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The Economic Viability of Jatropha Biodiesel in Nepal

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Abstract

Nepal depends entirely on imports for meeting its demand for petroleum products, which account for the largest share in total import volume. Diesel is the main petroleum product consumed in the country and accounts for 38 percent of the total national CO_2 emissions from fuel consumption. There is a general perception that the country would economically benefit if part of imported diesel is substituted with domestically produced jatropha-based biodiesel. This study finds that the economics of jatropha-based biodiesel depend on several factors, such as diesel price, yield of jatropha seeds per hectare, and availability of markets for production byproducts, such as glycerol and jatropha cake. Under the scenarios considered, jatropha biodiesel is unlikely to be economically competitive in Nepal unless seed yields per hectare are implausibly large and high returns can be obtained from byproduct markets that do not yet exist. In the absence of byproduct markets, even earnings from a carbon credit do not help jatropha biodiesel to compete with diesel unless the credit value exceeds US$50/$tCO_2$ (which is well above current values) and jatropha seed yield is at or above the midrange of the scenarios considered. Declines in diesel prices from the levels observed in 2009–13 only compound the economic competitiveness issue.

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The Economic Viability of Jatropha Biodiesel in Nepal

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Key words: Nepal, Jatropha, Biofuels, Biodiesel, Production costs, Economics of biofuels

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The Economic Viability of Jatropha Biodiesel in Nepal[1]

1. Introduction

Nepal, a land-locked mountainous country, depends entirely on imports for its petroleum supply. All petroleum products are transported through tankers from the Baurani refinery located in Bihar State of India. Petroleum is the largest import item in the country, accounted for 19.5% of the total import in fiscal year 2011/12 (Kantipur Publication, 2012). The demand for petroleum is ever increasing, thereby making the economy more vulnerable to volatile world oil prices. Dependency on imported petroleum along with the escalating price has already affected the Nepalese economy (Parajuli, 2014).

Being a least developed country with per capita income one of the lowest in the world, per capita ownership of private vehicles that consume gasoline is also one of the lowest in the world. The main petroleum product used in the country is diesel, which accounted for more than two-thirds of the total petroleum consumption in the country (see Figure 1). The consumption and hence import of diesel increased more than twofold from 2008 to 2013 (see Figure 2). At the same time, the price of diesel doubled during the same timeframe due to increased international oil prices, falling exchange rate and high inflation, though international oil prices have since fallen off dramatically.

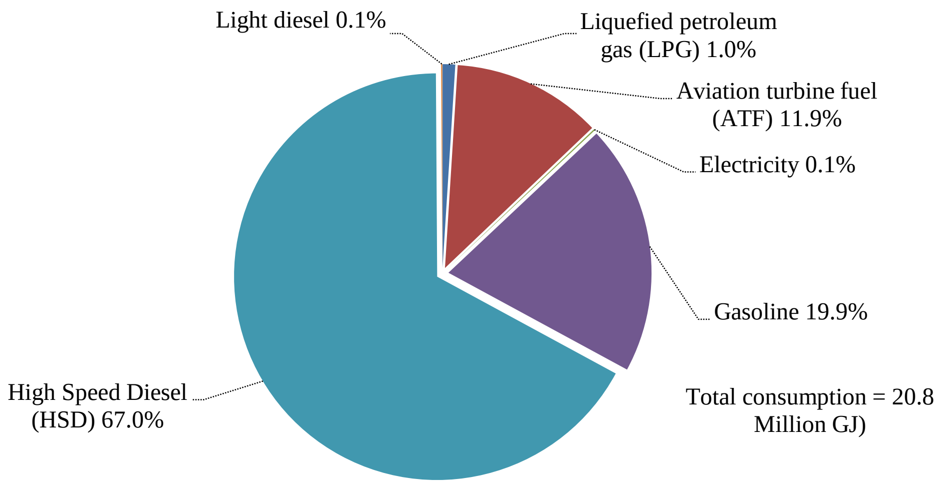
Jatropha[2]-based biodiesel could be a domestically produced alternative that also could be grown on unutilized lands, thereby not adversely impacting domestic food production. Various studies have indicated that it could offer benefits such as payments for credits from reducing

[1] We thank Durgalal Shrestha, Tri Ratna Bajracharya, Ram M. Shrestha, Masami Kojima and Mike Toman for constructive comments. The Center for Economic Development and Administration (CEDA), Tribhuvan University, Nepal, hosted a seminar on June 8, 2014 at CEDA in Kathmandu to discuss this paper. The Institute for Energy Studies (IES), Nepal, also organized a similar seminar on June 9, 2014 at IES in Kathmandu. We are grateful to both organizations for facilitating the discussions; we would like to thank the participants of both seminars to provide insightful comments. The paper also benefitted from comments, on its earlier version, received at the 7th Berkeley Bioeconomy Conference at UC Berkeley held on March 25-27, 2014. Punya P. Regmi provided some background information earlier. We also thank Forum for Rural Welfare and Agricultural Reform for Development, Nepal for providing some field data. Knowledge for Change (KCP) Trust Fund of the World Bank and the German Academic Exchange Service (DAAD) provided financial support for the study.

[2] Jatropha curcas L. (Euphorbiaceae) is a drought resistant tropical plant and can withstand conditions of severe drought and low soil fertility (Kumar and Sharma, 2008; Gübitz et al., 1999). It is a perennial plant, which can be grown on degraded land (Becker and Makkar, 2008). It can be cultivated in low to high rainfall areas (Kumar and Sharma, 2005). It produces seeds with 27 to 40% oil that can be converted into biodiesel (Achten et al., 2007). The fuel properties of jatropha biodiesel are comparable to those of petro-diesel (Parawira, 2010).

greenhouse gas (GHG) emissions,[3] reduced pressure on foreign exchange reserves, employment opportunity for unskilled agricultural labor, and reduced soil erosion in the hills (Mofijur et al., 2012; Garg et al., 2011; Eijck and Romijn, 2008; Achten et al., 2007). However, the critical question here is: would jatropha-based biodiesel be economically viable in Nepal? Does it produce more economic rent from the land than the crops that have been grown traditionally? Can it be economically produced from low-quality (or marginal) lands which are not suitable for producing other crops?

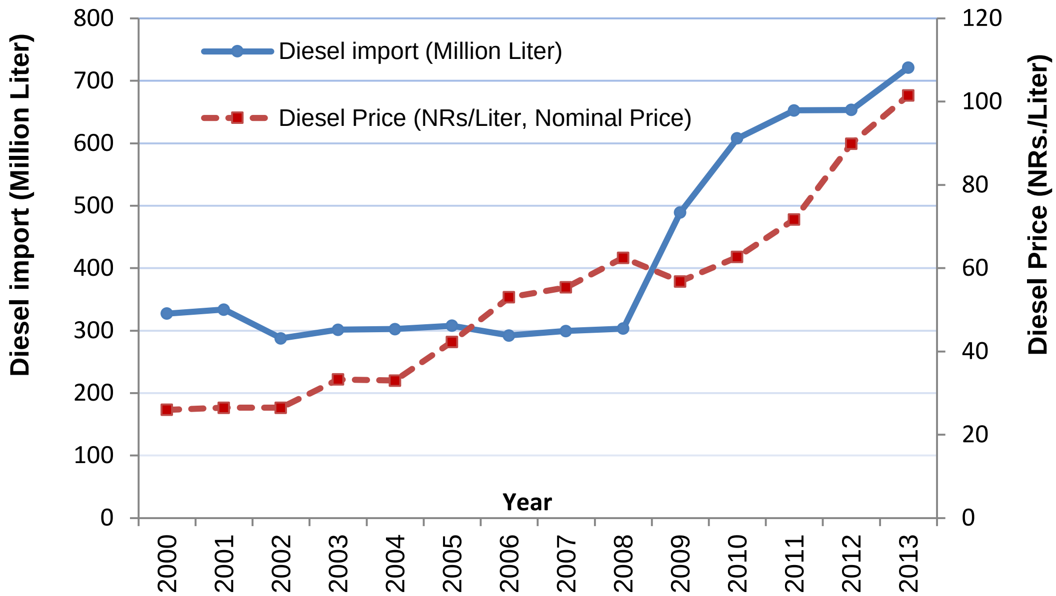
Figure 1: Transport sector energy consumption by fuel types in Nepal (2008/09)



Source: Water and Energy Commission Secretariat (WECS), 2010

[3] Jatropha biodiesel is considered as a potential activity to be implemented under the Clean Development Mechanism (CDM) which allows developing countries to sell carbon credits from their eligible GHG mitigation activities in the international markets.

Figure 2: Trends of import volume and price of diesel in Nepal



Source: Nepal Oil Corporation (http://www.nepaloil.com.np)

Existing studies show good potential for jatropha in Nepal (AEPC, 2010). It can be grown in all regions except in mountainous areas (Shrestha et al., 2013). Both governmental and non-governmental organizations in the country are encouraging jatropha cultivation for biodiesel. The National Planning Commission (NPC) and Alternative Energy Promotion Centre (AEPC) have been playing the leading roles to promote jatropha-based biodiesel. The government has implemented a National Biofuel Program since fiscal year 2008/09 through the AEPC. The major activities under the program include training to potential farmers and entrepreneurs, pilot projects in local communities, establishment of quality test labs for biofuel and support to research and development activities. The program has established 20 modern jatropha nurseries that have produced and distributed 1.25 million jatropha saplings to the farmers, and has established two processing plants to produce biodiesel from jatropha (Jhumsa, Palpa and Ramnagar, Chitwan) each with a production capacity of 1000 liters per day (K.C. et al., 2011).

