Water Policy 10 Supplement 1(2008) 95–106

Implications of India's biofuel policies for food, water and the poor

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Received 15 July 2007; accepted in revised form 25 September 2007

Abstract

Increasing consensus about the end of cheap oil, the consequences of global warming and the need for rural development are catalyzing the expansion of biofuels like ethanol and biodiesel. While most nations are promoting the expansion of conventional crops, India's strategy for biofuels is to promote *Jatropha curcas*, a drought-tolerant, perennial crop with little prior commercial track record. The aim of this paper is three-fold. (1) To compare the characteristics of various crops with their potential as biofuels in order to assess the relative advantages and disadvantages of *Jatropha curcas*. (2) To analyze the implications of current biofuel policies for food supply, agricultural water demand and the rural poor. (3) To highlight briefly some alternative strategies that can overcome drawbacks in the current strategy. One conclusion is that although *Jatropha curcas* has a low water requirement, which is an important benefit, it has several other disadvantages. Another recommendation that emerges from this paper is that biofuel policies should also focus on short-duration, multi-purpose and proven drought-tolerant crops like sweet sorghum that can be adopted by small landholders while wasteland rehabilitation policies should focus on broader array of options, which can provide greater direct benefits to the rural poor.

Keywords: Biofuel; India; Jatropha; Marginal land; Rural electrification; Sweet sorghum

1. Introduction

Increasing consensus about the end of cheap oil, the consequences of global warming and the need for rural development are catalyzing the expansion of alternatives like ethanol and biodiesel (henceforth referred to as biofuels). Several countries have already enacted laws that mandate the production of biofuels to meet future demand for transportation fuel (Kojima *et al.*, 2007). Since biofuels can be produced from a diverse set of crops, each country is adopting a strategy that exploits the comparative advantages it holds with respect to such crops. For example, sugarcane and maize are the main feedstock

doi: 10.2166/wp.2008.055

for ethanol in Brazil and USA, respectively together accounting for 90% of the global production of ethanol, while oil palm from Malaysia is the single largest source of biodiesel globally (Martinot, 2005).

The Government of India (GoI) has launched a National Mission on Biofuels with the aim of achieving a target of 20% blending of biodiesel by 2012 (GoI, 2003). Some key aspects of this policy are mentioned below. It should be pointed out that this target is however not mandated by law and is merely indicative of government preference at this point. The biodiesel is to be derived from vegetable oil produced from the seeds of the perennial shrub, *Jatropha curcas* which is to be planted on about 13.4 million ha of marginal land. The majority of these lands are classified as wastelands and are not under private control. The main justification behind the promotion of Jatropha and the targeting of wastelands seems to be the need to avoid competition of biofuels with food for land and water resources. It should be mentioned at the outset there is little commercial experience in the cultivation of Jatropha especially on marginal lands and conditions of severe water stress. Technical details about the characteristics of *Jatropha curcas* and its cultivation and processing technology can be found in a technical manual by the Tamil Nadu Agricultural University (TNAU, 2005).

The rest of the paper is organized as follows. Section 2 compares the land and water intensities of some major biofuel sources today and also summarizes the relative advantages and disadvantages of the various crops. Section 3 analyzes the implications of the biofuel mission's emphasis on *Jatropha curcas* and on marginal lands for food, water, energy and poverty. Section 4 describes some alternative strategies for biofuel production and wasteland rehabilitation. Section 5 concludes the paper.

2. Comparison of land and water intensity for potential biofuel crops

Section 2.1 compares the land and water intensity needed for various crops suitable for biodiesel production, while Section 2.2 compares crops that are suitable for ethanol production. The data presented in this section was collected from a wide variety of sources including the FAO online statistical database[1], the web pages of the national oil boards of Malaysia and Philippines, the Directorate of Economics and Statistics[2], Ministry of Agriculture, Government of India and other publications (they can be made available in detail by the author upon request). It should be borne in mind that point estimates such as these conceal large variability, which might be observed in reality. Average values are however still relevant for the kind of conclusions that we hope to draw from this analysis.

