IMOD

Inclusive Market Oriented Development

Innovate ● Grow ● Prosper ●

Working Paper Series no. 30

RP – Markets, Institutions and Policies

Assessing Viability of Bio-ethanol Production from Sweet Sorghum

G Basavaraj, P Parthasarathy Rao, Kaushik Basu, Ch Ravinder Reddy, A Ashok Kumar, P Srinivasa Rao and BVS Reddy

ICRISAT

Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

Citation: G Basavaraj, P Parthasarathy Rao, Kaushik Basu, Ch Ravinder Reddy, A Ashok Kumar, P Srinivasa Rao and BVS Reddy. 2012. Assessing Viability of Bio-ethanol Production from Sweet Sorghum. Working Paper Series no. 30, RP – Markets, Institutions and Policies. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 20 pp.

Abstract

To meet the energy requirement for transport, blending of ethanol with automotive fuels has been mandated in India as in several other countries across the globe. Currently, the entire blending requirement has to come from molasses (by-product of sugarcane). Ethanol produced from molasses will not be able to meet the blending targets due to cyclical nature of sugarcane production resulting in shortage of molasses and competing uses (potable and pharmaceutical use) of ethanol produced from molasses. This has promoted research efforts to augment energy sources that are sustainable and economically viable. One such source that can be commercially exploited for ethanol production is sweet sorghum. The sugars in the stalks of sweet sorghum can be crushed to produce juice, which can be processed into ethanol for blending. Since ethanol production is from the stalks, the harvested grain from sweet sorghum adds to food basket and the diversion land for ethanol production will not comprise on food production. An attempt is made in the paper to assess viability of ethanol production from sweet sorghum. Net Present Value (NPV) the indicator of economic viability is negative and would thus be difficult for the industry to take off under the current scenario of administered price of ethanol, feedstock price and recovery rate. To meet the future blending requirements ethanol production has to be augmented from alternate sources like sweet sorghum through appropriate policy support and improvement in technical efficiency parameters.

Keywords: Bio-ethanol, Sweet sorghum bio-ethanol, Economic viability, Land assessment

Working Paper Series no. 30
RP – Markets, Institutions and Policies

Assessing Viability of Bio-ethanol Production from Sweet Sorghum

**G Basavaraj, P Parthasarathy Rao, Kaushik Basu,
Ch Ravinder Reddy, A Ashok Kumar,
P Srinivasa Rao and BVS Reddy**

International Crops Research Institute
for the Semi-Arid Tropics

April 2012

Acknowledgment

This paper was prepared under the National Agricultural Innovation Project (NAIP) – Indian Council of Agricultural Research (ICAR), GOI, project 'Value Chain Model for Bioethanol Production from Sweet Sorghum in Rainfed Areas through Collective Action and Partnership'. We are grateful to NAIP for the funding support to implement the project. The authors would like to thank Rusni Distilleries Pvt. Ltd. for providing the data on sweet sorghum ethanol processing. We express our sincere thanks to MG Chandrakanth, Professor, Department of Agricultural Economics, University of Agricultural Sciences (UAS), Bangalore, Lalith Achoth, Professor & Head, Dairy and Business Economics, Karnataka Veterinary, Animal & Fisheries Sciences University (KVAFSU), Bangalore and Franklin Simtowe, Scientist, ICRISAT for their critical comments on the earlier version of the draft. However, the authors are solely responsible for any errors of omission in the paper.

Contents

Background

Over the past two decades India's economy has grown on an average at the rate of 5-6% per annum. Energy consumption is one of the major indicators of the country's economic progress and is one of the major inputs whose use increases with economic growth and development. India ranks sixth in terms of energy demand, accounting for 3.6% of the global energy demand (Prasad et al. 2007) and this is expected to increase by 4.8% in the next few years (Gonsalves 2006). Currently, India's energy demand is primarily met through non-renewable energy sources such as fossil fuels (coal, natural gas and oil). Being short in domestic production, India mainly depends on crude oil imports that have risen from 57.8 million tons in 1999-2000 to 140.4 million tons in 2009-10, which accounts for about 81% of the oil consumption in the country (Ministry of Oil and Natural Gas, Government of India 2009). This in turn puts pressure on scarce foreign exchange resources (import bill of $75.6 billion in 2009-10). In the near future the imports are slated to rise further with no major breakthrough in domestic oil production and the rise in vehicular population that has grown at 10% per annum between 2001 and 2006[1], and is expected to continue.

In lieu of the growing concerns of energy security and environmental pollution due to high dependence on fossil fuels, globally, the focus has shifted to resource augmentation through renewable alternative energy sources to meet the energy demand (Government of India 2009). To accomplish this, mandatory blending requirements of automotive fuels with biofuels have been introduced across several countries[2] and this has promoted research efforts towards energy sources that are sustainable and economically viable.

Among several alternative renewable energy sources like wind, solar, hydro and plant biomass, energy derived from plant biomass is gaining importance worldwide (Parthasarathy Rao and Bantilan 2007). Bioenergy derived from plant based biofuels[3] has been the major thrust across countries to develop alternative energy sources. Bio-ethanol and biodiesel are the two most common biofuels that are commercially exploited. *Palm, edible oil, Jatropha* and switch grass are some of the feedstocks that are used for production of biodiesel while sugarcane, corn and sugar beet are common commercially exploited feedstocks for bio-ethanol. In India, molasses, a by-product from sugar production, is commonly used for alcohol and ethanol production. However, current estimates indicate that ethanol from molasses alone will not be able to meet the mandated requirement of blending even at 5% blending, leave alone 10 or 20% blending as mandated in the biofuel policy document. Thus, there is a need for alternative feedstock to augment ethanol production. One such feedstock that can be commercially exploited for ethanol production is sweet sorghum.

