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Assessing Competitiveness of Sweet Sorghum for Ethanol Production: A Policy Analysis Matrix Approach

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Abstract

The rising prices of fossil fuels and the concerns towards reduction in vehicular pollution have put pressure on the governments to look out for cleaner and renewable alternatives to meet the energy demand. Biofuels (bioethanol and biodiesel) have emerged as a promising alternative source of renewable energy in recent years. To promote biofuels, mandatory blending requirements of automotive fuels with bio-ethanol were introduced in India in 2003. However, the mandatory blending programme in India has not taken-off successfully due to unsustainable ethanol production, which is currently from molasses. Thus, there is a need to augment bioethanol production through promotion of alternative feedstocks to meet the blending mandates. One such alternative feedstock is sweet sorghum that has been pilot tested on farmers' fields and its stalks are used to produce ethanol for commercial purpose (in small quantities). Using Policy Analysis Matrix framework, the study has assessed the competitiveness of cultivation of sweet sorghum as feedstock for ethanol production and has provided evidence based policy support for its promotion. The study has shown a significant potential in sweet sorghum cultivation in the rainfed agro-ecological regions of Maharashtra replacing sorghum even without any policy support.

Key words: Biofuels, bio-ethanol, sweet sorghum, Maharashtra, PAM approach

JEL classification: Q18, Q28, Q48

Introduction

The growing energy crisis, reflected in rising price of crude/fossil fuels and rising import bills, is one of the major challenges being faced by several countries. In India, about 70 per cent of the oil demand, primarily for the transport, is met through crude imports (GoI, 2009). The oil import would increase over time with the increase in number of vehicles that has grown at 10 per cent[1] a year from 2001 to 2006, while domestic production has remained virtually stagnant. Additionally, there are concerns on environmental pollution due to the increasing use of fossil fuels. The rising prices of fossil fuels and the concerns towards reduction in vehicular pollution have put pressure on governments to look for cleaner and renewable alternatives to meet the energy demand.

Biofuels (bioethanol and biodiesel) have emerged as the promising alternative source of renewable energy in recent years. These liquid fuels are derived from plant biomass and organic wastes. The potential plant biomass for production of biofuels includes sugarcane, maize, sorghum, wheat, sugarbeet and cassava. The choice of feedstock for the production of ethanol varies

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[1] Authors' estimates based on *Road Transport Year Book 2006-07*, Ministry of Road Transport & Highways (MoRTH), Government of India.

across countries. If sugarcane as a feedstock has comparative advantage in Brazil, it could be corn in America and wheat in Canada. Hence, the choice of the feedstock depends completely on the economic considerations of comparative advantage and efficiency in production of these feedstocks for processing into ethanol. Apart from economic considerations, environmental benefits also play a significant role in feedstock selection and processing it for ethanol production. Studies have also shown the environmental benefits of usage of ethanol as a bio-fuel in vehicles in terms of reduction in vehicular pollution and greenhouse gas emissions (Subramanian *et al*., 2005).

To reduce dependence on fossil fuels and promote biofuels, mandatory blending requirements of automotive fuels with bio-ethanol have been introduced in several countries[2]. In India, mandatory blending of biofuels was introduced in 2003 at 5 per cent level which was revised to 10 per cent in 2006 and is targeted to 20 per cent by 2017. In this connection, the Government of India has come up with Biofuel Policy to augment biofuel production from the existing feedstocks, and promote research efforts towards alternative feedstocks that are sustainable and economically-viable for ethanol production.

Biofuel Production in India and its Sustainability

India's biofuel production accounts for only 1 per cent of the global production which translates to around 425 million litres consisting of fuel ethanol and biodiesel (Raju *et al*., 2009). The available feedstocks for bioethanol production in India include sugarcane, sorghum, cassava, maize and in the recent years sweet sorghum stalk. At present, ethanol to a large extent, is produced in India only from molasses, a by-product of sugar industry. The supply of sugarcane and production of molasses are dependent on the sugar cycles in India. During the years of excess supply of cane, the Government of India has encouraged the sugar factories to produce ethanol directly from sugarcane. The policy decision of increasing the minimum purchase price of ethanol from ₹ 21.5 per litre to ₹ 27 per litre by the government has also encouraged the industry for conversion of sugarcane molasses to ethanol for blending.