The AEPC through the National Biofuel program is establishing a seed collection center in Palpa, Mahottari and Dhangadi districts. The government plans to promote a public-private partnership model through AEPC by motivating private institutions and local people through trainings and awareness programs to cultivate jatropha in community forests and degraded private lands. Earlier, the AEPC selected seven partner organizations representing different development regions to provide training to at least 200 farmers on jatropha plantation techniques (AEPC, 2009). In many places, community initiatives have been made to grow jatropha in community forests and community lands. For example, a local NGO named as Center for Integrated Rural Community Development Nepal (CIRCOD-Nepal) implemented a project in Siraha district where jatropha plants are already existed as wild or used as hedgerows to collect seeds and to produce biodiesel for irrigation pumps. The project was jointly supported by the Poverty Alleviation Fund (PAF) and AEPC.

There are a few private enterprises in Nepal that have invested in commercial farming of jatropha to produce biodiesel. These are Everest Biodiesel, High Himalayan Agro Nepal, and Crystal Bio-energy Nepal. Two companies working in this field namely Development Center Nepal (DC Nepal) and Everest Biodiesel Company Pvt. Ltd, with financial support from the AEPC, has established a “germplasm garden” in Chitwan district in order to screen the genetic diversity available on *Jatropha curcas* population and selection and distribution of best genotypes. A 10-year agreement between DC Nepal and Everest Biodiesel Company has been made for the establishment and maintenance of germplasm garden.

Despite governmental and non-governmental organizations’ interest in developing jatropha-based biodiesel to substitute for imported diesel in Nepal, rigorous analysis on the economics of jatropha-based biodiesel in Nepal is limited. Parajuli (2014) analyzes the economics of biodiesel considering three cases with different values for jatropha seed yield, price of jatropha seedlings, and the price of jatropha seeds, respectively. The study finds that the production of biodiesel is economically viable if jatropha seed yield exceeds 2kg/plant and if the price of jatropha seeds is below US$0.22/kg. The study is however based on the secondary information, and it does not carry out sensitivity analysis on key parameters. Nor does it provide evidence on how likely the stated conditions are to be met. Adhikari and Wegstein (2011), on the other hand, finds that the jatropha biodiesel is not economically attractive no matter whether it is grown in the Tarai region on a large-scale or it is grown in the hill regions on a small-scale. The paper’s conclusion is based on a single scenario with very low jatropha yield and does not consider different values for the jatropha yields. Shrestha et al. (2013) investigates the oil content of the jatropha seeds produced in eight districts of Nepal, and the physico-chemical properties of the jatropha oil. The study finds that oil contents of jatropha seeds significantly vary across districts of Nepal, with the highest content (58.3%) in Rolpa district and the lowest in Dolkha district (38.0%). However, the study does not consider the economic analysis of the jatropha oil production.

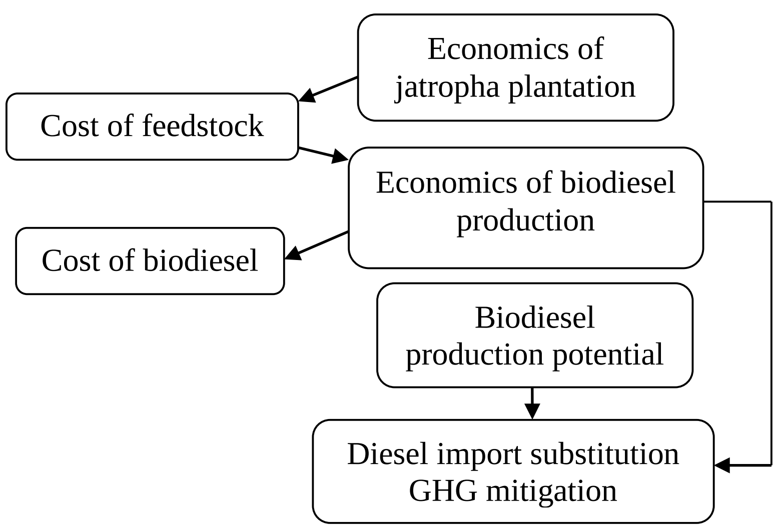
Compared to the existing studies, our analysis goes much further with a large number of sensitivity analyses, very detailed representation of production costs supported by field data, and assessment of the opportunity cost of land.

The paper is organized as follows. Section 2 presents the details of the analytical model we developed to assess the economics of jatropha-based biodiesel. This is followed by discussion of the data used and assumptions made for the analysis in Section 3. Section 4 presents the economic analysis along with sensitivity analysis on various parameters used for the economic analysis. Section 5 concludes the paper. We also estimate potential of biodiesel production on marginal lands in Nepal and GHG mitigation potential of jatropha-based biodiesel on those lands. However, those estimates are presented in Appendixes 1 and 2, respectively.

2. Methodology

The study analyzes the economics of the jatropha plantation followed by the economics of biodiesel production (Figure 3). The study then estimates the biodiesel production potential and the potential of CO_2 emission reduction through diesel replacement in Nepal. However, results of biodiesel production potentials and GHG mitigation potentials are presented in the Appendix so that the main body of the paper focus on the economics of jatropha based biodiesel in Nepal.

Figure 3: Methodological Framework used in the Study



2.1. Economic Analysis

We first calculate the costs and benefits of planting jatropha from a farmer's perspective, where a farmer decides whether or not the land he owns/lease be used for planting jatropha. Since there is no market for jatropha seeds currently in Nepal, we assume that the market will develop and farmers could make a 15% return on their investment. The rate of return is varied in the sensitivity analysis.

2.1.1. Economic Analysis of Jatropha Plantation

The average per unit cost of jatropha seed production is estimated as dividing sum of discounted total costs by the sum of discounted total quantity of jatropha seed production.

$$PUCj = \frac{\sum_t \frac{TCj_t}{(1+r)^t}}{\sum_t \frac{TQj_t}{(1+r)^t}} \tag{1}$$

where $PUCj$ represents the average per unit production cost of jatropha seed (NRs/kg), t is the production year (t = 1 to 29), r is the discount rate, TCj_t is the total cost of jatropha seed production in the year t (NRs), and TQj_t is the total quantity of jatropha seed production in the year t (kg). The total cost of jatropha seed production (TCj_t) includes the total fixed cost, total variable cost, and the overhead/management cost.

$$TCj_t = FCj_t + VCj_t + OvCj_t \tag{2}$$

where FCj_t represents the total fixed cost of jatropha seed production in the year t (NRs), VCj_t represents the total variable cost of jatropha seed production in the year t (NRs), and $OvCj_t$ is the overhead cost of jatropha seed production in the year t (NRs). The total fixed cost of jatropha seed production in the year t (FCj_t) is estimated by summing up the annual investment and the land rent for jatropha cultivation.

$$FCj_t = AIj + Lj_t \tag{3}$$

where AIj is the annual investment for planting jatropha (NRs), and Lj_t is the land rent for jatropha cultivation in the year t (NRs). The annual investment for planting jatropha (AIj) represents the annual flow of total investment. The total investment in the 1st year is allocated for the productive period (year) of planting jatropha. The production starts from the 2nd year and ends in the 30th year. The annual investment in planting jatropha (AIj) is considered as the annuity of total investment for the productive period, which is calculated as:

$$AIj = TIj.r.\frac{(1+r)^n}{(1+r)^n - 1} \tag{4}$$

where TIj is the total investment in planting jatropha (NRs), r is the discount rate, and n represents the economic life of the jatropha plantation. Total investment for jatropha plantation (TIj) includes the costs incurred in the first year for land preparation (costs for labor, tractor, and bullock animal), jatropha plantation (saplings and labor costs), fertilizer application (FYM/compost, Nitrogen, Phosphorus, Potash), pesticides and weedicides, irrigation, labor for de-weeding, and the first year land rent. Although most farmers in Nepal own their lands, one should not assume that the land is freely available. Therefore, we allocated rental value to capture the true economic costs of the lands even if a farmer uses own land to plant jatropha.

The total variable cost of jatropha seed production (VCj_t) is calculated by summing up all the costs incurred for the variable inputs. The cost of inputs is estimated by multiplication of the required quantity of input by per unit price of the corresponding input.

$$VCj_t = \sum_f QF_{f,t} \cdot PF_f + \sum_{pw} QPW_{pw,t} \cdot PPW_{pw} + CI_t + QLD_t \cdot PL + QLH_t \cdot PL \tag{5}$$

where *f* represents the fertilizer (FYM/compost, Nitrogen, Phosphorus, Potash), and *pw* represents the pesticide/weedicide. $QF_{f,t}$ is the required quantity of fertilizer *f* in the year *t* (kg), PF_f is the price of fertilizer *f* (NRs/kg), $QPW_{pw,t}$ is the required quantity of pesticide/weedicide *pw* in the year *t* (gm), PPW_{pw} is the price of pesticide/weedicide *pw* (NRs/gm), CIj_t is the total irrigation cost in the year *t* (NRs), QLD_t is the quantity of labor required for de-weeding in the year *t* (man-day), QLH_t is the quantity of labor required for harvesting jatropha seed in the year *t* (man-day), and PL is the per unit cost of labor (NRs/man-day).