Sweet Sorghum for Ethanol Production

Sorghum [*Sorghum bicolor* (L) Moench] is considered to be one of the most important food and fodder crop in arid and semi-arid regions of the world. Globally, it occupies about 45 million hectares, with Africa and India accounting for about 80% of the global acreage (Reddy et al.

1. Authors' own estimate based on Road Transport Year Book 2006-07, MoRTH, Government of India
2. The mandatory blending requirements across different countries are- 3% in United States; 25% in Brazil; 5.75% in European Union; 10% in China and Indonesia; 5% each in Canada, United Kingdom, Australia and India
3. For the details of future prospects of Biodiesel production in India, see Biswas et al. (2010)

2009). Like grain sorghum, sweet sorghum, a warm-season crop, can be cultivated by smallholder farmers in rainfed areas. The crop can be grown successfully on clay, clay loam or sandy loam soils and can tolerate salinity and alkalinity to a large extent (Reddy et al. 2008; Srinivasa Rao et al. 2009). Cultivation practices of sweet sorghum are similar to that of grain sorghum. The only dissimilarity between grain sorghum and sweet sorghum is seen in the accumulation of sugars in the stalks of sweet sorghum that can be crushed to extract juice, which is finally processed into ethanol for blending. Besides the juice extracted for bio-ethanol, additional benefits are the grain harvested for food, and bagasse left after extraction of juice from the stalk, which is an excellent feed for livestock.

In view of the potential benefits of sweet sorghum as a feedstock for bio-ethanol production, a value chain approach model of sweet sorghum as a food-feed-fodder-fuel is being tested on a pilot basis in Andhra Pradesh to augment incomes of farmers while promoting a sustainable sweet sorghum–ethanol value chain. Given this background, an attempt is made in this paper to assess

a. The financial and economic viability of ethanol production from sweet sorghum,
b. Supply and demand for ethanol in India and potential for sweet sorghum as an alternative feedstock, and
c. The future land requirement for sweet sorghum cultivation to meet a small proportion of mandated blending requirements if sweet sorghum is commercially exploited.

Economic Viability Assessment of Bio-ethanol Production from Sweet Sorghum

The main objective of the economic feasibility assessment is to examine whether ethanol production is profitable along the different segments of the supply chain of sweet sorghum. The economic assessment is carried out by taking a case study of a pilot project on sweet sorghum value chain for linking sweet sorghum farmers to the ethanol industry implemented under the ICRISAT- ICAR (NAIP) funded project. Under this project, sweet sorghum farmers were linked to a distillery established at Medak district of Andhra Pradesh in India. The farmers cultivating sweet sorghum around the distillery are directly linked for supply of sweet sorghum stalk, and the distillery entered into a buy back agreement with farmers to purchase the stalks at an agreed price prior to sowing of the crop.[4]

Sweet sorghum value chain

A flowchart of the sweet sorghum ethanol value chain is presented in Figure 1. After harvest, the sweet sorghum stalks are transported from the villages to centralized ethanol facilities for energy production. In the centralized ethanol production unit, the sweet sorghum stalks are crushed and separated into juice and bagasse. The juice is fermented into ethanol, which is blended into transport fuel replacing conventional gasoline. The bagasse obtained during the process of crushing is used internally as fuel in the ethanol production process and the balance sold for

4. Data on cost of cultivation collected over a period of 3 years by ICRISAT across various locations under the project "value chain model for bio-ethanol production" funded by NAIP, ICAR, Government of India, shows that the yield of sweet sorghum stalk has varied between 14 to 18 tons per hectare with feedstock priced at Rs 700-1000 ($15- $22) per ton of stalk. On an average, the cost of cultivation has varied between Rs 9476 ($211) to 11,765 ($261) per hectare excluding family labor.