In India, the price of molasses ranged between ₹ 500/ tonne to ₹ 6000/ tonne in during the previous decade. Ethanol produced from molasses in India is utilized by chemical and potable alcohol industry, apart from its utilization as ethanol (99% anhydrous) for blending with petrol. About 70 per cent of the alcohol produced from molasses is utilized by chemical and potable alcohol industry and only 30 per cent is available for ethanol blending (GAIN Report, 2011). Despite availability of 30 per cent ethanol for blending, Oil Marketing Companies (OMCs) have not been able to procure the required amount of fuel ethanol for blending as the administered price of ethanol for blending was lower than for other uses. With the increase in mandatory blending target to 20 per cent by 2017, it is estimated that total demand for alcohol (ethanol + alcohol) would be as high as 5.92 Mt (Shinoj *et al*., 2011). Even at 10 per cent blending if molasses alone has to meet the entire requirement, an approximate area covering 10.5 M ha with 736.5 Mt of sugarcane will have to be produced (around 20–23%) in excess of what is required for meeting the corresponding sugar demand). This translates into doubling of both area and production (Shinoj *et al*., 2011) which is neither practical nor feasible. Further, lower availability of molasses and consequently higher prices have also affected the cost of ethanol production, putting Ethanol Blending Programme (EBP) at stake.

On the contrary, the demand management of ethanol includes decisions to cap ethanol supply on considerations of fairness in distribution of ethanol to accommodate the needs of other sectors (potable and industrial). It was also recommended by the policymakers that the size of EBP should be linked to the availability of alcohol (GoI, 2009).

Thus, there is a need to augment bioethanol production to meet the blending mandates through policy support for alternative feedstocks. The National Biofuel Policy document does allude to alternative feedstocks and the need to promote these through research and pilot testing. One such alternative feedstock that has been pilot tested and used to produce bio-ethanol commercially (in small quantities) in recent years, is sweet sorghum.

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[2] The mandatory blending requirements across different countries are: 3 per cent in United States ; 25 per cent in Brazil; 8 per cent in Germany by 2015; 5.75 per cent in The European Union; 10 per cent in China and Indonesia; 5 per cent each in Canada, United Kingdom, Australia and India

Sweet Sorghum as a Source for Bio-ethanol Production

Sweet sorghum can be grown under dryland conditions with a minimum annual rainfall of 700 mm. Sorghum being a C4 tropical grass, is adapted to the latitudes ranging from 40°N to 40°S of the equator. Like grain sorghum, sweet sorghum is drought-resistant and can be cultivated by the poor in the rainfed areas of semi-arid tropics. The crop can be grown successfully on clay, clay loam or sandy loam soils which can tolerate salinity and alkalinity to a large extent and is considered a natural replacement for less water-efficient crops. The water requirement of sweet sorghum is only about 8000 m^3/ha compared to about 36000 m^3/ha for sugarcane (Reddy *et al*., 2005). Sweet sorghum matures in about 3-5 months which enables planting of two crops a year. Sweet sorghum has the highest per cent carbon emission reduction potential compared to other feedstocks. The net energy ratio (output energy/input energy) is the highest for sweet sorghum (7.06) than of other feedstocks (molasses, cellulosic biomass like bagasse and rice straw) in the production of ethanol due to high conversion efficiency of sweet juice to ethanol (DBT-CII Report, 2010).

Cultivation practices of sweet sorghum are similar to that of grain sorghum. The only dissimilarity between the two is the accumulation of sugars in the stalks of sweet sorghum which can be crushed to produce juice and finally processing into ethanol as a biofuel. Apart from stalk harvested for its juice content to produce bio-ethanol, sweet sorghum provides additional benefits in the form of grain as food and bagasse (left after extraction of juice) as an excellent feed for livestock. The potential food versus fuel conflict from diversion of crop land for sorghum cultivation is allayed as it meets the multiple requirements of food, fuel and fodder.

