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An Economic Assessment along the Jatropha-based Biodiesel Value Chain in India§

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Abstract

The Government of India had launched the National Biofuel Mission in the year 2003 as an initiative to limit the country's dependence on crude oil imports. An integral part of this mission is the Biodiesel Blending program and Jatropha, a tree-borne biodiesel yielding crop, is the cornerstone of the program. This study has been specifically designed to carry out economic assessment of the upcoming jatropha-based biodiesel value chain in the country. The study, based on primary data collected from three major jatropha growing states, has observed that jatropha cultivation is an economically viable proposition in the long-run as indicated by favourable values of net present value, internal rate of return and benefit cost ratio. Nevertheless, initial government support till attaining break even point is crucial to sustain the interest of the farmers. The jatropha seed processing industry has been found to be viable if operated at sufficient economies of scale, which in turn is determined by the level of backward integration with the seed market and a forward integration with biodiesel distribution channels. However, the existing biodiesel value chain in India lacks this integration and is characterized by under-developed seed markets, sub-optimal processing infrastructure and ill-defined biodiesel distribution channels. The involvement of corporate players to participate in processing and distribution activities has further delayed the program to take off. The study has cautioned that unless proactive orientation of all the stakeholders is ensured, the program may fail to meet its objectives, at least in the medium-term.

Introduction

With fast depletion of fossil fuels, increasing focus is being given to the development of bioenergy as a potential future source of energy and this has brought jatropha, a tree-borne oil seed crop, into limelight. The plant jatropha *(Jatropha curcas)* is widely known as a feedstock crop for biodiesel. World over, considerable investments are being made on the jatropha-based biodiesel development projects. A survey conducted by Global Exchange for Social Investment (GEXSI, 2008) has identified 242 jatropha projects in different parts of the world and a majority of them are located in Asia. India is currently the leading cultivator of jatropha with more than 0.4 M ha (million hectares) of area under this crop. In India, it is the Planning Commission report on development of biofuel that has officially endorsed the use of jatropha as a feedstock for biodiesel production (GOI, 2003). Even though various other oilseeds also qualify as feed stocks for biodiesel, jatropha has been specifically chosen because it is a non-edible oilseed crop which does not impinge on the food security of the nation even if promoted commercially. Also, jatropha is a drought-tolerant and hardy crop which can be grown in a relatively less fertile and marginal lands with minimal inputs and management. The scope of earning 'carbon credits' from jatropha cultivated lands is considered as an added advantage.

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Several studies at the global level too favour the cultivation of jatropha in marginal or less productive lands (Tilman *et al.*, 2009; Fargione *et al.*, 2008).

The Government of India has introduced a myriad of programs and policies to encourage the upcoming of biofuel sector in the country. As a part of this, the National Biofuel Mission (NBM) was launched in the year 2003, of which Biodiesel Blending Program (BDBP) and Ethanol Blended Petrol Program (EBPP) are the integral components. The BDBP mandates blending of biodiesel in high speed diesel (HSD) with a target of effecting 5 per cent blending by the year 2012, 10 per cent by 2017, and 20 per cent after 2017. As substantial area is to be brought under biofuel plantations to meet the mandated blending target, the government policy is to utilize the wastelands available across the country to grow non-food biofuel crops. In its 2003 report, the Planning Commission has mentioned that an estimated area of around 13.4 M ha is suitable to plant jatropha. To ensure fair price to the farmers growing jatropha, various state governments have announced Minimum Support Price (MSP) for jatropha seeds. The Minimum Purchase Price (MPP) offered by the oil marketing companies acts as a guarantee to the biofuel (both bioethanol and biodiesel) manufacturers against price troughs. Various subsidy programs and tax concessions/exemptions are also part of the government's effort to speed up the partial transition from fossil fuels to biofuels. For instance, National Oilseeds and Vegetable Oils Development Board (NOVOD) under the Ministry of Agriculture, Government of India, is providing a back-ended subsidy of 30 per cent for the promotion of tree-borne oilseeds like jatropha and pongamia. Along with government, other non-state actors such as non-governmental organizations (NGOs), self-help groups (SHGs), co-operative societies, private entrepreneurs, and corporate bodies are also involved at various levels in the jatropha-based biodiesel value chain.

In spite of all these efforts, the progress of the jatropha-based biodiesel production program in totality is far from anticipations. The program lags behind in terms of coverage of jatropha cultivated area, yield potential of the plants, number of biodiesel production units, establishment of seed collection and delivery channels, biodiesel distribution channels, etc. Because of these reasons, progress has been found to be highly varied across the states in India. Though slow, all these promotional efforts are being carried out under the assumption of environmental benefits (Subramanian *et al*, 2005; Mandal and Mithra, 2004), benefits of creating income and employment opportunities (UNCTAD, 2006; Deepak, 2008; Clancy, 2008; Raju *et al.*, 2009) for local populations as brought out by some studies. However, in a divergent line of thinking, a few studies (Ariza-Montobbio and Lele, 2010; Moraa *et al*., 2009) have pointed at the negative socio-economic consequences of jatropha cultivation on the impoverished farmers, which in a sense are questioning the basic legitimacy of the program itself. Under this backdrop, the paper attempts to make an economic assessment along the jatropha-based biodiesel value chain in major jatropha producing states of India.