The overhead/management cost of jatropha seed production ($OvCj_t$) accounts 5% of the total variable costs (VCj_t). This can be changed to various levels in the sensitivity analysis.

$$OvCj_t = 0.05 * VCj_t \tag{6}$$

The total quantity of jatropha seed production in the year *t* (TQj_t) is estimated as:

$$TQj_t = Yjp_t \cdot Njp \cdot Aj \tag{7}$$

where Yjp_t represents the yield of jatropha seed per plant in the year *t* (kg/plant), Njp is the number of jatropha plants on a hectare of land (No. of plants/ha), and Aj is the total area of jatropha plantation (ha).

2.1.2. Economic Analysis of Biodiesel Production

The energy equivalent cost of biodiesel production is estimated by dividing per unit cost of biodiesel production by the energy equivalent factor.

$$EECbd = \frac{PUCbd}{EFbd} \tag{8}$$

where $EECbd$ is the energy equivalent cost of biodiesel production (NRs/liter), $PUCbd$ is per unit cost of biodiesel production (NRs/liter), and $EFbd$ is the energy equivalent factor of biodiesel. The energy equivalent factor in the case of jatropha biodiesel is 0.88. The average per unit cost of biodiesel production ($PUCbd$) is equal to the sum of discounted total costs divided by the sum of discounted total quantity of biodiesel production.

$$PUCbd = \frac{\sum_t \frac{TCbd_t}{(1+r)^t}}{\sum_t \frac{TQbd_t}{(1+r)^t}} \tag{9}$$

where *t* represents the production year, and *r* represents the discount rate. $TCbd_t$ is the total cost of biodiesel production in the year *t* (NRs), and $TQbd_t$ is the total quantity of biodiesel production in the year *t* (liter). The total cost of biodiesel production ($TCbd_t$) includes the total fixed cost and total variable cost of biodiesel production.

$$TCbd_t = FCbd_t + VCbd_t \tag{10}$$

where $FCbd_t$ represents the total fixed cost in biodiesel production in the year *t* (NRs), and $VCbd_t$ is the total variable cost in biodiesel production in the year *t* (NRs). The total fixed cost of biodiesel production in the year *t* ($FCbd_t$) is estimated by summing up the annual investment for biodiesel extraction plant and the land rent. Certain amount of land is required to establish and operate a biodiesel plant.

$$FCbd_t = AIbd + Lbd_t \tag{11}$$

where $AIbd$ represents the annual investment for the biodiesel extraction plant (NRs), and Lbd_t is the land rent in the year *t* (NRs). Annual investment for establishing the biodiesel extraction plant ($AIbd$) represents the annual flow of total investment. The total investment in the 1st year is allocated for the productive years of the biodiesel extraction plant. The biodiesel production starts from the 2nd year and ends on 20th year. The annual investment for the biodiesel extraction plant ($AIbd$) is considered as the annuity of total investment for the productive periods of the biodiesel extraction plant.

$$AIbd = TIbd.r.\frac{(1+r)^n}{(1+r)^n - 1} \tag{12}$$

where $TIbd$ is the total investment for the establishment of the biodiesel extraction plant (NRs), *r* represents a discount rate, and *n* represents the economic life of the biodiesel extraction plant (here 20 years). Total investment for the establishment of the biodiesel extraction plant includes costs incurred in the first year for purchasing and establishing of machineries and equipment, construction of required buildings and infrastructure, and the first year land rent.

Total variable cost of biodiesel production is calculated by summing up the costs of jatropha seeds and the operation and management costs in biodiesel extraction.

$$VCbd_t = Cj_t + CO_t \tag{13}$$

where Cj_t represents the cost of jatropha seeds required for the biodiesel extraction plant in the year *t* (NRs), and CO_t represents the operation and management cost in biodiesel extraction in the year *t* (NRs).

$$Cj_t = Qj_t * PUCj_t \tag{14}$$

where Qj_t is the total quantity of jatropha seeds required for the biodiesel extraction plant in the year *t* (kg), and $PUCj_t$ is the per unit cost of jatropha seed production in the year *t* (NRs/kg).

$$CO_t = PUOCbdex_t * TQbd_t \tag{15}$$

where $PUOCbdex_t$ is the per unit operating cost of biodiesel extraction in the year *t* (NRs/liter), and $TQbd_t$ is the total quantity of biodiesel produced in the year *t* (liter). Per unit operating cost of the biodiesel plant ($PUOCbdex$) is assumed as NRs 12/liter (CJP website).

2.2. Potential of Biodiesel Production and GHG Mitigation

2.2.1. Biodiesel Production Potential

An analysis to estimate the land required to produce biodiesel for reducing the current import of diesel in Nepal has been made. The land requirement to produce the required quantity of jatropha seed for production of the required quantity of biodiesel is estimated as:

$$Lreq_t = \frac{Jsreq_t}{Yjs} \tag{16}$$

where $Lreq_t$ is the land required to produce the required quantity of jatropha seed in the year *t* (ha), $Jsreq_t$ is the jatropha seed requirement to produce the required quantity of biodiesel in the year *t* (kg), and Yjs is the average yield of jatropha seed (kg/ha).

$$Jsreq_t = \frac{Bdreq_t}{BdEr} \tag{17}$$

where $Bdreq_t$ represents the biodiesel required for replacing diesel import in the year *t* (liter), and $BdEr$ is the biodiesel extraction rate from the jatropha seed.

$$Bdreq_t = \frac{DI_t}{EFbd} \tag{18}$$

where DI_t represents diesel import in the year *t* (liter), and $EFbd$ is the energy equivalent factor of biodiesel.

2.2.2. GHG Mitigation Potential from Diesel Replacement

Replacement of the diesel by biodiesel contributes to the reduction of carbon dioxide (CO_2) emissions. The quantity of CO_2 emission reduction by biodiesel through diesel replacement is estimated as:

$$PCO2_t = DIR_t \cdot HC \cdot EF \tag{19}$$

where $PCO2_t$ is the potential of CO_2 emission reduction through diesel replacement (million tCO_2), DIR_t is the quantity of replaced diesel through biodiesel (million liters), HC is the heat rate of diesel (36.83 MJ per liter), and EF represents the CO_2 coefficient of diesel (74.067 t CO_2/TJ).

3. Data and Assumptions

The data were obtained through both primary and secondary sources. The primary data were obtained through field survey and telephone interview. Field visits of Chitwan district were made. Some data were not available as no commercial plantation of jatropha has started with the exception of some pilot plantation. Therefore, missing information were obtained from the secondary sources, particularly published/unpublished materials available from jatropha plantation and biodiesel production in India, where agronomic and climatic conditions are similar to our representative study site. Chitwan district of Nepal is our representative study site. We did not see a rationale of multiple sites in the Tearai region because the costs do not vary significantly across the different districts in the Terai region. However, some costs, particularly labor costs, would be lower in the hilly region as compared to that in Terai region. On the other hand, transportation costs would be higher in the hilly districts as compared to Terai districts. We did sensitivity analyses to capture the cost differences between hilly and Tarai districts, but did not find much difference in the results (i.e., costs of biodiesel). Moreover, the selected site, Chitwan district is a hilly Terai district (falls in the inner Terai region with more than half of the total area of the district is hilly). It could make a good representation of all districts where jatropha could be grown.

We assumed that jatropha plant produces seeds after the first year of plantation, but it takes five years to have good yield. For biodiesel plant, we assumed a plant with 1,000 liters per day production capacity with annual capacity utilization factor of 82%. All costs and benefits are converted to the present value by using a real discount rate available from Nepal Rastra Bank (NRB). Table 1 presents key data items, their values and sources.

4. Results of Economic Analysis

4.1. Economic Analysis of Jatropha Seed Production (Farmer's Perspective)

The economics of jatropha plantation cultivation is highly sensitive to yields of jatropha seeds. The yields depend on several factors including type of land (soil quality) and availability of irrigation. There do not exist pilot studies or field trials to provide a reliable estimation of jatropha yields in

Nepal. Therefore, we carried out economic analysis for three cases of jatropha seed yield: 3 tonnes/ha, 5 tonnes/ha and 10 tonnes/ha. Table 2 presents the cost structure under these three cases. In absolute terms, the capital or fixed costs remain the same in all cases, but the relative weight of the fixed costs (or share of fixed costs in the total costs) increases as yield decreases. For example, the discounted value of the total fixed costs over the 30 years (jatropha plantation's economic life) is estimated to be just above US$9,400/ha. This accounts for almost 56% of total production cost of jatropha seeds when jatropha yield is 3 tonnes/ha, 50% when yield is 5 tonnes/ha and 40% when yield is 10 tonnes/ha. The share of total variable costs increases along with the yield. This implies that the labor availability and the wage rate are the main factors for the success of a jatropha business.[4]

[4] Being a labor-intensive production process, jatropha production could provide employment opportunity for unskilled labor in the rural areas (Boccanfuso et al., 2013). However, we have not accounted for this benefit in our analysis.