Rationale for Promotion of Sweet Sorghum as Alternative Feedstock

Despite several advantages of sweet sorghum as a promising alternative crop for bio-ethanol production, the National Policy on Biofuels does not specify any clear road map for its commercialization and utilization. It is in this context that a modest attempt is made to analyze the major efficiencies (resource utilization) in the cultivation of sweet sorghum as feedstock for ethanol production in two states of India, viz. Andhra Pradesh and Maharashtra, which have considerable potential to grow sweet sorghum.

The scope of the present study is restricted to only the cultivation of sweet sorghum as a feedstock for ethanol production. Though the processing of stalks into bio-ethanol also requires inputs, the cost and returns of processing sweet sorghum to bio-ethanol have not been considered in assessing the competitiveness due to unavailability of relevant processing data and hence is a limitation of the study.

The study provides evidence-based policy prescriptions for bio-ethanol production from sweet sorghum which judiciously uses scarce resources like irrigation water and other inputs.

Methodology

The policy analysis matrix (PAM) framework developed by Monke and Pearson (1998) was used for computation of input-use efficiency in production, comparative advantage and degree of divergence between social and private costs. The PAM is a product of two accounting identities; one defining profitability which is the difference between revenues and costs, and the other measuring the effects of divergences (distorting policies and market failures) as the difference between observed prices and social prices that would exist if the divergences were removed.

The PAM matrix is presented in Table 1. The data in the first row provide a measure of private profitability (D), defined as the difference between observed revenues (A) and costs (B+C) valued at actual market prices. It shows the competitiveness of a commodity with the present technologies, output, and inputs valued at the current market prices. The second row in the matrix provides the social profitability measured at social prices that reflect social opportunity costs. The social profitability measures the comparative advantage or efficiency in the system. A positive social profit indicates that the country uses scarce resources efficiently and has a static comparative advantage in the production of that commodity at margin. A negative social profit indicates that the sector cannot sustain its current output without assistance from the government, resulting in waste of resource.

Three important indicators of competitiveness, viz. nominal protection coefficient (NPC), effective

Table 1. Policy analysis matrix framework

Particulars	Revenue	Cost		Profit
		Tradable input	Domestic factors	
Valued at private prices	A	B	C	D[1]
Valued at social prices	E	F	G	H[2]
Divergences	I[3]	J[4]	K[5]	L[6]

Notes: [1] Private profits, D= A- (B + C)
[2] Social profits, H= E - (F + G)
[3] Output transfers, I= A-E
[4] Input transfers, J= B- F
[5] Factor transfers, K= C-G
[6] Net policy transfers, L= D-H

Source: Based on Monke and Pearson (1998)

protection coefficient (EPC) and domestic resource cost (DRC) were computed and compared using the PAM framework. The NPC, a simple indicator of the incentives or disincentives in place, is the ratio of domestic price to a comparable world (social) price. It can be calculated for both output (NPCO) and input (NPCI). The domestic price in this computation could be either the procurement price or the farm gate price while the world reference price is the international price adjusted for transportation, marketing and processing costs. NPCI ratio shows how much domestic prices of tradable inputs differ from their social prices. If NPCI >1, the domestic input cost is higher than the input cost at world prices and the system is taxed by policy and if NPCI <1, the domestic price is lower than the comparable world price and the system is subsidized by policy. An NPCO larger than one indicates subsidies to output.

The EPC is the ratio of value added in private prices (A–B) to value added in social prices (E–F). An EPC value of greater than one suggests that government policies provide positive incentives to producers while the values less than one indicate that producers are not protected through policy interventions. The DRC is the most useful indicator and is used to compare the relative efficiency or comparative advantage among agricultural commodities. It is the shadow value of non-tradable factors used in an activity per unit of tradable value added (G/E-F). The DRC indicates whether the use of domestic resources is socially profitable (DRC< 1) or not (DRC >1).