2.1. Comparison of crops for biodiesel production

Table 1 shows, among other things, the annual water requirement, oil yield per hectare and oil yield per unit of water input for some major oil seed crops that could be used for producing biodiesel in India. The table shows that among the existing commercial crops (which exclude Jatropha and Pongamia) oil palm and coconut have the highest oil content, oil yield per hectare and also high water productivity. But the high water requirement renders them unsuitable for conditions in most parts of India. In fact oil palm acreage in India is insignificant compared to other crops, while coconut plantations area confined to coastal areas with high rainfall such as Kerala and a few other places with good water resources.

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[1] www.faostat.fao.org

[2] http://dacnet.nic.in/eands/agstat06–07.htm

Table 1. Land and water intensity of major oil seed crops.

Oil seed crops	Water required (mm/yr) (low)	Water required (mm/yr) (high)	Trees per hectare	Average Crop yield kgs ha^{-1}	Oil content as % of seed weight	Average oil yield in kg ha^{-1}	Oil yield per mm of water	Time to full maturity	Useful life (years)	Indian acreage (million ha)
Coconut	600	1,200	175	7,800	60	5,000	5.56	5 to 10 years	50	1.86
Oil palm	1,800	2,500	150	20,000	25	5,000	2.33	1 0 to 12 years	25	insignificant
Groundnut	400	500	na	1,015	50	508	1.13	100 to 120 days	na	7.2
Rapeseed	350	450	na	830	40	332	0.83	120 to 150 days	na	6.6
Castor	500	650	na	1,100	45	495	0.86	150 to 280 days	na	0.8
Sunflower	600	750	na	540	40	216	0.32	100 to 120 days	na	2.3
Soybean	450	700	na	1,105	18	199	0.35	100 to 150 days	na	7.2
Jatropha*	150	300	2,000	2,000	30	600	2.67	3 to 4 years	20	insignificant
Pongamia*	150	300	1,000	5,000	30	1,500	6.67	6 to 8 years	25	insignificant

*Estimates that are typically cited. na, data not available or not applicable.

The major oil seed crops in India in terms of acreage are groundnut, soybean, rapeseed and sunflower, which are used for production of edible oils. The residual oil cake, which is a co-product of oil extraction, is valuable as animal feed. On the positive side, these crops have a low water requirement and a short growing season. But from a biodiesel perspective, they have a lower oil yield per hectare than oil palm and coconut and are also more valuable as cooking oils.

Castor has the advantage of being a non-edible oil crop and the ability to grow under harsh conditions. Although limited production and high prices limits its use as a biodiesel feedstock, with higher production and lower prices castor can be expected to compete with other biodiesel feedstock. It however has a low productivity with respect to land and water compared to other non-edible crops like Jatropha and Pongamia. *Jatropha curcas* and *Pongamia pinnata* are estimated to have low water requirement, a high yield per unit water and higher oil yield per hectare than the existing annual oil seed crops. In addition they are also considered suitable for dry and semi-arid regions with scanty rainfall. Like most tree crops they have the disadvantage of a long growth period, which can be a barrier to adoption especially by small landholders. This is one of the reasons why, despite higher productivity with respect to land and water, Pongamia is not likely to be adopted as a commercial crop on a large scale. The above discussion reveals some plausible reasons behind the selection of Jatropha as the main biofuel crop. Nevertheless since claims about the yield of Jatropha under conditions of poor land quality and water scarcity are yet to be verified, there is a great deal of risk and uncertainty in a strategy that is developed on the basis of conjectures or small-scale trials.