Methodology

The study used both primary and secondary data, but is predominantly based on the survey data collected from three major jatropha cultivating states, namely Rajasthan, Chhattisgarh and Uttarakhand, using pre-tested questionnaires. The primary data pertains to the cost of cultivation, yields, input sources, marketing practices and other economic and livelihood aspects regarding jatropha cultivation. From each state, one district each (Sikar district in Rajasthan, Bilaspur district in Chhattisgarh and Dehradun district in Uttarakhand) and then two blocks (administrative unit) within it were selected purposively based on the prominence of jatropha plantations. Three villages from each block, i.e. six villages from each district were selected randomly and finally ten jatropha growing farmers from each village were chosen randomly as respondents for conducting personal interviews. The detailed sampling design has been provided in Appendix 1. In all, 60 sets of jatropha plots were sampled from each state. The socio-economic profile of the sampled farmers has been presented in Appendix 2. The study team also visited two biodiesel manufacturing units, one each in Rajasthan and Chhattisgarh to obtain detailed information on jatropha processing aspects. In addition, information collected through personal meetings and discussions with various state department officials, *panchayat* committee members, faculty of agricultural universities, market intermediaries and corporate officials was also used. Various secondary sources like published reports and websites were also relied upon, in the process of writing the paper.

Jatropha Value Chain

The jatropha value chain consists of various activities starting from raising of nursery to distribution of biodiesel to end-users. Broadly, the activities can be classified into four categories, viz. farm production of seeds, seed marketing, biodiesel production, and biodiesel distribution. A typical jatropha value chain has been depicted in Figure 1.

Various stakeholders like government, producer farmers, market intermediaries, traders, biodiesel processers, distributors and consumers are involved in the jatropha chain, though minor regional variations are observed. The following section provides detailed discussions on the major activities in the jatropha value chain.

Farm Production of Jatropha Seeds

(a) Farming Models

Farm production of jatropha seeds is the first major activity in this value chain. Different models of jatropha cultivation were observed in the selected states and are presented in Table 1. The widely-seen model was the farmer-centric cultivation model where farmers cultivate jatropha in their own lands with some government assistance like provision of subsidized seedlings and other inputs, extension support, etc. This