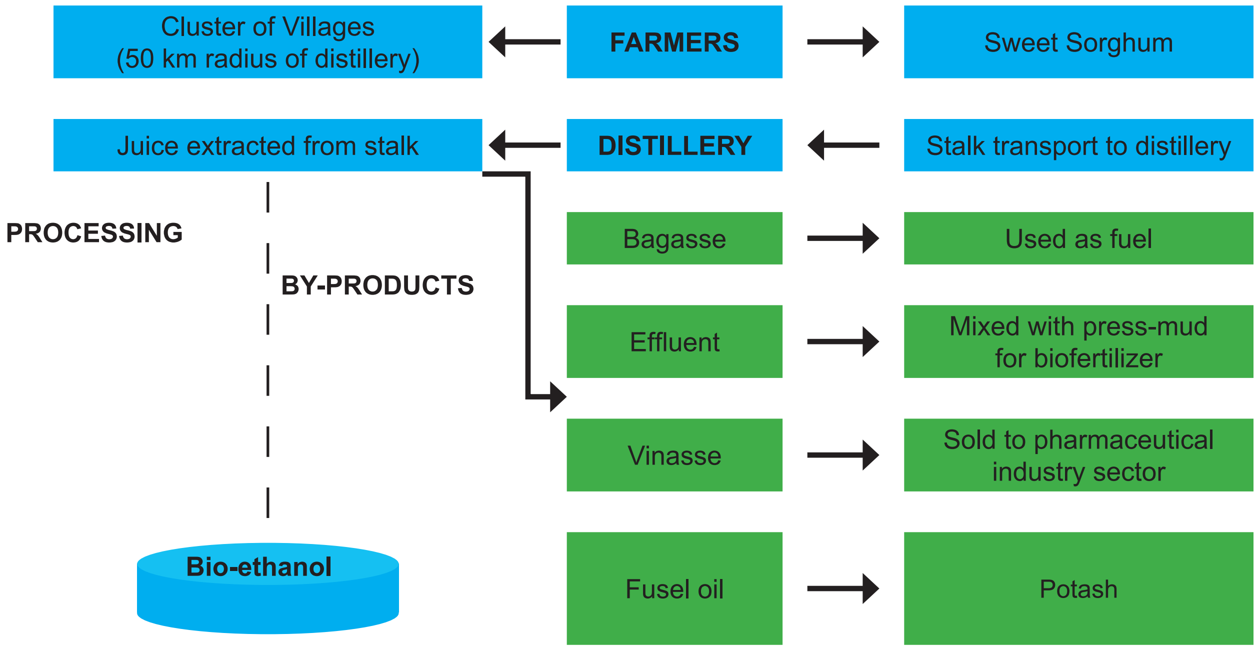

Figure 1: Sweet sorghum value chain for ethanol - Centralized Unit

cattle feed. The data used for estimating cost and revenues of ethanol production from sweet sorghum is obtained from the distillery. The costs include the investments made in setting up of the distillery, procurement cost of sweet sorghum stalk, operation and maintenance costs of distillery, labor costs, chemical costs, power cost to operate the plant, marketing and other related costs. The revenues include the returns generated from selling ethanol and the returns from selling by-products (bagasse, CO_2, vinasse and effluent) derived during ethanol production.

Methodology and Data on Indicators for Economic Feasibility Assessment

The evaluation of investments on long term projects from an economic assessment perspective is through the discounted cash flow technique. The net present value (NPV) and internal rate of return (IRR) are commonly used measures to evaluate the economic performance of the project and investment risks. Accordingly, these two measures are used in our analysis.

Net present value (NPV)

NPV is an important financial index that plays a key role in decision making of long-term investment projects. A positive, higher NPV indicates that the net profits are higher so the investment may have favorable economic performance, or the investment is considered as economically feasible.

NPV is calculated as:

$$NPV = \sum_{n=0}^{N} (B_n - C_n)/(1+d)^{\wedge n}$$

Where $B_n = P_n \times Q_n$

B_n= Benefits or the returns from the distillery by selling ethanol and by-products

P_n is the ethanol selling price during year n,

Q_n is the annual production volume of ethanol in year n

d is the discount rate (the required rate of return)

n is the economic life of the investment.

Internal rate of return (IRR)

The IRR refers to the average earned capacity of an investment/project during its economic life. It equals the discount rate when NPV is set to zero. In general, the IRR should be greater than the discount rate for a project for economic feasibility.

IRR is calculated as:

$$IRR \Rightarrow \sum_{n=0}^{N} (B_n - C_n)/(1+d)^{\wedge n} = 0$$

B_n= Benefits or the returns from the distillery by selling ethanol

P_n is the ethanol selling price during year n,

Q_n is the annual production volume of ethanol in year n

d is the discount rate (the required rate of return)

n is the economic life of the investment.

The data on various parameters used for the financial and economic assessment of ethanol production from sweet sorghum was collected from the distillery and is presented in Table 1. For parameters where the data was not available, assumptions were made based on expert opinion and secondary literature review.

The capacity of the plant is 40 kiloliters per day (KLPD) operating for 180 days. The reference year chosen is 2010 and the economic life of the project is 20 years. All economic costs and benefits (including by-products) are valued at current prices. The prevailing administered price of Rs 27/liter of ethanol announced by Government of India and recovery rate of 4.5% per ton of sweet sorghum[5] is considered for financial and economic viability assessment. The landed cost of feedstock to the distillery is Rs 1200/ton of stalk. Due to data limitations, environmental benefits accrued by the project are not taken into account in the cash flow stream.

5. A range was provided by the distillery on the recovery of ethanol, which varies between 4 to 4.8%. For economic feasibility assessment an average recovery of 4.5% is considered for our analysis.

Table 1. Details of the indicators used in financial feasibility assessment[1].

Assumption	Indicators
Capital expenditure (million Rs)	50
Operating days	180
Distillery capacity (kiloliters per day)	40
Sweet Sorghum feedstock requirement (tons/kiloliter)	22.3
Feedstock stock price (per ton of stalk at the gate)	1200
Requirement of bagasse as fuel (tons per kiloliter)	5
Cost of bagasse (Rs/ton)	1000
Labor cost (Rs/kiloliter per day)	400
Cost of power (Rs/kiloliter)	2500
Chemical cost (Rs/kiloliter)	1000
Operation and maintenance cost (Rs/annum)	30,000
General costs (Rs for entire life of project)	30,00,000
Marketing and other expenses (Rs/kiloliter)	1000
General inflation (%)	3
Output (Main product and by-products)	
Recovery of ethanol per ton of stalk (liters)	45
Output of ethanol (kiloliters per day)	40
Selling price of ethanol (Rs/liter)	27
Escalation in price of ethanol	1.5%[2]
Recovery of CO_2 (tons/40 KLPD)	20
Selling price of CO_2 (Rs/ton)	10,000
Additional recovery of bagasse (tons/40 KLPD)	150

1. The interest on working capital is taken as 13% and debt to equity ratio as 60:40. The investment made is for 25 years. The term loan interest assumed is 6% as loans provided are classified as priority sector lending. A depreciation rate of 5% is assumed on the capital expenditure and repayment of 10 years.
2. Though the demand for alcohol from potable and pharmaceutical sector are growing at 4% per annum, the assumed escalation in prices of alcohol is on a conservative basis.