2.2. Comparison of crops for ethanol production

Table 2 shows the annual water requirement, gasoline equivalent ethanol yield per hectare and ethanol yield per unit of water input for select crops in India. Wheat comprises the largest acreage but it is not suitable for ethanol production given its importance as a food crop and its low yield per unit of land and water. Production of ethanol from wheat in Europe is being sustained through a combination of subsidies for domestic producers and tariffs on imported ethanol (OECD, 2006). Compared to wheat, sugarcane has a much higher yield of ethanol per unit of land and water. But expansion of sugarcane faces major barriers because of its higher water requirement. Sugarcane is grown almost entirely under irrigated conditions in India unlike Brazil where it is rain-fed. Maize, despite being the single largest source of ethanol globally, also does not hold comparative advantage in India.

Sorghum, the most important cereal crop in dry and semi-arid regions of the world is widely cultivated in India but it faces two main challenges: one is a low ethanol yield per hectare and second, its use as food by the poor and as feed for livestock in some of the poorest regions in India. Sweet sorghum, a variant of grain sorghum, is today used mainly as livestock fodder in parts of China[3]. The stalks of sweet sorghum are rich in sugar, which can be processed to produce ethanol. Sweet sorghum has also been called "a camel among crops", owing to its wide adaptability, its marked resistance to drought and saline-alkaline soils and tolerance to water logging. Like Jatropha, one drawback is the lack of prior experience with cultivation. It is not commercially grown on a large scale in India today.

Sugar beet, the main crop for producing sugar and ethanol in Europe, is not suited to the agro-climatic conditions in India and is being grown only on an experimental basis. Bagasse, the fibrous residue that

[3] http://www.fao.org/ag/magazine/0202sp2.htm

Table 2. Land and water intensity of potential sources for ethanol.

Ethanol feedstock	Water required (mm/yr) (low)	Water required (mm/yr) (high)	Crop yield (tonnes ha^{-1})	Ethanol conversion efficiency (l $tonnes^{-1}$)	Gasoline equivalent ethanol yield (l ha^{-1})	Ethanol yield per mm of water	Growing season (months)	Indian acreage (million ha)
Sugarcane	1,500	2,500	70	70	3,300	1.65	10–12 months	3.6
wheat	450	650	2.6	340	600	1.09	4–5 months	26.5
Sorghum	450	650	1.8	390	450	0.82	4–5 months	9.4
Maize	500	800	1.8	360	450	0.69	4–5 months	6.3
Sweet Sorghum	450	650	40	70	1,900	3.45	4–5 months	insignificant
Sugar beet	550	750	100	110	7,370	11.34	5–6 months	insignificant
Bagasse*	na	na	18.9	280	3,550	na	na	na

* Estimates that are typically cited. na, data not available or not applicable.

results when sugar cane is processed into sugar, is another promising source given its high conversion efficiency. But there are two important considerations. First, this requires commercialization of cellulosic conversion technology, which is still at the research and development stage. Second, bagasse is widely used for generation of steam and electricity for process heat in sugar mills. Therefore despite being a residue, there is an opportunity cost associated with it like cultivated energy crops.

To conclude this section, when one compares the major crops keeping in mind the various desirable characteristics such as high productivity with respect to land and water, suitability to drought-prone and marginal lands, usefulness as food crop, and so on. *Jatropha curcas* and sweet sorghum seem promising crops for biofuel production. Next let us investigate the implications of cultivation of a crop like Jatropha on marginal lands for food, energy and the livelihood of the rural poor.

3. Implications of biofuels for food, energy and income distribution

Much of the literature that analyses the impact of future biofuel expansion tends to focus on traditional agricultural crops, which are grown on private farmland (FAPRI, 2005; Rosegrant *et al*., 2006; OECD, 2006). There are two unique aspects of the biofuel mission in India as a result of which much of the current literature that exists on the impacts of biofuels is inadequate.

1. Emphasis on new crops: While most countries want to expand production of existing commercial crops like sugarcane, maize, oil palm, rapeseed and so on, the emphasis in India is on *Jatropha curcas*, a perennial crop that has not been commercially grown before (GoI, 2003).
2. Emphasis on marginal lands: More than 10 million ha of the targeted 13.4 million ha is to be comprised of degraded forests, cultivable fallows and other wastelands (GoI, 2003).