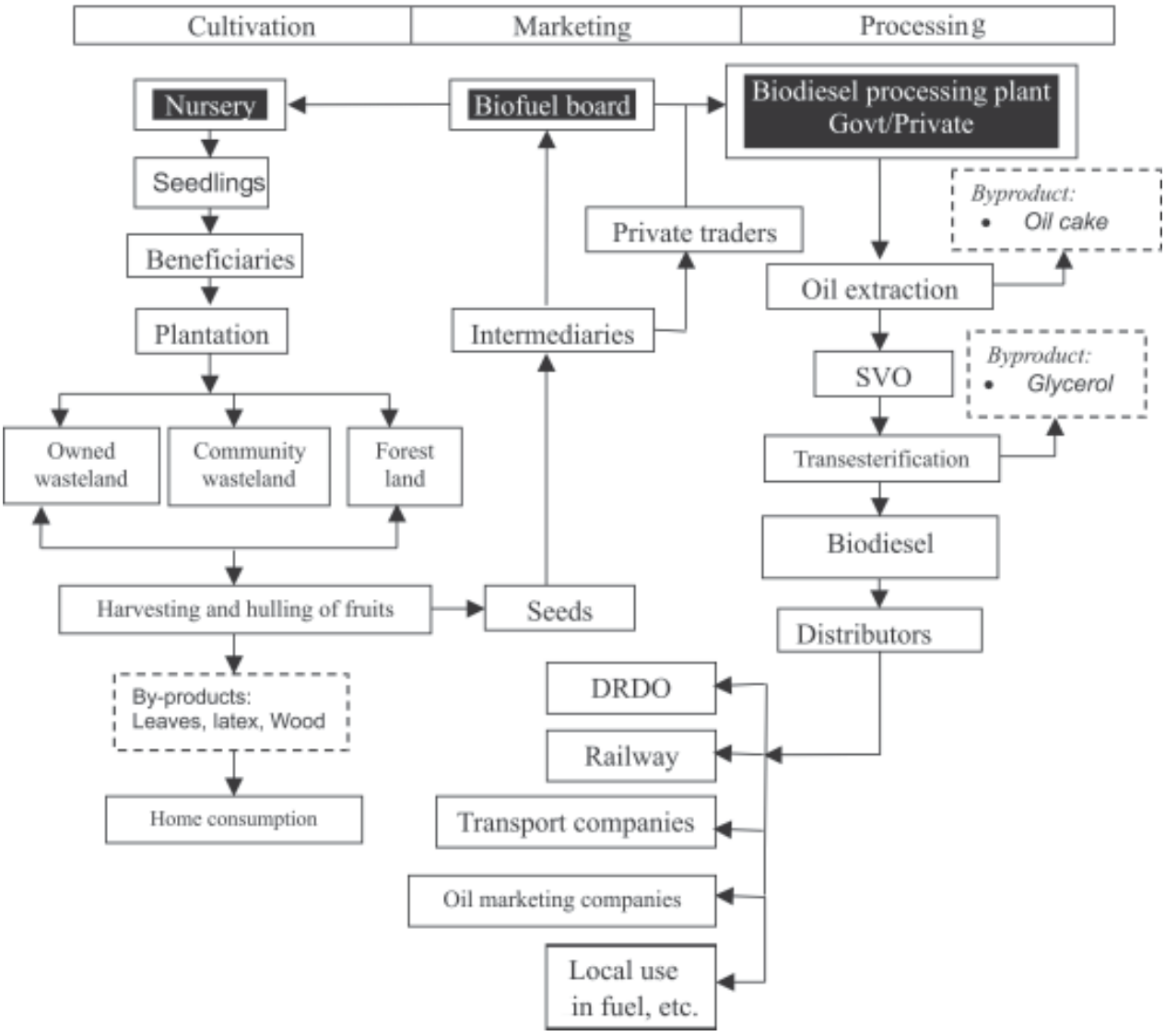

Figure 1. A typical jatropha-based biodiesel value chain: Schematic representation
DRDO: Defence Research and Development Organization; SVO: Straight Vegetable Oil

Table 1. Different models of jatropha cultivation at farm level

Operator	Land ownership	Rights on harvest	Government role
Farmer	Farmer	Farmer	Subsidy on seedlings
Farmer (SHG/JFMC)	Community	SHG/JFMC	Lease of land, subsidy on inputs, employment guarantee
Corporate	Private/Community	Corporate	Subsidy for setting up processing plants

was predominant in the Sikar district of Rajasthan and Bilaspur district of Chhattisgarh, where the surveys were conducted. Another common model was the government-mediated production wherein the community wastelands are leased out to local SHGs or Joint Forest Management Committees (JFMCs). The farmers, as members of SHGs or JFMCs, are granted rights to cultivate and harvest jatropha seeds. Various governmental bodies like National Oilseeds and Vegetable Oils Development Board, state biofuel boards[1], forest departments, etc. are instrumental in sustaining the activities. The government extends substantial encouragement to the farmers by providing inputs like free or subsidized seedlings, other inputs like fertilizers and manures, follow-up and monitoring support for plant maintenance, marketing support, etc. Also, the labour involved in the initial establishment is being sourced under Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) by paying mandatory wages. This practice is under operation in 11 districts of Rajasthan, 9 districts of Uttarakhand and several districts of Chhattisgarh. A number of recognized NGOs are also active participants in this model of cultivation, by being involved in different promotional activities.

The third was the corporate, business-oriented model of cultivation. *Estate Farming* and *Contract Farming* were the two variants within this model. In the *Estate Farming* model, large corporate companies like D1 Mohan Biofuels Ltd. based in Chhattisgarh and Tamil Nadu, Nandan Biometrics in Andhra Pradesh and Jain Irrigation Systems Pvt. Ltd. in Maharashtra cultivate jatropha in either their own land or community land leased-in from the local *panchayats*. In this model, the company employs the local villagers to cultivate the crop and the right to harvest rests with either the company or is shared with the *panchayats*. *Contract farming* mode of operation with buy-back arrangements with the farmers was also found prevalent in some parts of jatropha-growing areas. In this mode, the company provides inputs, technical guidance and other extension services during the initial years of establishment. The contracts can be reached either at a pre-decided price for the seeds or just with the understanding that the company will purchase the seeds at the prevailing market price. Some public sector undertakings like Indian Oil Corporation (IOC), Oil and Natural Gas Corporation (ONGC) and private bodies like Indian Farmers Fertilizer Cooperative Limited (IFFCO) have also recently entered into contract farming arrangements with the farmers.