Results and Discussion

The indicators of economic viability assessment are presented in Table 2. The results show negative NPV of the project at a discount rate of 10% (bank rate) and benefit cost ratio of 0.89. Clearly, the production of ethanol is highly sensitive to ethanol selling price, feedstock price and recovery rate. It would thus be difficult for the industry to take off under the current scenario of ethanol price, feedstock price and recovery rate.

Table 2. Indicators of economic viability assessment for ethanol production from sweet sorghum.

	Feed stock price (Rs/ton)	Recovery rate (%)	Ethanol price (Rs/liter)
Indicators	1200	4.5	27
NPV (million rupees)		(344)	
BCR		0.89	

Source: Authors' own estimates.

Sensitivity analysis

Sensitivity analysis was performed to derive the values of the key parameters where the project NPV becomes zero. The key parameters identified include recovery rate, feedstock price and ethanol price. Findings from scenarios using varying values of key parameters are presented in Tables 3 and 4.

Table 3. Scenario 1- Sensitivity analysis with change in feedstock prices.

Recovery rate (%)	Feedstock price @ Rs 1200/ton of stalk (IRR)	Expected ethanol pricing (Rs/ltr)	Feedstock price @ Rs 1500/ton of stalk (IRR)	Expected ethanol pricing (Rs/ltr)
4.9	10.53	29	13.19	36

Source: Authors' own estimates.

Table 4. Scenario 2-Sensitivity analysis with changing ethanol and feedstock prices.

	Ethanol pricing (Rs/liter)					
	27		32		37	
Feed stock price (Rs/ton of stalk)	IRR	Expected ethanol recovery (%)	IRR	Expected ethanol recovery (%)	IRR	Expected ethanol recovery (%)
1200	8.10	5.3	13.7	4.3	9.60	3.7
1500	12.83	6.7	13.7	5.5	8.91	4.6

Source: Authors' own estimates.

Two scenarios are developed, one based on increase in feedstock price and the other on anticipated increase in price of ethanol as gasoline prices are also increasing. In the first scenario, at an optimistic recovery rate of 4.9 and feedstock price fixed at Rs1200/ton of stalk, the price of ethanol should be Rs 29/liter where the project NPV becomes positive (Table 3). With the rise in cost of cultivation of sweet sorghum, if the stalk price increases to Rs 1500/ton with the recovery rates at 4.9%, the price of ethanol has to be increased to Rs 36/liter.

In the second scenario, since it is mandated to blend petrol with ethanol, it is anticipated that ethanol prices will increase with the increase in prices of petrol. If the ethanol prices increase to Rs 37/liter, even with a lower recovery of 3.7% the centralized unit can break-even. If the feedstock price increases to Rs 1500/ton of stock with the ethanol prices remaining unchanged, the expected ethanol recovery should be 4.6% to generate zero NPV (Table 4). Sensitivity analysis carried out has shown that even with a marginal improvement in recovery rate the NPV becomes positive.

Before we compare sweet sorghum economics with alternative feedstocks for ethanol production, we take a look at the supply and demand scenario of ethanol in India.

Current Status of Demand and Supply of Ethanol in India

The Government of India has set an indicative target of 20% blending of ethanol with petrol and also for diesel with biodiesel across the country by 2017. Given the mandatory blending and projected demand for petrol in India, ethanol demand for blending is estimated at 5, 10 and 20% blending mandates (Table 5). Based on the projections, it is estimated that bio-ethanol requirement would be 3.46 billion liters by 2020 at the rate of 10% blending.

Currently, the entire bio-ethanol requirement has to come from molasses, a by-product of sugarcane. The availability of molasses to meet blending mandates depends on cane and sugar production, which are cyclical in nature. Lower molasses availability will put pressure on molasses prices and availability of molasses for ethanol production. The molasses prices in the last decade have fluctuated substantially and have ranged between Rs 1000 and Rs 5000 per ton (Shinoj et al. 2011). Additionally, ethanol produced has many other alternative uses such as potable alcohol, and as input into the chemical and pharmaceutical industries. During a normal year, cane converted into sugar generates enough molasses to produce alcohol that can meet the needs of both the potable alcohol and chemical sectors (30-40% each). Another 20-30% surplus alcohol is available for conversion into ethanol for blending. However, during 2008–09, though the demand for blending at 5% worked out was 0.56 million tons of ethanol, the actual blending was only 0.08 million tons (100 million liters). Though the total supply of ethanol (2.4 million tons

Table 5. Projected demand for petrol and ethanol blending in India.