Table 1: Overview of key data and assumptions

Data item	Value	Source
Jatropha plantation		
Economic life of jatropha plantation	30 years	Assumption
Planting density of jatropha	2.5 m * 2.5 m (1600 plants/ha)	CJP, India
Labor requirement for jatropha plantation (man-day/ha)	Land preparation = 15, Digging holes = 32, Planting of saplings = 16	Adhikari and Wegstein, 2011
Nutrient requirement of NPK (gm/plant)	60:100:60	Mohapatra and Panda, 2011
Fertilizer requirement (kg/ha)	Urea = 73, Diammonium Phosphate (DAP) = 348, Muriate of Potash (MOP) = 160	Authors' calculation
Fertilizer prices (NRs/kg)	Urea = 19.3, DAP = 46.3, MOP = 22.3	AIC, Nepal
Jatropha seed yield on arable land (tonne/ha)	3 tonnes/ha, 5 tonnes/ha, 10 tonnes/ha	Alternative assumptions
Labor requirement for harvesting jatropha fruits	1 labor (man-day) for harvesting 60 kg seed	Mitchell, 2011
Land rent (NRs/ha/year)	60,000	Field survey
Labor wage (NRs/man-day)	400	Field survey
Biodiesel production		
Economic life of biodiesel plant	20 years	Assumption
Biodiesel plant capacity	1000 liters per day; Operation of 300 days in a year	Assumption
Land required for establishing biodiesel plant	0.33 ha	Field survey
Total investment required for biodiesel plant installation	NRs 25,000,000	Field survey
Operating cost of oil extraction	US$ 0.12/liter	CJP, India
Oil extraction rate	36% of processed seeds	Mitchell, 2011
Glycerol production	4.6% of processed seeds, NRs 48/kg	Shinoj et al., 2010
Oil-cake production	70% of processed seeds, NRs 9.6/kg	Shinoj et al., 2010
Others		
Import price of diesel in Nepal	NRs 86.6/liter	NOC, Nepal
Diesel import in Nepal in the fiscal year 2012/13	721,203 KL	NOC, Nepal
Discount rate (real)	6.5%	NRB, Nepal
Exchange rate	US$ 1 = NRs 97	NRB, Nepal

Table 2: Cost structure of jatropha seed production

Cost component	Yield : 3 tonnes/ha	Yield : 5 tonnes/ha	Yield : 10 tonnes/ha
Cost/kg of jatropha seeds	NRs. 42.3 (US$ 0.5)	NRs. 28.2 (US$ 0.33)	NRs. 17.6 (US$ 0.21)
	Share of various cost item in the total costs (%)		
Fixed costs	55.8	50.2	40.2
Initial investment	8.5	7.7	6.1
Land rent	47.3	42.6	34.1
Variable costs	42.1	47.4	56.8
Fertilizers	19.2	17.3	13.9
Pesticides/Weedicides	0.8	0.7	0.6
Irrigation	1.3	1.2	1.0
Labor for de-weeding	5.0	4.5	3.6
Labor for harvesting	15.8	23.7	37.9
Overhead/Management cost	2.1	2.4	2.9

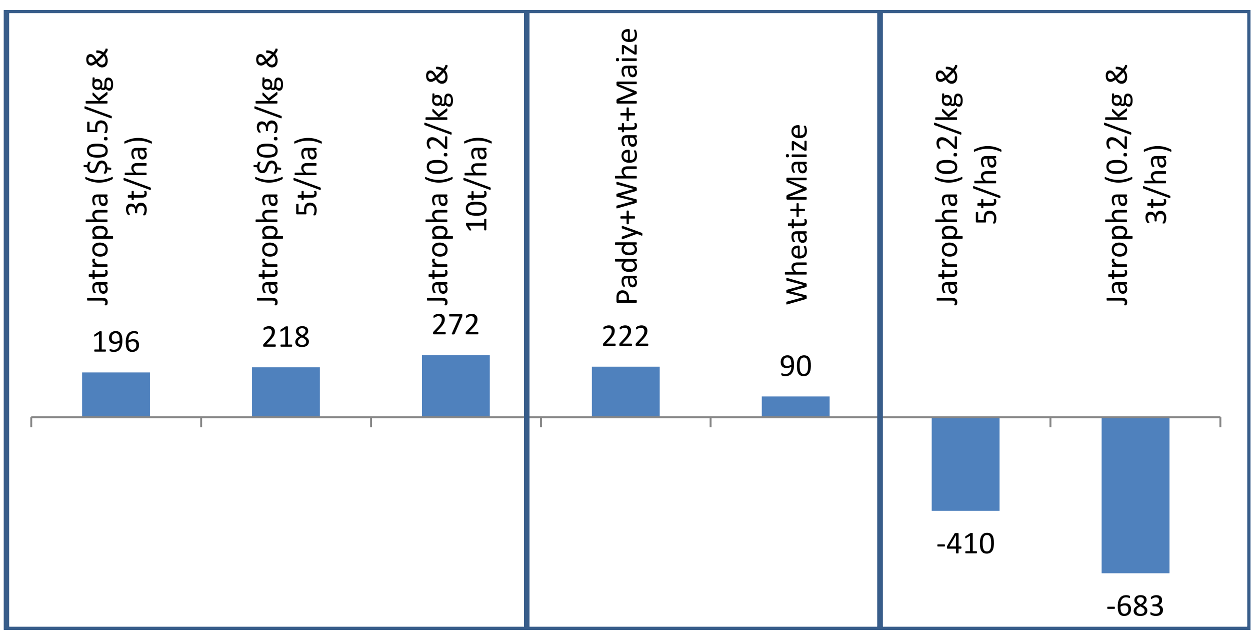
Whether or not to grow jatropha on a given area of agricultural land depends on the return that can be produced through jatropha compared to that produced through alternative use of the land – in other words, opportunity cost of that land if jatropha were to be grown in existing agricultural lands. Note that while we consider only low-quality lands to estimate the potential production of jatropha based biodiesel in Nepal (presented in Appendix 1), here we examine the economics of jatropha biodiesel considering both existing agricultural lands and low-quality (or marginal) lands. In the best quality of arable land in the site of this study (Chitwan district) where irrigation is available, three crops – paddy, maize and wheat are – grown in one year. If irrigation is not available, normally two crops are grown (maize and mustard; paddy and wheat; paddy and maize). To get the maximum opportunity cost of the land, we considered three crops: paddy (summer season), wheat (winter season) and maize (spring season). The annual gross margin from the alternative use vis-à-vis jatropha in a hectare of land is presented in Figure 4.

As can be seen from the figure, if jatropha price covers its costs plus 15% margin to the farmers,[5] production of jatropha seeds creates more value to a hectare of land than alternative crops

[5] In order to cover the production costs and 15% farmer's margins, sales price of jatropha seeds requires to be 0.5, 0.33, 0.21 US$ per kg under the yield of 3, 5 and 10 tonnes per hectare, respectively. Please see Table 2. If market prices for jatropha were available, we could have estimated the farmer's margin by comparing market prices and cost of production, but market prices do not exist as there is no commercial production of jatropha.

(paddy, maize and wheat) when jatropha yield is 10 tonnes per hectare (see left pane in Figure 4). However, a much higher jatropha price would be needed to cover its production costs when jatropha yield is low, such as 3 or 5 tonnes per hectare. If, for example, the price of jatropha seeds is US$0.21 per kg (i.e., price to cover production costs under the 10 tonnes per hectare yield case), there would be a net loss of US$683 and US$410 if jatropha yields are 3 and 5 tonnes per hectare respectively. This analysis suggests that the plantation of jatropha would not be economically attractive to farmers if jatropha yield is low, because farmers gets higher rents from their lands through traditional crops than that from jatropha. If only two cereals are grown in the land under the alternative use, plantation cultivation of jatropha is more economically favorable. Note here that we have assumed a market for jatropha seeds is available. Since biodiesel is a new commodity, farmers and investors might perceive much higher risk on jatropha compared to traditional crops.