(b) Agronomic and Economic Performance at Farm Level

Agronomic and economic assessments of jatropha cultivation were carried out based on the primary data collected from the states of Rajasthan, Chhattisgarh and Uttarakhand. A majority of the jatropha farmers in the surveyed area fell under the category of marginal and small farmers. Some medium category farmers were also involved in growing of jatropha but large category farmers were totally absent. In Uttarakhand, only the marginal farmers were involved under government-mediated cultivation. The average plot size was of less than one quarter of a hectare in Rajasthan, while it was a little more than half a hectare in Chhattisgarh. The highest area under any SHG in Uttarakhand was of 8 ha and the lowest was of 2 ha, with an average size of 3.87 ha (Table 2). The age of seedlings had crossed three years in Rajasthan, nearing 3 years in Chhattisgarh and was more than four years in Uttarakhand. The density of jatropha seedlings and their survival were observed much higher in Chhatisgarh than in other states, resulting in a higher yield per hectare in Chhatisgarh. The yield estimates were consistent with the yield estimates reported under moderate management conditions (Paramathma *et al.*, 2009).

[1] Biofuel Authority (BFA) in Rajasthan, Chhattisgarh Biofuel Development Authority (CBDA) in Chhattisgarh and Uttarakhand Biofuel Board (UBB) in Uttarakhand.

Table 2. Details of jatropha cultivation at farm level in selected states

State	Farmer category[£]	Area under jatropha (ha)	Age of seedlings (years)	Number of seedlings per ha	Survival rate of seedlings (%)	Yield (t/ha)
Rajasthan	Marginal (26)	0.08	3.4	1850	73	2.01
	Small (22)	0.10	3.0	1910	79	2.41
	Medium (12)	0.26	3.6	2146	84	2.92
Chhattisgarh	Marginal (6)	0.72	2.8	3657	86	2.52
	Small (36)	0.60	2.7	2558	87	2.62
	Medium (18)	0.72	2.7	2264	84	2.70
Uttarakhand	Marginal (60)	3.87*	4.5	2054	61	2.22

Notes: *Community area allotted to self-help groups where marginal farmers were growing jatropha.
[£]Marginal: Less than 1 ha; Small: 1-2 ha; Medium: 2-10 ha.
Figures within the parentheses indicate number of sample farmers in each category

The initial establishment activities of jatropha cultivation during the first three years were found to create employment for 85-108 human days in the selected states under moderate management conditions (Table 3). An additional human day labour per 50 kg of pods harvested was required from the third year onwards. Therefore on an average, employment for around 40-50 human days would be created per hectare per year as the plants start yielding, and it would further increase as the plants reach maturity. In all sampled households, more than 80 per cent of labour used in jatropha cultivation was from the family. In all the three states, farmers were found to apply fertilizers and manures only in the first year. The farmers applied both manures and fertilizers in Rajasthan, while in the other two states, they applied only manures. The plants were irrigated during the initial 2-3 years, but with varying intensity in different states. In Rajasthan, around 40 per cent farmers irrigated three or more times during the initial years, while 48 per cent famers irrigated twice and rest 12 per cent only once. In Chhattisgarh, around 43 per cent farmers irrigated twice, while 57 per cent irrigated only once in the first year. In contrast, in Uttarakhand, all farmers irrigated only once in the first year leaving the crop rain-fed in the rest of the years. None of the farmers in any of the locations was found to follow any crop protection measures.

It is seen from Table 2 and Table 3 that use of inputs was much higher in the state of Rajasthan (except seedling rate) than in Chhattisgarh and Uttarakhand; but even then the yield was lower in Rajasthan than in the latter states. It was because of soil structure with low water-holding capacity, poor soil fertility and climate conditions prevailing in Rajasthan.

The economics of jatropha cultivation was found to vary considerably depending upon the state policy on subsidy of seedlings and other inputs as is evident from the cost of cultivation figures for the three states presented in Table 4. While Rajasthan farmers incurred a cost of around Rs 31,295/ha, during the first year, the estimates for Chhattisgarh and Uttarakhand were Rs 8,319/ha and Rs 12,050/ha, respectively. This can be attributed to the inter-state variations in subsidies on seedlings and other inputs, variations in labour charges, differential usage of inputs, etc. The farmers in the Sikar district of Rajasthan had to pay Rs 6-10 per seedling as they did not get any subsidy from the state government[2]. The cost of seedling alone came around 35 per cent of their total cost. In contrast, Chhattisgarh farmers were getting seedlings at a highly subsidized rate of Rs 0.50 per seedling and the Uttarakhand farmers were provided hundred per cent subsidy on seedlings. Wage rate was another major component of cultivation cost and it also varied across states (wage rates in Rajasthan, Chhattisgarh and Uttarakhand were Rs 150, Rs 50 and Rs 120 per day, respectively). These differences also got manifested in profits, pay back period etc. and indicated the differential level of

[2] Rajasthan government provides jatropha seedlings at subsidized rate under the government-mediated jatropha cultivation program operational in only11 districts, in which Sikar district does not fall.