3.1. Implications for food supply and agricultural water demand

The implication of biofuels for food production will depend on several factors. These include:

- *Type of crop*: The diversion of a food crop such as corn or sugarcane to produce fuel will have greater impact on the supply of food compared to the use of a non-food crop such as Jatropha or switch grass for biofuel production. The recent increase in the price of corn tortillas in Mexico has been associated with an increase the production of ethanol in the USA (Economist, 2007). But since the oil from *Jatropha curcas* has little use for food, there will be little direct impact on food supply. However this can induce land use change (discussed next).
- *Land use change*: A change in land use away from a food crop to a non-food biofuel crop will also have an adverse impact on the supply of food. For example, the conversion of land under cultivation of wheat or sorghum to Jatropha can reduce the supply of food. In the USA, soybean acreage is expected to be lower on account of an increase in corn acreage and this is expected to raise the price of soy products (Ash & Dohlman, 2007). Similarly the conversion of pastures or rangeland into energy crops can also raise the price of livestock products. The conversion of land under cultivation of a crop like cotton, or idle lands can be expected to have much less impact on food supply. In this context, since Jatropha plantation is being targeted on wastelands, which are not under commercial cultivation, the impact on national food production will be insignificant.

- *Competition for water*: Like the impact on food supply, the impact of biofuels on demand for irrigation water will depend on several factors. If biofuel crops are cultivated under irrigated conditions, then this will increase the demand for irrigation. If supply of water is inelastic, which may be the case in water-scarce regions, this should lead to an increase in the optimal price for water and a reduction in the amount of water going to irrigation of food crops. But in reality the price of water is not determined by supply and demand and hence the former effect may not be noticed. If the cultivation of Jatropha takes place under rain-fed conditions, it should have little impact on irrigation demand. But while it may be true that trees are able to survive long spells of dry weather compared to short duration crops, even trees require well-spaced irrigation especially during the initial few years of development, barring which their growth and productivity is permanently affected. Scientific studies on horticultural crops have shown that irrigation regime has a significant positive impact on both yield and quality of fruits.

One study on Jatropha reports wide variation in seed yield ranging from 0.4 tonnes ha^{-1} to 12 tonnes ha^{-1} with the best yields having been reported only under irrigated conditions and intensive cultivation (Prayas, 2007). Personal communications with agronomists and field visits to agricultural experiment stations such as those at the Tamil Nadu Agricultural University, Coimbatore by the author revealed that trials are indeed being carried out under drip irrigation. As if in recognition of this fact, the state government of Andhra Pradesh is offering a 90% subsidy for drip irrigation sets for farmers cultivating Jatropha[4]. Rain-fed cultivation of Jatropha, while beneficial in terms of reducing irrigation water demand, will at the same time result in poor yield. Similar scenarios can be envisioned for other agricultural inputs such as chemicals and labor. But since supply of fertilizers and pesticides is relatively more elastic, the effect on food production will be pronounced.

The impact of changes in each of the above factors can be attenuated or accentuated by the following two factors.

- *Co-products*: The production of biofuel today is accompanied by co-products, which have a variety of uses like feed for livestock (distiller's dried grains (DDG) from corn or soy meal from soy bean), organic manure (oil cake from oil seed crops) and electricity (from sugarcane bagasse). In the case of corn ethanol, each bushel of corn (25.4 kg of corn)[5] yields 7.71 kg of DDG, which can be a substitute for grain corn as cattle feed. Bagasse, the fibrous residue after sugar extraction from cane is already widely used to generate steam and electricity in sugar mills. In the case of non-edible oil seeds like Jatropha, the co-product would be oil cake, which can be used as organic manure. It may therefore have no additional effect on the impact of food supply. It could argued that increasing the availability of organic fertilizer could have a positive impact on productivity.
- *Degree of integration with national and international markets*: The level of integration of a biofuel producing region with national and international markets will determine the net impact of biofuels on the local food supply. Under autarky every unit of land devoted to biofuel crop will lower food production, while if the region is well integrated with international markets then there will be little net impact since reduction in production can be offset through greater imports.