Figure 4: Gross margin from agricultural land (US$/ha/year)

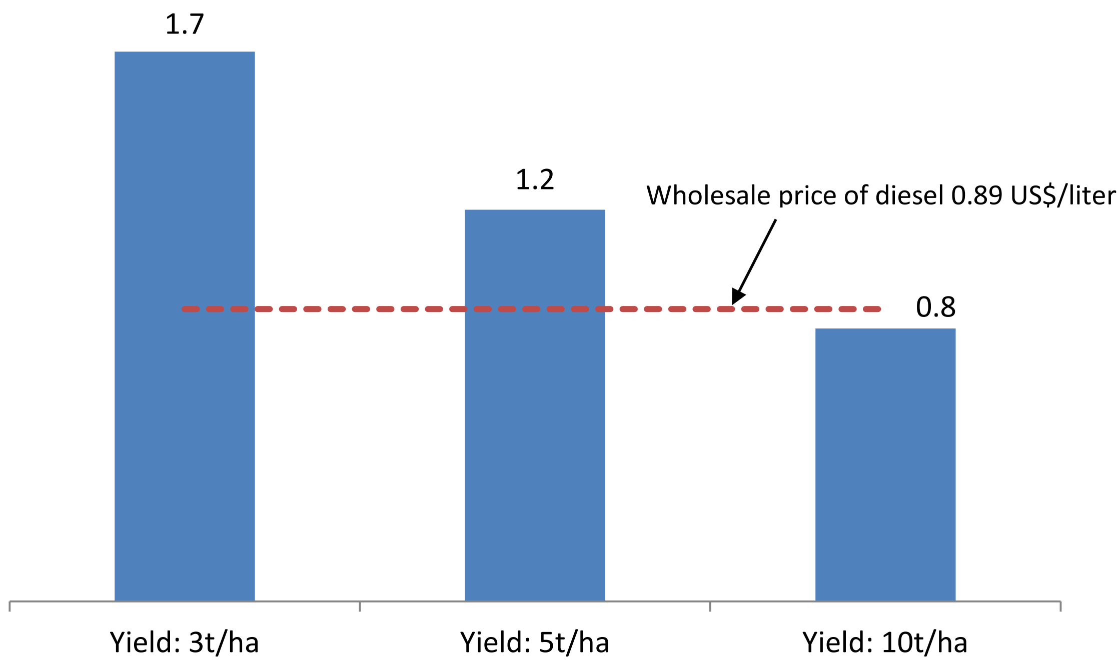


Note: The required data for cereal crops (crop yield, production cost, and producer price) were obtained from the field survey (household interview) in Chitwan district. Appendix 3 presents the overview of the data used for comparisons of the gross margins from cereals and gross margin from jatropha seed production.

4.2. Economic Analysis of Biodiesel Production (Biodiesel Plant Owner's Perspective)

The production costs of biodiesel under various levels of jatropha yield are compared with the price of diesel in Figure 5. The comparison is made on the energy equivalent basis accounting for the fact that a liter of biodiesel contains 12% less calorific value compared to diesel. The wholesale price of diesel at Amalekhgunj depot, the main storage and distribution facilities of imported petroleum products in Nepal, was US$0.89 per liter in 2013 excluding any taxes and subsidies. The production cost of jatropha-based biodiesel is higher than the price of diesel when jatropha yield is lower than 8 tonnes per hectare.

Figure 5: Comparison of production costs of biodiesel with wholesale price of diesel in Nepal (US$/liter)

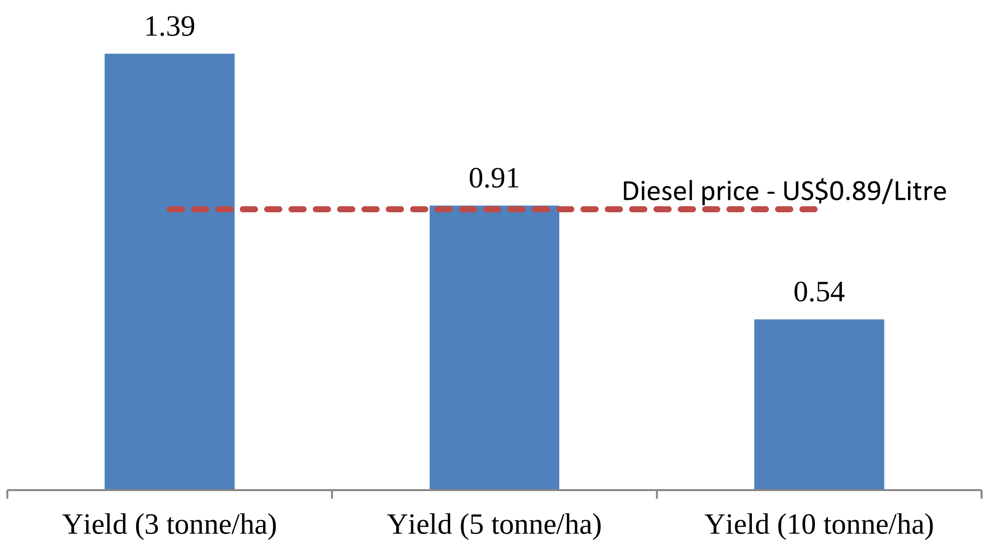


If biodiesel yield is 3 tonnes per hectare, biodiesel would be competitive with diesel only at twice the reference price we are considering here, everything else remaining the same. Similarly, biodiesel would be competitive at jatropha yield of 5 tonnes per hectare for a diesel price 35% higher than our reference price.

Based on Figures 4 and 5 it can be concluded that jatropha-based biodiesel would not be economically attractive to biodiesel producers nor to jatropha seed farmers unless the jatropha seed yield is relatively high, more than 8 tonnes per hectare. Note however that the economic analysis presented above does not account for some additional benefits such as revenue from byproducts (e.g. glycerol, jatropha cake), or the potential value of carbon credits from replacing fossil fuels. Moreover, we have considered use of arable lands with market rents for the lands. Several studies (e.g. Achten et al., 2010; FACT Foundation, 2010; Becker and Makkar, 2008; Kumar and Sharma, 2008; Gübitz et al., 1999) claim that jatropha can be grown in low-quality lands (or so called marginal lands) where other crops cannot be grown. Below we discuss several cases considering byproducts markets, climate change benefits and utilization of low-quality lands.

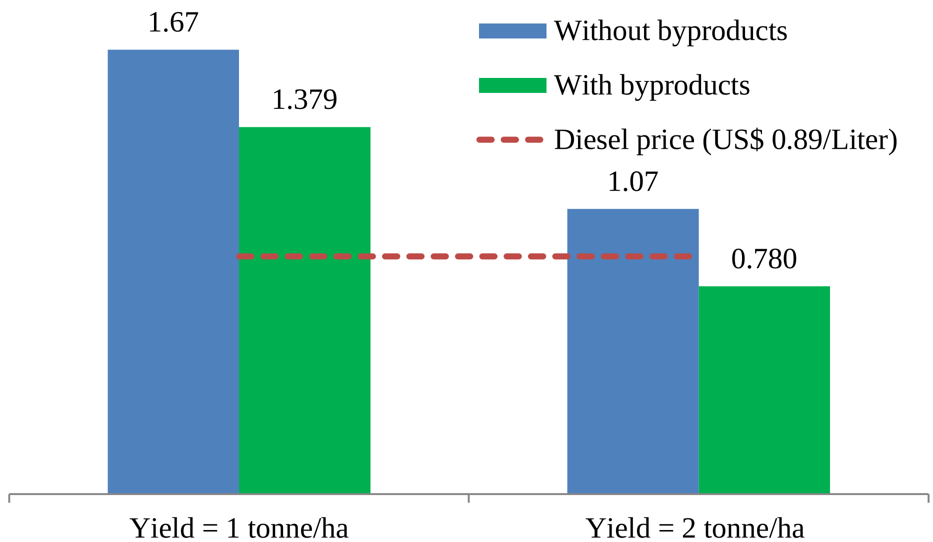
Economic analysis with byproduct markets: The main byproducts considered in the analysis are glycerol and jatropha cake. Based on data presented in table 1 above, processing of one kilogram of jatropha produces 46 grams of glycerol and 700 grams of jatropha cake (Shinoj et al., 2010). Glycerol is used in food and beverage, chemical and other industries, jatropha cake is used as organic fertilizer. The price of glycerol is US$0.49 per kilogram in the local market and jatropha cake is US$0.09 per kilogram. Our analysis shows that if there exist markets for byproducts with these prices, production of biodiesel would be competitive with imported diesel when jatropha seed yield exceeds 5 tonnes per hectare (see Figure 6). However, if jatropha yield is 3 tonnes per hectare, jatropha-based biodiesel would be economically competitive with diesel in the presence of byproducts markets only for a diesel price 56% above our reference price.

Figure 6: Economics of jatropha biodiesel when byproducts have markets (US$/liter)



Economics of jatropha-based biodiesel when low quality or marginal lands are used: In this case, we assumed that the opportunity cost of the land would be much lower compared to that of the arable land (i.e. 30% of that of arable land). Cultivation of jatropha would protect against soil erosion on these lands. There would be additional land preparation costs in the first year (10% higher as compared to arable lands) when this type of land is used. There would be no irrigation capability, and therefore chemical fertilizers are not applied. The yield would be very low. We considered two yields in our analysis: 1 tonne per hectare and 2 tonnes per hectare. The results are presented in Figure 7. As can be seen from the figure, jatropha-based biodiesel would not be economically viable if low-quality lands (or so called marginal lands) are used even if jatropha yield is 2 tonnes per hectare, unless byproducts markets also are available.

Figure 7: Economics of jatropha biodiesel when low-quality land is used (US$/liter)



Economics of jatropha-based biodiesel when carbon credit payments are accounted: Since biodiesel replaces diesel, the main fossil fuel responsible for CO_2 emissions in Nepal, we have also analyzed the economics of biodiesel accounting for possible financial benefits from the carbon market. However, there is a huge uncertainty in global carbon prices. Instead of considering a single carbon price, we considered a range of carbon prices from US\$10/tCO_2 up to US\$50/tCO_2. The former is roughly the price of carbon in the California market, where there is a price floor; the latter is above any carbon prices that have obtained in the past or that are likely to obtain at least in the near term future.

