa de Naciones Unidas para el Desarollo (United Nations Development Programme). 2006, Parte I, pp. 1-42.

[38] Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), Fotoprojekt vom Projekt zur nachhaltigen Resourcennuntzung im Chaco Sudamericano, Mein Leben mit der Natur des Chaco. Without year of publication, pp. 1-73.