Year	Total Supply of Petrol[1] (billion liters)	Ethanol demand for blending (billion liters)		
		@5%	@10%	@20%
2006-07	15	0.77	1.53	3.06
2007-08	16	0.82	1.64	3.27
2008-09	17	0.85	1.70	3.40
2009-10	20	1.01	2.02	4.05
2010-11	21	1.06	2.13	4.25
2011-12	22	1.12	2.23	4.46
2012-13	23	1.17	2.34	4.69
2013-14	25	1.23	2.46	4.92
2014-15	26	1.29	2.58	5.17
2015-16	27	1.36	2.71	5.43
2016-17	28	1.42	2.85	5.70
2017-18	30	1.50	2.99	5.98
2018-19	31	1.57	3.14	6.28
2019-20	33	1.65	3.30	6.60
2020-21	35	1.73	3.46	6.92

Source: Authors' own estimates based on crude utilization available from Hand Book of Statistics on Indian Economy, RBI.

1. Assumptions made for projecting demand for petrol and ethanol blending are:
   Growth rate of 8% per annum is assumed for crude oil supply, which is the average of 2000-01 to 2009-10.The share of petrol in total crude is 9% for 2007-08, 14% for 2009-10 and 13% for rest of the years. Based on the report of the working group on petroleum and natural gas sector for the XI plan (2007-2012) and the conversion of metric ton to liters is based on the conversion rate of 1 metric ton of crude = 7.33 barrels, and a barrel is equal to 0.159 kiloliters.

in 2009) was sufficient to meet total amount demanded (1.80 million tons), the utilization was more towards potable and industrial uses due to inability of the oil marketing companies (OMC) to procure the required amount of fuel ethanol at prevailing market prices (Shinoj et al. 2011). Import of ethanol for fuel usage is currently restricted through policy, and even if made free, would cost the exchequer very dearly, as the international markets for ethanol are already very tight due to demand from other biofuel-consuming countries.

Under the 10% blending requirement, the growing demand for alcohol from the potable and chemical sector (growing at 3-4% per annum) and the highest available alcohol from molasses pegged at 2.3 billion liters, there will be a shortage of ethanol for blending (Table 6). If molasses alone has to meet the entire requirement, an area of 10.5 million ha with 736.5 million tons of sugarcane has to be cultivated to meet the 10% blending requirement (around 20–23% in excess of what is required for meeting the corresponding sugar demand), which translates into doubling of both area and production. Presently, the country lacks both technology and infrastructure required to implement this. Further, it is not possible to increase the area under sugarcane beyond a certain limit given that sugarcane is highly water intensive, with a requirement of 20,000–30,000 m^3 of water per ha per crop. Also, increasing the area under sugarcane will be at the cost of diverting land from other staple food crops (Shinoj et al. 2011). Hence, ethanol production has to be augmented from alternative feedstocks. One such alternative that we are exploring/proposing in this paper is sweet sorghum, which is both resource saving and sustainable (Ray 2012).

Table 6. Availability and utilization of ethanol in India.

Year	Highest available alcohol from molasses (billion liters)	Ethanol utilization (billion liters)		Balance (billion liters)	Ethanol required for Blending (billion liters)	Deficit/ Surplus
		Potable	Industry		@ 10%	
2010-11	2.3	0.86	0.82	0.62	1.53	-0.96
2011-12	2.3	0.89	0.84	0.57	1.64	-1.14
2012-13	2.3	0.91	0.87	0.52	1.70	-1.32
2013-14	2.3	0.94	0.90	0.46	2.02	-1.53
2014-15	2.3	0.97	0.94	0.39	2.13	-1.76
2015-16	2.3	1.00	0.97	0.33	2.23	-1.99
2016-17	2.3	1.03	1.00	0.27	2.34	-2.24
2017-18	2.3	1.06	1.04	0.2	2.46	-2.51
2018-19	2.3	1.09	1.07	0.14	2.58	-2.78
2019-20	2.3	1.12	1.11	0.07	2.71	-3.09
2020-21	2.3	1.16	1.15	-0.01	2.85	-3.42

Source: Planning Commission (2003) estimates on highest available alcohol from molasses.

Potential Benefits of Sweet Sorghum as Feedstock for Ethanol Production

It is a well-known fact that sweet sorghum has the ability to adapt to drought, saline and alkaline soils and water logging conditions (Reddy et al. 2008; Srinivasa Rao et al. 2009). Besides a shorter growing period of four months, it has a low water requirement of 8000 cubic meters (over two crops) that are about four times lower than that required for sugarcane (12−16 month growing season and 36,000 cubic meters of water) (Soltani and Almodares 1994, Table 7). Its lower cost of cultivation[6] and familiarity with cultivation of sorghum, the ability and willingness of farmers to adopt sweet sorghum makes it much easier to grow. The potential food versus fuel conflict, from the diversion of crop land for its cultivation is allayed as sweet sorghum meets the multiple requirements of food, fuel and fodder.

Table 7. Comparison of some indicators between sugarcane, sweet sorghum and sugar beet as feed stocks for ethanol production.

Crop	Cost of cultivation (USD ha^{-1})	Crop duration (months)	Fertilizer requirement (N-P-K kg ha^{-1})	Water requirement (m^3)	Ethanol productivity (liters ha^{-1})	Average stalk yield (t ha^{-1})	Per day productivity (kg ha^{-1})
Sweet sorghum (over two crops)	435	4	80:50:40	8000	4000 $year^{-1}$ [1]	50	416.6
Sugarcane (per crop)	1079	12−16	250 - 400: 125:125	36000	6500[2]	75	205.4
Sugarcane molasses	-	-	-	-	850 $year^{-1}$ [3]	-	-
Sugar beet		5-6	120:60:60	8 000-10 000	6000-6400[4]	75-80	500-444

Source: Reddy et al. (2005).
1. 50 t ha^{-1} millable stalk per crop @ 40 l t^{-1}
2. 85–90 t ha^{-1} millable cane per crop @ 75 l t^{-1}
3. 3.4 t ha^{-1} @ 250 l t^{-1}.