Table 3. Input application pattern during initial period of establishment of jatropha in surveyed plots

State	Labour (human days/ha)*			Manure	DAP£	Per cent farmers irrigating/year		
	Family	Hired	Total	(t/ha)	(kg/ha)	Once	Twice	Thrice or more
Rajasthan	90	18	108	1.90	150	12	48	40
Chhattisgarh	85	12	97	1.60	0	57	43	0
Uttarakhand	71	14	85	0.80	0	100	0	0

Notes: Farmers applied manures and fertilizers only in the first year in all three states.
*Labour incurred during first three years for planting, fertilizer and manure application, irrigation, etc.
£Only 35 per cent of the farmers applied fertilizer (di-ammonium phosphate) while planting in Rajasthan.

Table 4. Economic analysis of jatropha cultivation in selected states

(Rs/ha)

Particulars	Rajasthan			Chhattisgarh			Uttarakhand		
	I year	II year	III year onwards	I year	II year	III year onwards	I year	II year	III year onwards
Land preparation	1125	0	0	375	0	0	900	0	0
Digging pits	5625	0	0	2125	0	0	4800	0	0
Sapling cost	11250	1500	0	1065	225	0	0	0	0
Planting	3000	375	0	1125	375	0	2400	0	0
Manuring	3125	0	0	2375	0	0	2400	0	0
Fertilizer	3325	0	0	0	0	0	0	0	0
Irrigation	1000	1000	1000	500	0	0	500	0	0
Harvesting	0	0	6750	0	0	2500	0	0	5400
Sub-total	28450	2875	7750	7565	600	2500	11000	0	5400
Incidentals (10%)	2845	288	775	756	60	250	1050	0	540
Total cost	31295	3163	8525	8321	660	2750	12050	0	5940
Gross returns	0	0	17812.5	0	0	17875	0	0	13500
Net returns	**-31295**	**-3163**	**9288**	**-8321**	**-660**	**15125**	**-12050**	**0**	**7560**

Notes: The figures are averages across sampled farmers.
Cost of fertilizer: Rs 9.50 / kg of DAP and manure @ Rs 500 per tonne.
Cost of irrigation: Rs 500 per irrigation per hectare
Price of jatropha seeds: Rs 7.50/kg in Rajasthan, Rs 6.50/kg in Chhattisgarh and Rs 6/kg in Uttarakhand.

incentives for jatropha cultivation in different locations in India.

The above analysis shows that the break-even period and profitability of jatropha cultivation will depend on the price policy of seedlings, seeds and oil of jatropha. In Rajasthan the farmers may take 5-6 years to cover the initial establishment cost, while in Chhattisgarh and Uttarakhand, farmers start realizing profits from the third year of crop plantation.

Considering the long-term nature of investment in jatropha cultivation, a few discounted measures of financial assessment like net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) were worked out for the selected states and are presented in Table 5. The long-term prospects of jatropha cultivation were found promising in all the three states due to low recurring costs associated with farm management[3]. In relative terms, the farmers of Chhattisgarh would benefit more than those of other two states due to lesser initial investment, minimal input usage and lower wage rates prevailing there. However, it is cautioned that this analysis would hold only if the current parity of seed prices is maintained in the future also.

Table 5. Financial measures for assessing the feasibility of investment in jatropha cultivation

Period	Rajasthan			Chhattisgarh			Uttarakhand		
	NPV (Rs)	BCR	IRR (%)	NPV (Rs)	BCR	IRR (%)	NPV (Rs)	BCR	IRR (%)
Year 5	-12197	0.76	-5	22033	3.47	72	5105	1.19	24
Year 10	17461	1.23	20	61023	6.13	85	26853	1.63	42
Year 15	35876	1.39	24	85233	8.17	85	40358	1.75	44
Year 20	47310	1.47	25	100265	10.18	85	48743	1.81	45

Note: A 10 per cent discount rate was used for the calculations

None of the sampled farmers in any of the three states reported any case of crop land being substituted for jatropha cultivation. Farmers who cultivated jatropha in their own lands used only waste or fallow lands which were previously lying unused. Some farmers cultivated jatropha as fences around the crop lands. Some farmers in Rajasthan and Chhattisgarh did express concern about the loss of grazing land for cattle due to jatropha cultivation, it being an animal deterrent crop. The loss of common grazing land could result in the shortage of fodder and thus could negatively affect the livestock economy in the jatropha growing areas as has been reported in a recent study conducted in Tamil Nadu by Ariza-Montobbio and Lele (2010). A majority of the farmers were of the opinion that the currently available germplasm is low-yielding with long gestation period and the government has to take necessary steps to develop high-yielding varieties. They also believe that the full yielding potential of jatropha cultivation would only be realized when adequate irrigation and fertilizers are made available; presently, it is not a profitable proposition due to low prices of jatropha seeds. The ability of jatropha to prevent soil erosion in the hilly terrains was also brought into notice. In a nutshell, the farmers considered jatropha not as a major profit winning crop but only a supplementary crop that provides them with additional employment and income, that too with government support during the initial years of establishment.