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[4] http://www.aphorticulture.com/apmip.htm
[5] kg - kilogram

All else remaining equal, the cultivation of Jatropha on marginal lands will have less impact on food production compared to cultivation on good quality lands, which are likely to be under production of food crops. But further empirical evidence is necessary for more rigorous verification of the qualitative conclusions that have been drawn here.

3.2. Implications for the poor

The impact of biofuels on the poor is often narrowly described in terms of the implications for food prices. This may be true as far as the impact on the urban poor is concerned. But from the perspective of the rural poor, even if at a local level, the impact of wasteland cultivation of Jatropha on food supply may be minimal (for reasons explained earlier), although there are likely to be several other important implications such as greater scarcity of fodder and fuel wood. This is because of the following reason.

Wastelands identified by the national mission for cultivation of Jatropha are *de facto* considered common property despite *de jure* government rights (Gundimeda, 2005). Research on common property resources (CPRs) has revealed that such resources play a vital role in the lives of the rural poor by supplying a wide variety of commodities like food, fuel wood, fodder, timber, thatching material for home roofing and so on (Ravindranath & Hall, 1995; Gundimeda, 2005). Gundimeda cites evidence from several studies (Jodha, 1990; Iyenger & Shukla, 1999; Beck & Ghosh, 2000) on CPRs in arid and semi-arid regions of India that show: (1) CPRs contribute between 12% and 25% of the poor household income; (2) the poorer the households, the more important the contribution of CPRs. In light of this evidence, the choice of crops and trees planted on wastelands is very important. Ignoring such considerations will increase hardship for the poor and give rise to conflicts with growers of biodiesel or other plantations on such lands. Jatropha has several drawbacks in this context. First, the leaves of Jatropha are not suitable for livestock, that is, not suitable as fodder.

The situation with regard to the severe shortage of fodder for livestock has in fact been deemed the "other food crisis" (Narain, 2005). Therefore Jatropha can aggravate the fodder crisis. Second, Jatropha yields insignificant amount of wood per tree. A case study of a Gujarat village showed that the poor collect 70% of their fuel and 55% of their fuel wood from CPRs (Chen, 1991). Therefore another spillover of Jatropha plantations could be deforestation of previously unexploited lands for fuel wood and fodder as the displaced seek new sources of supply. While biodiesel plantations may create new jobs in plantations, plantation of other crops or trees will also create new jobs. There is no evidence to suggest that Jatropha is more labor intensive than a plantation of Eucalyptus or other woody trees which can and have been grown on these lands (discussed in more detail Section 4). Moreover being a perennial crop, Jatropha will require less labor than an annual crop. The relative impact of biofuel crops on labor demand should be an area of future research.

4. Alternative strategies for biofuel production and wasteland use

The principal drawbacks of the current approach arise from two sources, namely, uncertainty in yield of Jatropha and the implications of wasteland use for the landless poor. Let us now consider some alternative options.

4.1. Short-duration, multi-purpose crops suited to private farmlands

In comparison with wastelands, India's net cropped area is about 140 million ha of which less than 30% is irrigated while the rest is rain-fed[6]. Farmers in dry and drought prone regions are unable to raise higher value crops like rice, wheat, sugarcane, edible oil seed crops and so on, owing to scarcity of water and are facing economic distress. The cultivation of biofuel crops that are both commercially valuable and yet not intensive in water needs can provide new opportunities for raising their income. While Jatropha or Pongamia seem to be suitable crops, the long maturation phase and the lack of experience can be a major barrier to adoption because of risk aversion. Sweet sorghum on the other hand has several advantages here.