Source: Shinoj et al. 2011.
4. 75–80 t ha^{-1} of sugar beet @ 80 l t^{-1}.

Additionally, bio-ethanol produced from sweet sorghum is more eco-friendly compared to ethanol produced from molasses due to:

a) Impacts of climate change having adverse effects on irrigated crops like sugarcane due to scarcity of water (IWMI 2008)
b) The pollution levels in sweet sorghum-based ethanol production has 25% of the biological oxygen dissolved (BOD), ie, 19,500 mg $liter^{-1}$ and lower chemical oxygen dissolved (COD), ie, 38,640 mg $liter^{-1}$ compared to molasses-based ethanol production [as per pilot study conducted by Vasantdada Sugar Institute (VSI), Pune, India]

6. The economic competitiveness of sweet sorghum worked out from on-farm data for three years by the authors in Medak District, Andhra Pradesh has shown that sweet sorghum is competitive with dryland crops such as sorghum and maize. The benefit cost ratio for sweet sorghum was 1.55 while it was 1.30 and 1.37 for maize-pigeonpea intercrop and sorghum-pigeonpea intercrop, respectively.

Table 8. Relative economics of ethanol production from different feedstocks in India.

Parameter	Sweet sorghum	Sugarcane molasses	Sugarcane juice	Grains (Pearl millet & broken rice)
Cost of raw material (Rs t^{-1})	700[1]	3000-5000[2]	1200[3]	8000[3]
Cost of processing (Rs t^{-1})	384	1890	490	2800
Total cost of ethanol production (Rs t^{-1})	1084	4890-6890	1690	10800
Output of ethanol (l)	45	270	70	400
Value of ethanol (Rs t^{-1})	1215	7290	1890	10800
Net returns (Rs t^{-1})	131	2400-400	200	0
Cost of feedstock (Rs l^{-1})	15.56	11.11-18.51	17.14	20
Cost of ethanol (Rs l^{-1})	24.08	18.11-25.51	24.14	27
Profit from ethanol (Rs l^{-1})	2.91	8.88-1.48	2.85	0

Note: The information on the parameters is collected from Rusni Distilleries for sweet sorghum, Nizam Deccan Sugars Pvt. Ltd. for molasses and AGRO Bio-tech, Ajitgarh, Rajasthan for grains.

The value of by-products is not considered in the analysis.

1. Even when the feedstock is priced at Rs 800, it becomes profitable to produce ethanol from sweet sorghum without accounting for capital costs. However, the cost of feedstock has varied in the range of Rs 700-1200/ton.
2. The molasses prices have ranged between Rs 3000 to 5000/ton during the last few years and hence the profitability of molasses ethanol production is highly sensitive to fluctuating molasses prices.
3. The data on all the other feedstock costs is for the year 2009. The prices of feedstock (sugarcane and grains) have increased in the recent years.

Source: Authors' own estimates.

The result of relative economics of ethanol production from different feedstocks in India favors ethanol conversion from molasses (Table 8). Yes, although economics favors production of ethanol from molasses, there is the problem of sustainability and enhancing molasses production due to the reasons already discussed.

Though the profits are positive for ethanol production from sweet sorghum, the economic viability assessment performed above has shown that the present administered price of Rs 27/liter is not viable for the industry for ethanol conversion after accounting for capital costs. Hence policy and enabling environment support is required to promote production of ethanol from alternate feedstocks such as sweet sorghum.

Some lessons learned from the pilot model for crushing sweet sorghum for ethanol production

The distillery (centralized system) did not realize potential benefits from the sweet sorghum value chain due to a few shortcomings. One of the major shortcomings is extensive co-ordination and planning requirements in the supply chain management. Delay in crushing stalks beyond 24 hours of harvest causes low recovery of ethanol per ton of stalk. Additionally, the distillery faced some teething problems in terms of functioning of crushers, boilers and other equipment. A 40 KLPD ethanol distillery requires feedstock from 8000 ha of crop area per year spread over two seasons – 3500 ha in the rainy season (rainfed) and 4500 ha in the postrainy season (irrigated). Hence mobilizing farmers to cultivate sweet sorghum and sourcing the raw material becomes difficult. However, field observations have shown that under the centralized system, considerable scope exists for increasing the efficiency of the value chain both at crop production and processing stages.

One of the major limitations of the financial viability assessment studies is that they look at benefits only from financial returns. The same limitation holds good here also. This study is also not able to incorporate the expected environmental benefits of producing ethanol from sweet sorghum due to unavailability of data. The environmental benefits in cultivation of sweet sorghum for ethanol production incorporated in viability assessment should be assessed and thus make a case for justifying policy support and enabling environment, which does not exist in the current scenario. Assuming an enabling environment is in place it would be interesting to know the future area required to cultivate sweet sorghum to meet a small proportion of the blending mandate. A land requirement exercise was carried out to estimate this.