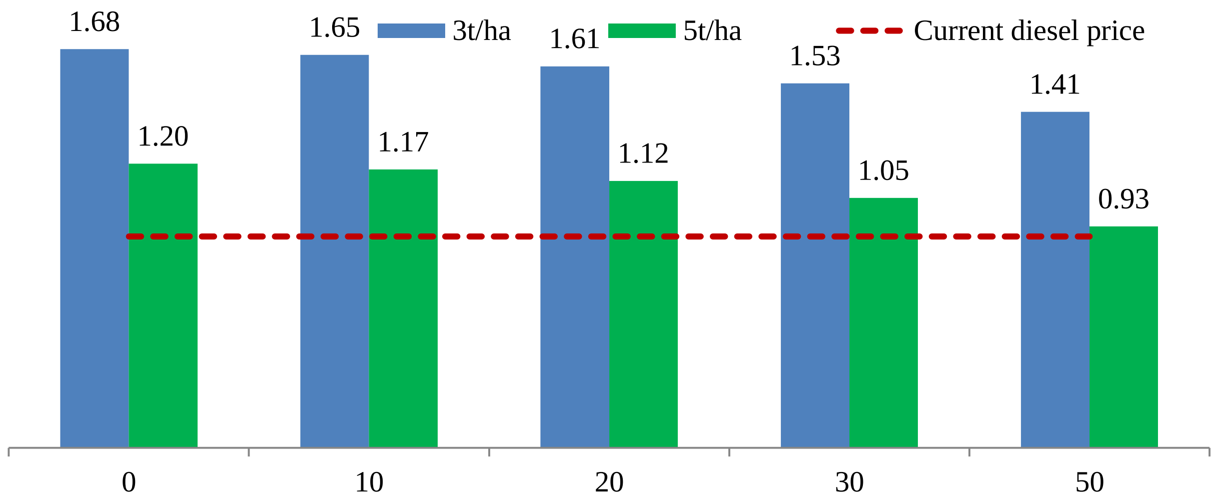
Two cases are considered here: without byproduct markets, and with them. The results are presented in Figures 8(a) and (b). Our analysis finds that for the carbon prices we considered, the potential carbon revenue from producing jatropha-based biodiesel is not large enough to make the biodiesel economically competitive with diesel without byproduct markets. A US\$10/tCO_2 carbon price provides only 2.4 US cents carbon credits to a liter of biodiesel. As illustrated in Figure 8 (a), jatropha-based biodiesel would not be cheaper than imported diesel even if carbon price is US$50/t$CO_2$ when jatropha yield is below 5 tonnes per hectare. If byproducts markets exist, however, jatropha-based biodiesel would be economically competitive when the carbon price exceeds US$10/t$CO_2$ with jatropha yield is 5 tonnes per hectare or higher (see Figure 8b). It remains uncompetitive with a yield of only 3 tonnes per hectare, however.

4.3. Sensitivity Analysis Related to Other Assumptions

The economics of jatropha-based biofuels depends on several cost variables, such as wage rate, rental rate of land, capital cost, operation and maintenance costs, jatropha seeds collection costs which differ across locations, economic life of jatropha plantation and so on. There is uncertainty in the values of these variables. Primarily, there are two sources of cost uncertainty. The first source is uncertainty in the future evolution of some cost variables such as wage rate and capital cost. The other source of uncertainty reflects the lack of precision in estimates of some current cost related information, such as land rent, collection costs, labor requirement for jatropha fruit harvesting, and oil contents in jatropha seeds. Therefore, we carried out a large number of sensitivity analyses to cover the both types of uncertainties. Below we briefly discuss the rationale for and results from the various sensitivity analyses we considered in this study. Table 3 summarizes sensitivity results.

Figure 8: Economics of jatropha biodiesel at different (US$ 0 to 50 per ton of CO_2) carbon prices (US$/liter)

(a) Without byproducts markets



(b) With byproducts markets

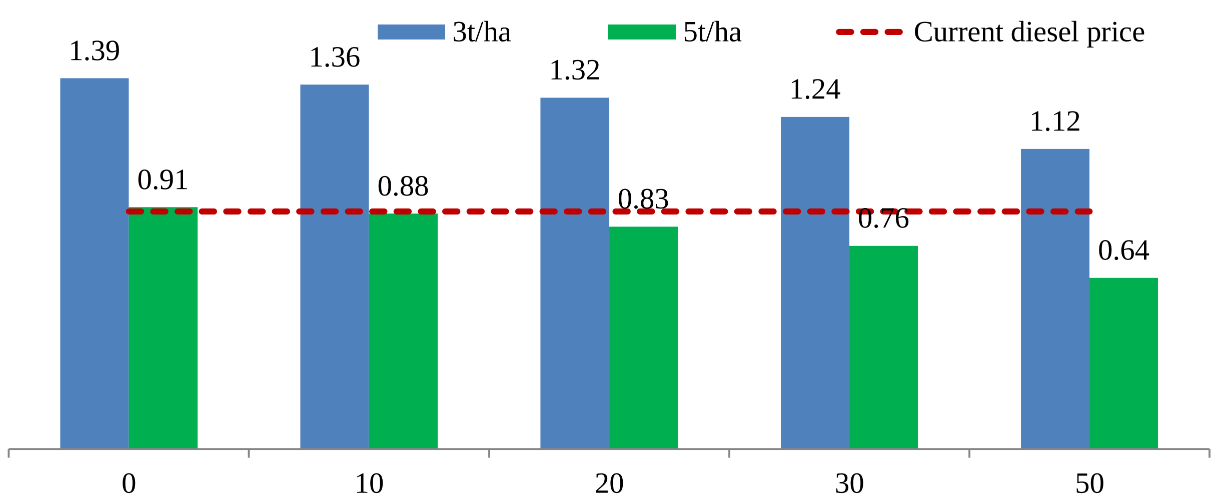


Table 3: Sensitivity analysis results: biodiesel production costs (US$/liter)

	Arable Lands			Low quality lands	
	10t/ha	5t/ha	3t/ha	2t/ha	1t/ha
	Main case				
	0.83	1.20	1.68	1.07	1.67
	Sensitivity cases				
Increasing the social discount rate from 6.5% to 10%	0.87	1.25	1.75	1.15	1.79
Increasing wage rate by					
15%	0.87	1.24	1.73	1.13	1.75
50%	0.97	1.35	1.85	1.27	1.95
Increasing land rent by 15%	0.87	1.26	1.79	1.12	1.77
Decreasing labor productivity of jatropha seeds harvesting to 45 kg per day form 60 kg per day	0.91	1.28	1.76	1.15	1.75
15% increased collection cost	0.89	1.29	1.82	1.15	1.81
Decreasing economic life of jatropha plantation from 30 to 20 years	0.88	1.29	1.83	1.23	2.00
Decreasing oil contents of jatropha seeds from 36% to 25%	1.10	1.62	2.31	1.44	2.30
Increasing capital costs of biodiesel extraction plant by 15%	0.85	1.21	1.69	n.a.	n.a.

Increasing the social discounting rate from 6.5% to 10%: The discount rate is always an uncertain variable. Based on Nepal's Central Bank's data we used 6.5% real discount rate in our main analysis. This rate is increased to 10% in the sensitivity analysis. The increase of discount rate to 10% from 6.5% causes the production costs of jatropha to increase by 4.2%, from US$1.2/liter to US$1.25 per liter under the 5 tonnes per hectare yield case. This implies that increased discount rate would lower the competitiveness of jatropha with diesel.

Increased wage rate: Although the average wage rate for agricultural labor in Nepal is one of the lowest in the world it is increasing rapidly in the recent years. The trend for rural to urban migration has been accelerated and the trend to go abroad (Middle East, Malaysia, the Republic of Korea) for unskilled jobs has increased greatly in the recent past. The trend is such that it is difficult to find agricultural labor, especially youth, in many villages in Nepal. We used current wage rate in the Chitwan district, the case study site, in the main analysis. The wage rate is US$4 (NRs 400) per day (not per hour). We carried out two sensitivity analyses on this wage rate, 15% increase and 50% increase. If wage rate increases by 15%, production cost of biodiesel increases by four to eight cents per liter (or 3% to 6%) depending on jatropha seed yields. If the wage rate increases by 50%, jatropha biodiesel cannot compete with diesel even if the yield is 10 tonnes per hectare; jatropha biodiesel prices increase by 10% to 17% depending upon the yield of jatropha seeds.

Increased land rent: The value of land is ever increasing in Nepal no matter whether it is in urban or rural areas. However, the trend of land rent is relatively flat compared to the trend of wage rate. We assumed, based on current average rental price of existing agriculture land, US$619 per hectare for land rent. However, the trend of land rent is relatively flat compared to the trend of wage rate. Therefore, we considered only a 15% increase in land rent instead of 50% that we assumed for the wage rate. The 15% change land rent would increase production costs of biodiesel by 4 to 11 cents (or 5% to 7%) depending upon the yield of jatropha seeds.