Seed Marketing

The farm-produced jatropha seeds take different routes to reach the processing plants. Largely three types of actors are involved in this activity: (i) government agents who collect the seeds on behalf of the state biofuel boards or government-owned processing plants, (ii) local traders who collect the seeds and then supply to the processing plants or their agents, and (iii) corporate agents who collect seeds directly from the farmers.

In the Sikar district of Rajasthan, all the sampled farmers sold the seeds to local traders only (Table 6). In most cases, petty shopkeepers were involved in collection of seeds from the farmers; they either transported them to processing plants or sold to the company agents who procured the seeds in bulk. At some instances, these seeds were even transported to Chhattisgarh to be used in raising nurseries for new planting. In Chhattisgarh, farmers in the Kota block of Bilaspur district sold seeds to government agents, while those of Marwahi block marketed the seeds to the private company agents. The farmers could get a higher price of Rs 10.00/kg for their seeds from the private company, but they got only Rs 6.50-7.00/kg when they sold the seeds to the government agents. The State Biofuel Boards also used the seeds for both processing and raising new plantations. In Uttarakhand, where the government mediated production was dominant, farmers sold the seeds only to the government agents at a price of Rs 6/kg. It was noted that in places where local traders were involved in jatropha seed procurement, the marketing margin was considerably high. In Rajasthan, the price at which the processing plant[4] purchased the seeds from traders was around Rs 12.00-13.00/kg, whereas the farmers sold the seeds at the rate of Rs 7.50 to Rs 10.00/kg, depending on the locality. It means that the marketing margin between the farmers and the processing plant was around Rs 3.00- 5.50/kg. This margin included both the traders profit and costs on transportation and handling. To avoid

[3] The future costs were worked out based on the present package of practices being followed by the farmers as obtained from the surveyed data.

Table 6. Marketing of jatropha seeds and price received by farmers across states

State	Share of seeds marketed to different agencies (%)		
	Government agents	Local traders	Private companies
Rajasthan	0	100 (7.50)	0
Chhattisgarh	50 (6.50)	0	50 (10.00)
Uttarakhand	100 (6.00)	0	0

Note: Figures within the parentheses indicate prices received by farmers in Rs/kg

this extra margin, some private processing plants were procuring the seeds directly from the farmers by paying a higher price, as was in the case in Chhattisgarh.

Seed Processing and Biodiesel Production

Seed processing infrastructure is one of the key requirements in the jatropha seed-based biodiesel value chain and is presently a major constraint holding back the development of the biodiesel sector in India. In most of the jatropha-growing areas, modern processing plants have not come up in sufficient numbers so far. This is because of two major reasons; first, the government intends to bring private participation to build this capacity but the private players visualize potential risks in investing in this area because of uncertainty regarding the supply of sufficient feedstock and market demand for biodiesel. Second, the unavailability of processing capacity is making the farmers to down-scale their production and this poses threat to even the existing processing plants. The cost of production of biodiesel increases substantially if the units are run under low economies of scale. The problem worsens with increase in the price of seeds due to the involvement of middlemen and higher transportation costs when the seeds are sourced from distant places. To substantiate these points, the cost of production of biodiesel in two processing plants, viz., Rajasthan State Mines and Minerals Ltd. (RSMML) biodiesel plant in Udaipur and Chhattisgarh Biodiesel Development Authority (CBDA) processing plant at Raipur was compared in the study[5].

The physical and monetary details regarding input requirement per day and corresponding production of biodiesel and other byproducts in the two manufacturing plants have been presented separately in Table 7. The RSMML plant has crushing capacity of 1 tonne jatropha seeds while capacity of CBDA plant was 10 tonnes. The recovery of biodiesel was higher (273 kg/t) in CBDA plant than in RSMML plant (250 kg/t) because of economics of scale in plant operation. The cost of biodiesel production in RSMML facility was around Rs 40 per kg, whereas in CBDA unit it was nearly Rs 19 per kg, the difference being significant. However, there were multiple reasons behind the cost difference. In Rajasthan, the cost of seeds at factory gate was around Rs 12/kg because of the reasons stated above. In contrast, the CBDA unit could procure the seeds at Rs 6.50/kg directly from the farmers and incurred nominal costs on handling and transportation as sufficient seeds was available in the nearby locality. In addition, the economy of scale favoured the CBDA processing plant in bringing down the cost in comparison with the RSMML plant. The RSMML plant also faced shortage of seeds in spite of the fact that sufficient seeds are produced in Rajasthan, the reason being diversion of seeds for nursery raising under government support. Due to all these constraints, the RSMML plant is on the verge of closure and currently uses the produced biodiesel in the company's own fleet of trucks.

The above discussion makes it clear that, if processed at sufficient levels of economies of scale, as in the CBDA processing plant, jatropha based biodiesel is economically viable and can substitute petro-diesel, with a current price of Rs 18-20 per litre san taxes. The technology would prove more profitable in the event of further hikes in price of crude oil. However,

[4] The Rajasthan State Mines and Minerals Ltd. (RSMML) owned jatropha processing plant at Udaipur.