Land requirement assessment for sweet sorghum ethanol production

To understand how the ethanol blending demand would translate into future requirements of sweet sorghum area and production, an analysis was performed to assess the land requirement for sweet sorghum cultivation by 2020 if it is commercially exploited as an alternate source of ethanol production. It is expected that a crop like sweet sorghum would only bridge the gap in ethanol requirement supply from the existing feedstock ie, molasses. The land requirement assessment for cultivation of sweet sorghum and production is undertaken with certain assumptions, with sweet sorghum meeting the entire deficit or partially in varying proportions.

Land requirement for sweet sorghum cultivation is dependent on farm productivity and recovery rate of ethanol. On-farm trials have shown that farmers can harvest upto 40 tons/hectare of sweet sorghum and there is significant scope to improve productivity on farmers' fields. Taking into consideration the research efforts to improve the productivity of sweet sorghum with higher recovery rates, the assessment is developed based on the existing scenario of 20 tons per hectare with 4.5% recovery and a case where productivity improves to 30 tons/hectare with 4.5% ethanol recovery. Since in the short run it would not be possible to bring a large area under sweet sorghum cultivation, the following scenarios are developed to meet the deficit of ethanol for blending at 10% mandatory blending – (a) to meet 30% of the ethanol deficit for blending; (b) 50% of the ethanol deficit for blending; and (c) 80% of the ethanol deficit for blending. Based on the assumptions made above and the demand for bio-ethanol, land requirement for cultivation of sweet sorghum to meet the bio-ethanol demand till 2020 is presented in Table 9.

The estimates show that to meet the deficit at 10% blending by 2020 (3.47 billion liters), at 20 tons/hectare productivity and 4.5% recovery, the area required will be about 1.16 million hectares with the assumption that 30% of the deficit is met from sweet sorghum. However, with the improvement in productivity to 30 tons per hectare, the requirement of land would be only 0.77 million hectares. Assuming that 80% of the deficit ethanol requirement for blending is met through sweet sorghum, still a modest area of about 2.06 million hectares will be required to cultivate sweet sorghum. This would amount to about 50% of the current kharif (rainy season) sorghum area that is under cultivation. Given that grain sorghum area under rainy season sorghum in Maharashtra is declining, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is an enabling environment in place to support sweet sorghum cultivation for ethanol production.

Table 9. Land assessment for sweet sorghum cultivation in ethanol production.

Year	Deficit @ 10% blending requirement (billion ltrs)	Area requirement (million hectare)					
		Meeting 30% of the deficit		Meeting 50% of the deficit		Meeting 80% of the deficit	
		20 tons yield & 4.5% recovery	30 tons yield & 4.5% recovery	20 tons yield & 4.5% recovery	30 tons yield & 4.5% recovery	20 tons yield & 4.5% recovery	30 tons yield & 4.5% recovery
2011-12	-1.66	0.55	0.37	0.92	0.62	1.48	0.99
2012-13	-1.83	0.61	0.41	1.02	0.68	1.63	1.09
2013-14	-2.01	0.67	0.45	1.11	0.74	1.78	1.19
2014-15	-2.19	0.73	0.49	1.22	0.81	1.95	1.30
2015-16	-2.38	0.79	0.53	1.32	0.88	2.12	1.41
2016-17	-2.58	0.86	0.57	1.43	0.96	2.29	1.53
2017-18	-2.79	0.93	0.62	1.55	1.03	2.48	1.65
2018-19	-3.01	1.00	0.67	1.67	1.11	2.67	1.78
2019-20	-3.23	1.08	0.72	1.80	1.20	2.87	1.92
2020-21	-3.47	1.16	0.77	1.93	1.29	3.08	2.06

Source: Authors' own estimates.

Conclusions

The economic and financial viability analysis has shown that viability of ethanol production from sweet sorghum stalk depends on the ethanol and feedstock pricing, besides recovery rate of ethanol. With a marginal improvement in recovery to 4.9% from the current level of 4.5%, and feedstock price fixed at Rs 1200/ton of stalk, ethanol production becomes attractive at Rs 29/liter. The current administered price of ethanol in India is Rs 27/liter. Even with the rise in cost of cultivation of sweet sorghum, if the stalk price increases to Rs 1500/ton with the recovery rate remaining the same at 4.9%, the price of ethanol has to be increased to Rs 36/liter. This analysis does not take into account the expected environmental benefits of producing ethanol from sweet sorghum due to unavailability of data. The economic viability assessment would become more attractive with the environmental benefits incorporated and could make a better case for justifying policy support for sweet sorghum. With further improvements in crop and processing technology for ethanol production, the overall profitability of sweet sorghum cultivation and processing can be increased.

The estimates of ethanol blending to meet mandatory requirements show deficits from the current level of supply, and that requirement will outstrip supply. With the highest available alcohol from molasses at 2.3 billion liters coupled with the inability to increase area under sugarcane and adverse impacts on food production, the future supply of bio-ethanol has to be augmented through alternative feedstock. The potential food versus fuel conflict from the diversion of crop land for cultivation of sweet sorghum does not arise as sweet sorghum meets the multiple requirements of food, fuel and fodder for smallholder farmers. Land requirement assessment for sweet sorghum cultivation has shown that area required for cultivation will be a modest 1.16 million hectares with the assumption that 30% of the mandated 10% blending deficit is met from sweet sorghum at 20 tons/hectare productivity with 4.5% recovery.