Lower labor efficiency in jatropha fruit harvesting: In the main analysis, we assumed, based on existing literature, that one person harvests 60kg of jatropha seeds per day. Considering very low experience with jatropha plantations and lack of data from multiple fields, this value could be optimistic. Hence, in this sensitivity analysis we assumed that one person harvests 45kg of jatropha seeds in a day. Decreasing labor productivity of jatropha seeds harvesting from 60kg per day to 45kg per day, increases production costs of biodiesel by 5 to 10% depending upon the yield of jatropha seeds.

Increased collection costs: Although transportation facilities and rental vehicles are available for transportation of jatropha seeds from fields to site of biodiesel extraction site in the location where this case study has been undertaken (Chitwan district), similar transportation facilities would not available if the jatropha plantation sites are hilly areas. This implies higher costs in collecting jatropha seeds. In this sensitivity analysis, we assumed that collection cost increases by 15%, which would lead to increase of biodiesel production costs by 7 to 8% depending upon the yield of jatropha seeds.

Decreased economic life of jatropha from 30 to 20 years: Commercial plantation of jatropha has not started in Nepal except for a few pilot cases. Existing literature suggests 30-40 years for the economic life of jatropha plantation. As this assumption has not been tested in the field yet, we considered a sensitivity analysis with a conservative economic life of the jatropha plantation. If the economic life of the plantation is reduced to 20 years from the 30 years that we assumed in our analysis, production cost of biodiesel increases by 6% to 9% in the case of arable lands and 14% to 20% in the case of low-quality lands. The plantation cultivation of jatropha in low-quality lands is highly sensitive to economic life of the plantation because of low yields.

Decreasing oil content of jatropha seeds from 36% to 25%: Literature suggests oil content of jatropha seeds varies depending on several factors such as seed variety, climatic conditions in the plantation sites, extraction method used. Through a chemical analysis of jatropha seeds collected from eight districts in Nepal, Shrestha et al. (2013) find that oil content of jatropha seeds vary from 20% to 47% (or 38% to 58% if jatropha kernel instead of jatropha seed is considered). In our main analysis, we considered 36% oil content. We decreased it to 25% in this sensitivity analysis to be more conservative on the assumption of oil contents. We found that production cost of biodiesel is highly sensitive to oil content of jatropha seed. If the oil content of jatropha seeds decreases to 25% from 36%, production cost of biodiesel increases by 32% to 38%.

Increasing capital costs of biodiesel extraction plant: There is no standardization on the cost of jatropha feed biodiesel extraction plants. It depends on where the plant accessories are manufactured (e.g., China, Europe, India). We increased the capital cost of biodiesel extraction plant by 15%. This would lead to increase the production cost of biodiesel by 0.5% to 1.2%.

Overall the results of the various sensitivity analyses reveal that the competitiveness of jatropha biodiesel relative to diesel decreases in most of the sensitivity analyses considered. However, the cost increases are less than 10% in most of these scenarios, irrespective of the yield of jatropha seeds. Though the cost increases in most of the sensitivity analyses are relatively mild, they further reduce the competitiveness of jatropha biodiesel given that it is already more expensive than diesel for the more realistic range of jatropha seed yields in Nepal. While sensitivities favorable to jatropha economics also could have been considered, we could not find any plausible scenarios. For example, it would be unlikely to assume labor price or land rent decreases. The one factor that could change the economic balance toward jatropha biodiesel relative to diesel in Nepal, as already noted, would be a major increase in diesel prices relative to 2013 levels, which were already double the level of diesel prices in 2009.

5. Conclusions

Nepal, a land-locked mountainous country, depends entirely on imports for its petroleum supply. Currently, petroleum is the largest import item in the country and demand for it continues to increase. Diesel is the main petroleum product used in the country for transportation. Substitution of diesel with alternative fuels, such as biodiesel, could be beneficial to the country, if biodiesel can be produced in an economically competitive way. This study aims to investigate this hypothesis by undertaking an economic analysis of jatropha-based biodiesel.

The study finds that the economics of jatropha depends mainly on two factors: yields of jatropha seeds and availability of market for byproducts from biodiesel extraction plants. If markets for byproducts (i.e., glycerol and jatropha cake) do not exist, production costs of jatropha-based biodiesel would be higher than current wholesale price of diesel unless the yield of jatropha seeds exceeds 8 tonnes per hectare. Such a high yield of jatropha is difficult to materialize considering current agricultural practices in Nepal and existing barriers to improve the yield (e.g., experimental stage of jatropha plantation, lack of irrigation, farmers' lack of information and knowledge). On the other hand, if the byproducts can be marketed through expansion of chemical industries demanding glycerol and promotion of use of jatropha cake through information and awareness programs, biodiesel could be economically attractive as long as yields of jatropha seeds remain above 5 tonnes per hectare.

The benefits from carbon credits are not much help to make jatropha biodiesel economically attractive unless the carbon price is high. In the absence of byproduct markets, jatropha biodiesel would not be able to compete with diesel even if the carbon price is US$50/t$CO_2$ as long as yield of jatropha seeds remains below 5 tonnes per hectare. If low-quality or so-called marginal lands that can yield only a tonne of jatropha seeds per hectare are utilized, biodiesel would not be economically attractive even if markets exist for byproducts. If the yield of low-quality lands doubles (2 tonnes per hectare), jatropha biodiesel could be economically attractive provided that byproducts get markets – though this finding also assumes diesel prices at the level prevailing in 2013.

Most sensitivity analysis reflecting plausible scenarios indicate that production costs of jatropha would increase. Thus, unless the wholesale price of diesel drastically increases and yield of jatropha seeds is higher, jatropha biodiesel would not be an economically attractive alternative fuel in Nepal. The economic viability of jatropha based biodiesel has deteriorated further due to current drop in oil prices.

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Appendix

Appendix 1:

Technical Potential of Biodiesel Production from Low Quality/Marginal Lands in Nepal

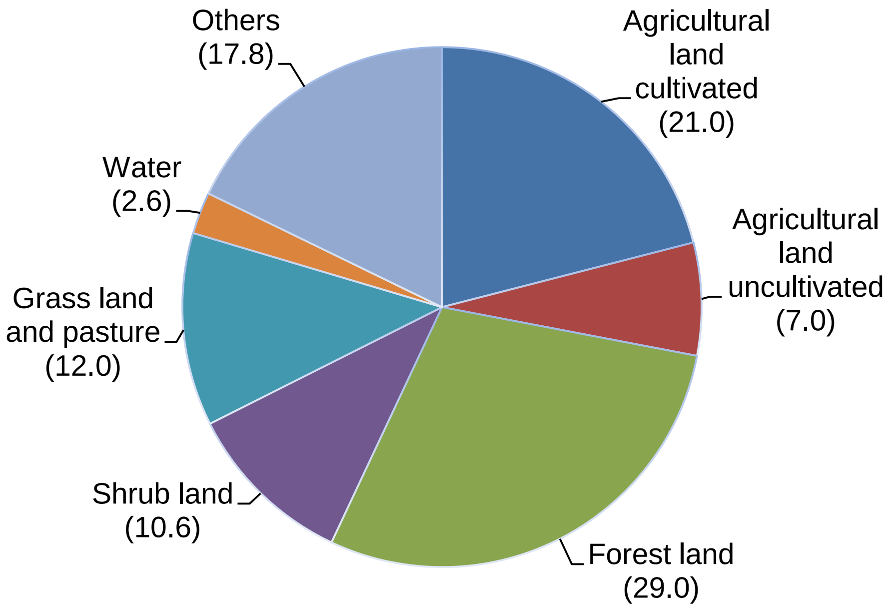
Of the total land area (14.7 million hectares) in Nepal, 7.0% (1.03 million hectares) is uncultivated (Figure A1) (MoAD, 2012; DOA, 2010). Mountain, Hill and Terai regions occupy respectively 21%, 51% and 28% of the total uncultivated land, and the eastern, central, western, mid-western, and far-western development regions occupy respectively of 28%, 19%, 31%, 14%, and 9% of total uncultivated land in Nepal (ISRC, 2008 cited in Parajuli, 2009).

Table A1: Distribution of uncultivated land in Nepal

Development region		Mountain	Hill	Terai	Total
Eastern	Ratio to total uncultivated land (%)	12.81	11.44	3.44	27.69
	Total uncultivated land (ha)	131,943.0	117,832.0	35,432.0	285,207.0
Central	Ratio to total uncultivated land (%)	3.21	11.10	4.36	18.67
	Total uncultivated land (ha)	33,063.0	114,330.0	44,908.0	192,301.0
Western	Ratio to total uncultivated land (%)	0.08	14.74	16.64	31.46
	Total uncultivated land (ha)	824.0	151,822.0	171,392.0	324,038.0
Mid-western	Ratio to total uncultivated land (%)	2.37	9.16	2.07	13.60
	Total uncultivated land (ha)	24,411.0	94,348.0	21,321.0	140,080.0
Far-western	Ratio to total uncultivated land (%)	2.49	4.85	1.24	8.58
	Total uncultivated land (ha)	25,647.0	49,955.0	12,772.0	88,374.0
Total uncultivated land (ha)		215,888.0	528,287.0	285,825.0	1,030,000.0

(Sources: MoAD, 2013; ISRC, 2008 cited in Parajuli, 2009)

Figure A1: Land use statistics in Nepal (% of total country land)



Source: MOAD (2012) and DOA (2010)

We have considered the uncultivated low quality land for jatropha farming in Nepal. This is because jatropha plantation cultivation in the uncultivated land does not create a conflict with existing food production system. However, not all the uncultivated land is feasible for jatropha plantations; for example, uncultivated land in the mountain region is climatically not suitable. Therefore, we have not included uncultivated lands of the mountain region in our estimation. The uncultivated lands of the hills (528,287 ha) and Terai (285,825 ha) are considered as potential lands for jatropha cultivation.