[5] In Uttarakhand, a transeterification unit having capacity of 50 Mt per day oil has been established by Uttarakhand Biofuel Ltd. (UBL) at Haridwar. However, since the study team could not gain access to their data, details are not presented here.

Table 7. Cost of production of biodiesel in Rajasthan and Chhattisgarh — A comparative study

Inputs	RSMML plant		CBDA plant	
	Quantity	Value (Rs)	Quantity	Value (Rs)
Jatropha seeds	1 tonne / day	12000	10 tonnes / day	65000
Unskilled labour	2 human days	300	6 human days	720
Managerial labour	1 human day	450	1 human day	600
Administrative labour	1 human day	250	4 human days	1600
Chemicals				
Methanol	60 litres	630	600 litres	6600
Sodium hydroxide	2 kg	50	21 kg	540
Electricity	25 units	250	250 units	2500
Interest on fixed capital	@ 10%	650	@ 10%	6800
Depreciation on machinery	@ 10 %	270	@ 10 %	1700
Depreciation on other assets	@ 4 %	440	@ 4 %	2740
Freight and other incidentals		350		6500
a.Total cost		15640		95300
Revenue from byproducts				
Glycerol	46 kg	1380	467 kg	10274
Oil cake	700 kg	4200	6750 kg	33750
b. Total revenue		5580		44024
Net cost incurred (a-b)		10060		51276
Recovery of biodiesel per tonne of jatropha seeds	250 kg		273 kg	
Net cost / kg of biodiesel		**40.24**		**18.78**

it is mandatory to build up the necessary infrastructure in places where the feedstock crops are growing well and where a future potential is visible. In this context, private sector has a major role to play. Several private companies like Nova Biofuels, Panipat; Emami Biotech, West Bengal; Universal Biofuels, Andhra Pradesh; Royal Energy; Mumbai and many others have already shown their presence in the field. A demand pull arising out of mandatory blending requirement can be a strong stimulus to such initiatives. But, even though a necessary step, it is not sufficient to sustain the momentum in developing the sector. Rather developing a full-fledged value chain, from farm production of jatropha seeds to distribution of biodiesel, is equally important and critical. The next section outlines the current state of affairs regarding the identified biodiesel distribution chains in India in general and in the selected states in particular.

Biodiesel Distribution

Presently, the biodiesel distribution does not follow any well-developed supply chain, even though several public sector undertakings and private companies have ambitious plans to enter into the sector in a big way. As of now, the consumers of biodiesel in the country include Indian Railways, Defence Research and Development Organization (DRDO), state road transport corporations, some private companies, etc. Other than this, local consumption in tractors, trucks, diesel pump sets, etc. is also prevalent. Public sector oil marketing companies (OMCs) like Hindustan Petroleum (HP), Bharat Petroleum (BP), IOC and ONGC are in the process of setting up an extensive network of biofuel distribution chain connecting various processing industries and retail outlets across the country. However, presently they are concentrating more on developing jatropha plantations through contract farming arrangements with local governments and farmers. Some efforts of establishing commercial tie-ups with private companies for setting up processing capacity are also underway. The Indian Railways, have started using 5 per cent blend of biodiesel in narrow gauge engines. A separate body 'Indian Railways Organization for Alternate Fuels' (IROAF) instituted under the Indian Railways is building networks with potential biodiesel suppliers like Southern Online, Hyderabad and Royal Energy, Mumbai. Several state transport corporations like Andhra Pradesh State Road Transport Corporation (APSRTC), Navi Mumbai Municipal Transport Corporation (NMMTC), Uttar Pradesh State Road Transport Corporation (UPSRTC), Calcutta Tramways Company Ltd, etc. have also

started blending biodiesel with HSD in their fleet of buses. The Kolkata Police Department has tied up with Emami Biotech for regular supply of biodiesel to be used in their wireless fleet.

An account of the status of biofuel distribution in the selected states is also provided based on the interviews conducted with the various stakeholders in these states. In Rajasthan, RSMM is the only major jatropha oil processing unit, though some smaller oil expelling units are also working locally. RSMML utilizes the produced oil only in its fleet of trucks due to lack of cost-effectiveness in production. The Rajasthan State Road Transport Corporation (RSRTC) is sourcing biodiesel from some local small-scale biodiesel units to conduct pilot runs in their buses. Along with this, some farmers are using Straight Vegetable Oils (SVO) made from jatropha in their tractors and diesel pumps. The CBDA processing plant in Chhattisgarh is supplying the biodiesel produced in its unit to Indian Railways, DRDO, Mahindra and Mahindra Ltd. and some transport companies within the state. Some village electrification committees based in Chhattisgarh are also using biodiesel to cater the local electricity needs. In Uttarakhand, commercial use of biodiesel is yet to be started. Currently, it is only used for meeting local energy needs.