- It has higher yield of biofuel per unit of land and per unit of water than sugarcane or Jatropha (see Tables 1 and 2). Sweet sorghum is estimated to have a water requirement (applied water) which is about one-quarter that of sugarcane (Reddy *et al.*, 2005). Although it has uses three to four times the water that is applied to Jatropha, the yield of fuel is also three times higher. Drip irrigation may have the potential to reduce further the water applied to sorghum. It has been proven to reduce the water requirement and improve productivity of sugarcane (Narayanamoorthy, 2004). And since subsidies for drip irrigation are beginning to be provided for Jatropha cultivation in the southern India state of Andhra Pradesh, it is then worth investigating the relative costs and benefits of cultivating sweet sorghum under drip irrigation.
- Sweet sorghum can be used to produce fuel without displacing food or feed since it is the sugar-rich stalk that is used for ethanol production leaving the grain intact for use as food or feed. Like with sugarcane, bagasse, the fibrous residue that remains after crushing the cane stalk can be used to generate electricity (Reddy *et al.*, 2005).
- Sweet sorghum has a growing season of 4 to 5 months compared to a whole year for sugarcane. Being a short duration crop it will allow farmers the flexibility to practice crop rotation and the flexibility to shift to more profitable crops depending on market conditions. Jatropha, on the other hand, has single fruiting season implying one harvest per year. Moreover it also has a maturation phase of three years and an even longer pay back period.
- Since it is a close relative of sorghum, the most widely grown grain crop in dry and semi-arid parts of India (and the world more broadly), farmers are likely to be more familiar and willing to adopt sweet sorghum. The resistance to drought, to saline alkaline soils and to water logging has been proven by the wide prevalence of sorghum in various regions of the world today (Reddy *et al.*, 2005).

4.2. Plantation of woody biomass on wastelands

A survey of 38 different studies on the economics of reclamation of wastelands by Balooni (2003) concludes that afforestation either with existing natural root stock or using specially adapted crops like *Acacia nilotica*, *Prosopis juliflora*, *Casuarina equisetifolia*, *Sesbania egyptia* and various *Eucalyptus* species are financially viable based on the yield of fuel wood, fodder, timber and other forest produce (Balooni, 2003). Most of these studies do not even include environmental benefits and yet find a positive

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[6] http://dacnet.nic.in/eands/agstat06–07.htm

return on investment. According to the 55th round of the National Sample Survey of India conducted in 1999/2000, which covered 120,000 households, 86% of rural households and 24% of urban households rely on biomass as their primary cooking fuel (Parikh *et al*., 2001). Biomass gasifier systems based on wood, raised on wastelands, are considered to have the largest potential to meet rural electricity needs in India. Production of woody biomass, as feedstock for power gseneration, can provide economic incentive to transform wastelands into energy forests (Ravindranath *et al*., 2004). Hence if the goal of public policy is the rehabilitation of wastelands, there are a broad array options and there is little evidence to suggest biodiesel crops are the best alternative.

4.3. Biodiesel for rural electrification

Plantations of crops like Jatropha on common property lands might be more viable if the oil that is extracted is used to meet rural energy needs for household and agricultural uses. According to the statistics of the central electricity authority of India less than 40% of the rural households in India have access to electricity. Given the rapidly rising demand for electricity from urban and commercial demand centers, there is little reason to be optimistic that remote and poor rural households will gain access to reliable electricity from the electric grid in the near future. Under such circumstances, the generation of electricity for household use, agricultural water pumping and small commercial enterprises using small and medium diesel generators fueled by vegetable oils is an option that might provide greater local benefits compared to the utilization of plant oils to supply fuel for urban transportation. Such projects may also have a higher probability of gaining acceptance within rural communities and receive greater cooperation in regeneration of wastelands.