Given that grain sorghum area under rainy season in Maharashtra (biggest state cultivating sorghum in India) has declined in the last decade, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is enabling environment in place to support ethanol production from sweet sorghum. The relative economics augurs well in the agro-ecological regions of Maharashtra and Andhra Pradesh, where sorghum is predominantly cultivated. Since ethanol production is from the stalks, the harvested grain from sweet sorghum adds to the food basket. As such, land for cultivating food will not be diverted for ethanol production.

References

Biswas P, Pohit S, Kumar R and **Jha J.** 2010. "Biodiesel from Jatropha: Can India meet the 20 percent Blending Target?" Energy Policy, Vol. 38:1477-1484.

Gonsalves JB. 2006. An assessment of the biofuels industry in India. UNCTAD/DITC/ TED/2006/6, Geneva, Switzerland, United Nations Conference on Trade and Development.

Government of India. 2003. Report of the committee on Development of Bio-fuel, 16 April, Planning Commission.

Government of India. 2009. National Policy on Biofuels. New Delhi, India: Ministry of New and Renewable Energy.

Hand Book of Statistics on Indian Economy, Reserve Bank of India, http://www.rbi.org.in/scripts/Annual Publications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy.

International Water Management Institute (IWMI). 2008. Water implications of biofuel crops: understanding tradeoffs and identifying options. Colombo, Sri Lanka: International Water Management Institute (IWMI). 4p. (IWMI Water Policy Briefing 30)

Ministry of Petroleum and Natural Gas. 2009. Basic Statistics on the Indian Petroleum & Natural Gas, http://petroleum.nic.in/petstat.pdf

Ministry of Road Transport and Highways. 2006. Basic Road Statistics of India, http://morth.nic.in/ index.asp

Prasad S, Singh A, Jain N and **Joshi HC.** 2007. Ethanol Production from Sweet Sorghum Syrup for Utilization as Automotive Fuel in India, Pages 2415-2420 *in* Energy & Fuels 21(4).

Parthasarathy Rao P and **Bantilan MCS**. 2007. Emerging bio-fuel industry: a case for pro-poor agenda with special reference to India. Policy Brief No. 12. Patancheru 502324, Andhra Pradesh, India: IMPI, ICRISAT.

Ray S, Goldar A and **Miglani S.** 2012. The Ethanol Blending Policy in India. Pages 23-35 *in* Economic and Political Weekly, Vol XLVII, No 1.

Reddy BVS, Ramesh S, Ashok Kumar A, Wani SP, Ortiz R, Ceballos H and **Sreedevi TK.** 2008. Bio-fuel crops research for energy security and rural development in developing countries. Bioenergy Research 1:248–258.

Reddy BVS, Srinivasa Rao P, Ashok Kumar A, Sanjana Reddy P, Parthasarathy Rao P, Sharma Kiran K, Blümmel Michael and **Ravinder Reddy Ch.** 2009. Sweet sorghum as a biofuel crop: Pages 193−202 *in* proceedings of the Sixth Winrock International Workshop on Biofuels.

Shinoj P, Raju SS, Chand R, Kumar P and **Msangi S.** 2011. Biofuels in India: Future Challenges. Policy Brief No. 36. Pusa, New Delhi – 110 012, India: National Centre for Agricultural Economics and Policy Research.

Soltani A and **Almodares A.** 1994. Evaluation of the investments in sugar beet and sweet sorghum production. National Convention of Sugar Production from Agricultural Products, 13−16 March 1994, Shahid Chamran University, Alwaz, Iran.

Srinivasa Rao P, Reddy BVS, Blümmel M, Subbarao GV, Chandraraj K, Sanjana Reddy P and **Parthasarathy Rao P.** 2009b. Sweet Sorghum as a Biofuel Feedstock: Can there be Food-Feed-Fuel Tradeoffs? ICID. http://www.wg- crop.icidonline.org/ sweet%20sorghum_dec09.pdf

About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

Contact Information

ICRISAT-Patancheru (Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

ICRISAT-Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT-Nairobi (Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Bamako (Regional hub WCA)
BP 320
Bamako, Mali
Tel +223 20 223375
Fax +223 20 228683
icrisat-w-mali@cgiar.org

ICRISAT-Niamey
BP 12404, Niamey, Niger
(Via Paris)
Tel +227 20722529, 20722725
Fax +227 20734329
icrisatsc@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 383 311 to 15
Fax +263 383 307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297, 071, 067, 057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

www.icrisat.org

93-2012

IMOD
Inclusive Market Oriented Development
Innovate ● Grow ● Prosper ●

Working Paper Series no. 30

Assessing Viability of Bio-ethanol Production from Sweet Sorghum

G Basavaraj, P Parthasarathy Rao, Kaushik Basu, Ch Ravinder Reddy, A Ashok Kumar, P Srinivasa Rao and BVS Reddy

ICRISAT
Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

About ICRISAT

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

Contact Information

ICRISAT-Patancheru (Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

ICRISAT-Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT-Nairobi (Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Bamako (Regional hub WCA)
BP 320
Bamako, Mali
Tel +223 20 709200
Fax +223 20 709201
icrisat-w-mali@cgiar.org

ICRISAT-Niamey
BP 12404, Niamey, Niger
(Via Paris)
Tel +227 20722529, 20722725
Fax +227 20734329
icrisatsc@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 383 311 to 15
Fax +263 383 307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297, 071, 067, 057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

www.icrisat.org

93-2012