Addressing the Constraints

The above discussion makes it clear that the development of a commercial biodiesel industry based on jatropha and other non-edible oilseeds is at a very nascent stage in India at present. The farm surveys have suggested that the farmers are not happy with the current yield of the crop. To address this constraint, identification of superior germplasm with high-yield potential through systematic varietal improvement programs is a pre-requisite to large scale planting. A centrally coordinated breeding program that replaces the current piecemeal approach in research can pay high dividends. It is also widely felt that jatropha is not a fully domesticated crop and cannot be grown successfully in all kinds of marginal lands. Unscrupulous planting irrespective of the geographical and climatic contours can only sabotage the program. Most of the jatropha growing farmers being marginal, small or resource-poor, initial support in the form of subsidized seedlings and other inputs, technical assistance, buy-back assurance, minimum support price (MSP), etc. is of utmost importance for the success of biodiesel production. Premature withdrawal of support facilities may jeoparadise the program. Economic viability of jatropha plantations is critical in retaining the interest of the farmers. Higher prices of seeds are being realized presently because of their demand for seedlings of new plantings. However, once this phase is over, there is every chance of prices going down unless a jatropha seed market with both backward and forward integration is evolved. The probability of the program to topple down would be higher if this transformation does not happen in the course of time. The promoters of this industry including various government organizations, OMCs, private enterprises, NGOs, etc., seem to be concentrating too much on increasing the area under the crop. But simultaneously, it is also vital to develop stable supply chains so that the feedstock produced is effectively marketed, processed and brought to the end-users. Even though some progress has been made in terms of area coverage, the processing infrastructure is way less than optimal. Moreover, most of the existing processing facilities are working under sub-optimal capacities. An area-wise critical assessment should precede investing in processing infrastructure so as to fully utilize the economies of scale in processing. Also, a demand pull for biodiesel is lacking due to which distribution channels are not well defined. Since cost-effectiveness of biodiesel also depends on the revenue from its by-products like oil cake and glycerin, simultaneous expansion of by-product markets is also equally important.

Conclusions

It is too early to judge the success of India's biofuel program though it was launched seven years ago. There are too many unknowns at this stage particularly about the jatropha based biodiesel program. Still, farm studies suggest that jatropha is a profitable crop in the long-run, provided, government support in the form of input subsidies and technical and marketing assistance is made available during the initial few years. The farmers consider jatropha as a supplementary crop which can augment their income and employment to a certain extent but are also concerned about the uncertainty regarding its yield potential, long-term economic viability essentially linked with a sustained demand for seeds, undesirable externalities like loss of common grazing land, etc. On the seed processing front, biodiesel can compete with petro-diesel if the processing

plants are operated at sufficient economies of scale. This can be realized by ensuring a stable supply of feedstock and consistent market demand of biodiesel and its byproducts. Proper backward and forward integration at each level of the supply chain is therefore crucial in making the biodiesel industry operate at economically viable scale. So far, the participation of corporate sector in developing the processing infrastructure and distribution channels has been feeble. Necessary steps have to be taken to bridge this gap. A centrally co-coordinated mechanism to supervise research, extension, development of processing and market infrastructure and various other assistance programs should replace the existing piecemeal approach. Legal provisions to check a possible diversification of jatropha area towards food crops is also worth considering. To conclude, proactive orientation of all the stakeholders is critically important in sustaining the momentum of the program and to contribute towards the efforts to find answers for the perennial concerns of energy security, environmental sustainability and poverty reduction in the country.

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Appendix 1

Sampling design in the selected states

State	District	Administrative Block	Villages
Rajasthan	Sikar	Sikar	Rakaipura
			Piprali
			Shivrankabas
		Shrimadhopur	Lasadia
			Hathidea
			Hanumanthpura
Chhattisgarh	Bilaspur	Kota	Basajall
			Kanchanpur
			Mazawani
		Marwahi	Danikundi
			Rumga
			Kotmi
Uttarakhand	Dehradun	Kalsi	Chapnu
			Dhodav
			Amraya
		Raipur	Bhopalpani
			Kallimitti
			Sodasaroli

Appendix 2

Socio-economic profile of sample farmers in the selected states

Parameter	Rajasthan	Chhattisgarh	Uttarakhand
Average age of farmers (years)	46.3	42.6	33.2
Average household size(No.)	9.0	5.3	7.9
Literacy (%)	38.3	66.6	23.3
Total operational holding (ha)	1.60	1.56	0.80
Irrigated area (%)	60.0	48.7	0.0
Total annual income (Rs)	187261	91182	145588
Share of income (%) from			
a. Crop	23.7	52.9	9.1
b. Livestock	44.1	7.6	15.4
c. Jatropha	1.7	18.4	45.1
d. Non-farm sources	30.5	20.9	30.4