We estimate the production potential of jatropha seed and biodiesel from the uncultivated land in the Hill and Terai regions of Nepal (see Figure A2). The basic assumption of jatropha plantation on uncultivated land is the same as in the marginal land (jatropha seed yield of 2 tonnes/ha). The estimated production of jatropha seeds from the total uncultivated land is 1,056,574 tonnes/year in the hills and 571,650 tonnes/year in the Terai. Considering the oil content as 36% of processed seeds, the potential of biodiesel that can be produced from the total uncultivated land in the hills and Terai is 586,160 kiloliters or KL (Hills = 380,366 KL, and Terai = 205,794 KL) in a year. Considering the energy equivalent of biodiesel as 88%, the potential of energy equivalent production of biodiesel from the total uncultivated land in the Hills and Terai is 515,821 KL in a year (Figure A2). The western

Hills is found to have the highest potential to produce jatropha biodiesel followed by the eastern Hills, central Hills, mid-western Hills and far-western Hills.

Our analysis shows that if all uncultivated land in Hill and Terai regions are used to cultivate jatropha with seeds yield 2 tonnes per hectare, it could be enough to produce biodiesel equivalent to 72% of the current (2012-13) diesel consumption in Nepal. Use of 70% of available uncultivated lands in the Hill and Terai regions could produce enough biodiesel to substitute half of current diesel consumption in the country.

Appendix 2:

Technical Potential for GHG Mitigation from Biodiesel Grown on Marginal Lands

As mentioned earlier, diesel is the main fossil fuel used in Nepal. In 2010, it accounted for 38% of the total national CO_2 emissions from fuel combustion (Figure A3). Figure A4 illustrates the percentage reduction of GHG emissions under various rates of substitution of diesel with biodiesel. A 10% substitution of current consumption of diesel with biodiesel, could reduce 3% of current national GHG emissions. Jatropha would need to be cultivated in 14% of the total uncultivated lands available in the Hill and Tarai region with jatropha seed yields of 2 tonnes per hectare to achieve this level of substitution. If all the uncultivated lands available in the Hill and Tarai region is planted with jatropha with seeds and yields are 2 tonnes per hectare, enough biodiesel could be produced to substitute 71% of current diesel consumption, thereby reducing 27% of the current national GHG emissions (Figure A4).

Figure A2: Energy equivalent potential of biodiesel from the uncultivated land in the Hill and Terai regions of Nepal

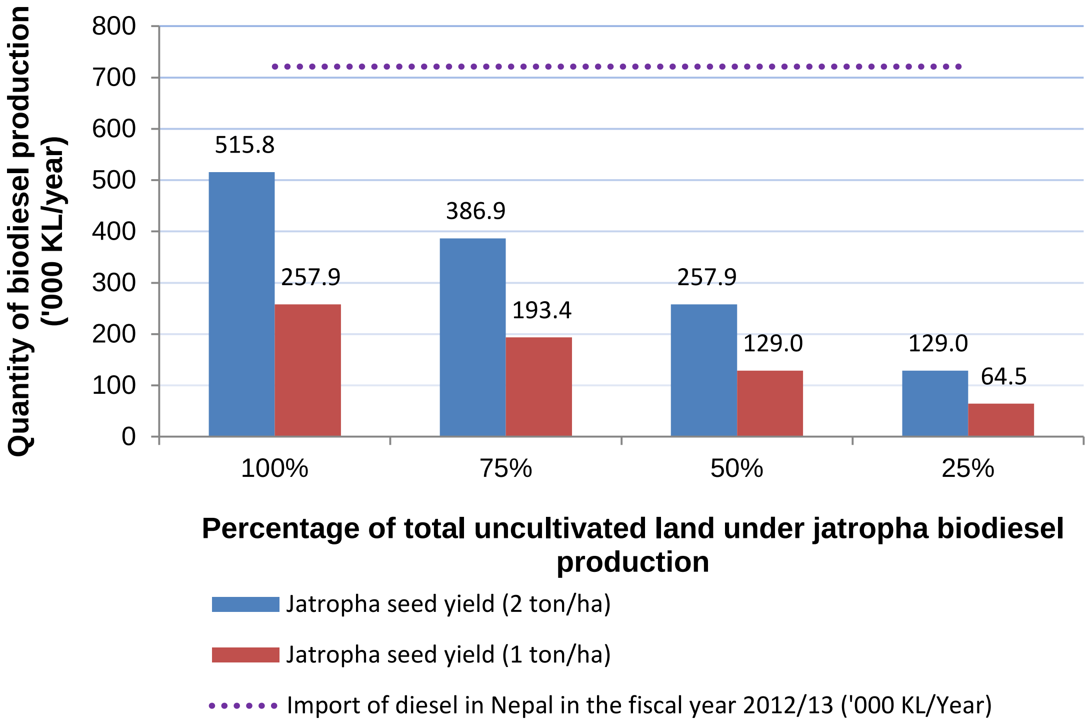
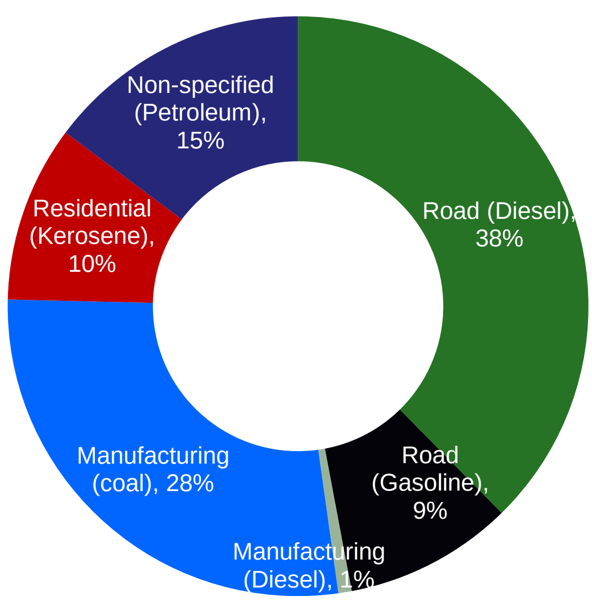
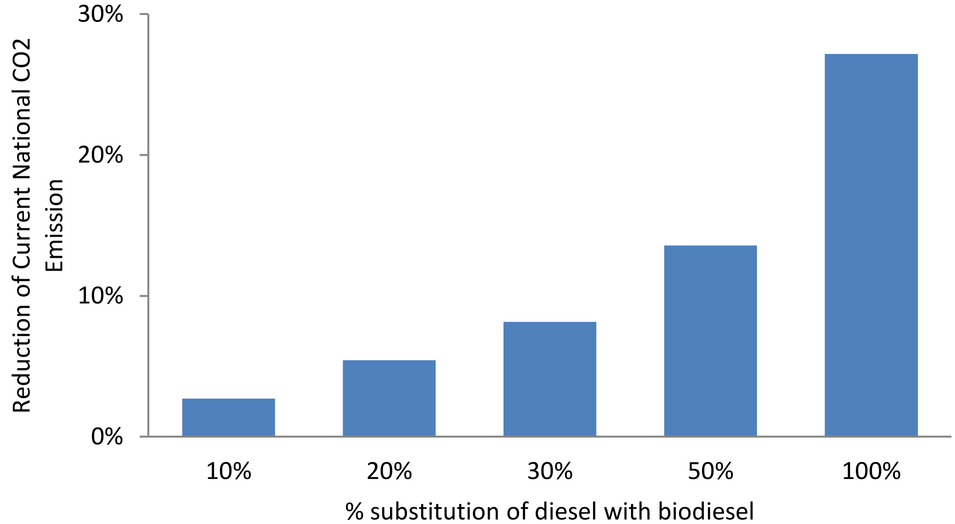


Figure A3: Fuel shares in total fuel consumption related CO_2 emissions in Nepal in 2010



Source: IEA (2012)

Figure A4: Total national CO_2 reduction potential under various biodiesel-diesel substitution rates



Appendix 3:
Yield, production cost, producer price, and gross margin from jatropha and cereals farming in Chitwan district of Nepal

Crop	Yield (kg/ha)	Production cost (NRs/kg)	Producer price (NRs/kg)	Total production cost (NRs/ha)	Gross income (NRs/ha)	Gross margin (NRs/ha)
Paddy	4,280.0	14.724	18.86	63,018.7	80,720.8	17,702.1
Wheat	2,660.0	16.088	19.11	42,794.1	50,832.6	8,038.5
Maize	3,080.0	15.072	18.55	46,421.8	57,134.0	10,712.2
Paddy+Wheat+Maize						36,452.8

Source: Authors' calculations; data from field survey