Table 3. Calculation of land needed to electrify rural home using biodiesel.

a	Number of households per village (assumed)	100
b	Electricity demand per household in watts (assumed)	100
c	Number of hours of supply per day (assumed)	8
d	Energy supplied per household per day (= b*c)	800 watt hours
e	Total energy supplied to village per year (= d*a*365/1,000)	30,000 kwh/year
f	Specific fuel consumption of diesel generator (assumed)*	300 grams/kwh
g	Oil required to generate electricity for one year for one village (= e*f/1000,000)	9 tonnes/year
h	Oil yield per hectare from Jatropha (assumed)	0.6 kgs/hectare
i	Total amount of land required to produce the oil required for one village (= g/h)	**15** hectares
j	Total number of village households in India (assumed)	150,000,000
k	% of households with no electricity access (assumed)	60%
l	Number of unelectrified households (= j*k)	90,000,000
m	**Total land required to electrify all rural homes in India (= L*l/a)**	**13** million hectares
n	Annual consumption of diesel in India (assumed)	42 million tonnes
o	**Total land required to meet 20% of diesel demand (= n*0.2/h)**	**14** million hectares

* Specific fuel consumption refers to the amount of oil needed to produce one kilo watt hour of electricity.

Table 3 shows a back of the envelope calculation, which estimates the amount of village common land required to produce oil for local electricity generation using diesel generators. An interesting calculation is that providing an average of 100 W of electricity for 8 hours per day to approximately 90 million rural households with no electricity access today can be achieved using less land than it would require to meet 20% of India's demand for diesel (compare row m with row o in Table 3). Further, when one considers the rate of increase in transportation fuel demand in India, an increasingly larger area will need to be converted to energy plantations to meet a given percentage of the demand using biofuels.

5. Conclusion

India's biofuel strategy is unique in that it emphasizes the use of wastelands and drought-resistant crops with a view to minimizing the competition with food production for scarce supplies of land and water. And it is indeed likely that this strategy will have little negative impact on food and water supplies. But it also has two main drawbacks. The first drawback is the sole emphasis on Jatropha, a crop with little track record whereas superior alternatives exist. The economic viability of this crop under harsh conditions is unproven. The second drawback is the emphasis on common lands, which are an important source of livelihood for the landless rural poor. Jatropha cultivation will worsen access to fuel wood and fodder by the landless poor. The arguments presented in this paper raise two broad sets of questions that should be addressed by policy makers before large-scale upstream and downstream investments are made in biofuel production.

1. If the goal is reduction of the nation's dependence on petroleum by producing biofuels, what type of land resources and what type of biofuel crops should be targeted to achieve good results? Are there better alternatives to marginal lands that would not adversely affect food production or the natural environment? Would focusing on private farmlands and on more familiar crops be more successful? Is Jatropha the best feedstock given the various uncertainties?
2. If either regeneration of common lands or rural development is the main goal, is there evidence to suggest that single purpose crops like Jatropha are superior to other multi-purpose crops like those that would supply wood for cooking and/or electricity production, fodder for livestock and so on?

While energy security, reduction of harmful emissions associated with energy use, wasteland rehabilitation, rural development and poverty alleviation are all important goals, there appears to be little scientific evidence to suggest public investments in biodiesel plantations on wastelands can contribute positively to each one of those goals. In fact there is reason to believe planting of Jatropha might be detrimental to some of those goals. The reliance on just one or two crops also presents a higher risk of scarcity in biofuel supply owing to crop failure caused by drought or pest attacks. This is especially important in cases where cultivation is to be undertaken on marginal lands with little or no modern input. Scientific research should therefore be directed towards development of a wide variety of crops and technologies that are suited to the diverse socio-economic and environmental conditions in rural India.

Acknowledgements

Funding for this research was made possible through partial support from the Energy and Resources Group, UC Berkeley and from the Climate Decision Making Center, which was created through a cooperative agreement between the National Science Foundation (SES-034578) and Carnegie Mellon University. The author would also like to thank Udipi Shrinivasa, Sharad Lele, Alex Farrell, David Zilberman and several other individuals who provided invaluable technical and logistical support.

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