One of the main strengths of PAM approach is that it allows varying degrees of disaggregation. It also provides a straightforward analysis of policy-induced effects. Despite its strengths, the PAM approach has been criticized because of its static nature and its results sometimes are not considered to be realistic in a dynamic setting (Nelson and Panggabean, 1991). One of the ways to overcome this limitation is to conduct sensitivity analysis under various assumptions (Samarendu *et al*., 2003).

Data and Modelling Assumptions

The data required for construction of PAM are crop yields, inputs used and their market prices, and output prices. These data were generated under a pilot project on ‘sweet sorghum value chain for linking sweet sorghum farmers to bio-ethanol industry’. The project was implemented by ICRISAT in the Medak district of Andhra Pradesh with funding support from the National Agricultural Innovation Project (NAIP) of the Indian Council of Agricultural Research (ICAR). Under this project, farmers cultivated sweet sorghum and supplied stalks to the distillery for ethanol production. In this study, primary data were collected from a sample of 50 farmers. The data were collected on the cost of cultivation of sweet sorghum and its competing crops like sugarcane and maize for a period of four years (2007-2010) and were used for construction of farm budgets and PAM. A similar dataset compiled from another pilot project site in Nanded district of Maharashtra, funded by the Common Fund for Commodities (CFC), The Netherlands, was used for construction and comparison of PAM indicators.

The most difficult tasks in constructing a PAM framework are the estimation of social prices for outputs and inputs, and decomposition of inputs into their tradable and non-tradable components (Yao, 1997). The choice of social prices has a significant impact on the calculation of the PAM. For computing social prices of various commodities including outputs, and inputs, world prices were used as the reference prices and adjusted for transportation costs and marketing costs to be comparable with farm gate prices. These prices were converted to domestic currencies using market exchange rates.

Gulati and Kelly (2000) have used the shadow prices of primary non-tradable factors of production as approximations to estimate the social prices. The shadow price of a resource is the value of benefits foregone by the society in using that resource for the production of a particular commodity. Thus, the shadow price or the opportunity cost is the marginal value product of a resource, foregone elsewhere because of its use in the production of a particular commodity. However, shadow prices are difficult to estimate empirically because there are numerous activities in which a resource can be used. As a result, several approximations have to be made to estimate social prices, particularly of non-tradable inputs.

In the present study, the shadow prices of non-tradable inputs were estimated as the marginal value product of the resource at optimum, and the estimated shadow prices of the resource in question were taken as proxy for the social prices. The profit maximizing input level is given by Equation (1):

$$MP * P_y = P_x * X \text{ Ò! } MVP_i = MFC_i \qquad \ldots(1)$$

where, MVP_i and MFC_i are marginal value product and marginal factor cost of the i^{th} resource. In the framework of Euler's theorem (product exhaustion theorem), the factors of production are rewarded equal to their marginal product and will exhaust the total product. This principle was used in the current study to compute partial production elasticities (b_s). These are equal to the factor shares when a firm is in equilibrium. Hence, the shadow price of a non-traded input is the product of the marginal product of the non-traded input and the domestic price of the output.

Thus, the social price of the i^{th} non-traded input at the average level of input-use at optimum can be calculated as factor share (S_i) of various inputs (X_i) to the mean value of inputs, output (Y) and its price (P_y), as given in Equation (2):

$$P_{Xi} = [(S_i/X_i)*Y]\ P_y$$

$$= \frac{X_i}{\left(\sum P_i X_i / n\right)} * \frac{Y}{X_i} * P_y X_i \qquad \ldots(2)$$

The inputs used for the production of sweet sorghum were disintegrated into tradable inputs and non-tradable inputs (domestic resources). For this study, fertilizers, nitrogen, phosphate and potash, plant protection chemicals, and tractor hours were considered as tradable inputs while labour, irrigation, farm yard manure as non-tradable inputs. The factor divergences were calculated based on the private prices of tradable and non-tradable inputs used and social prices were estimated at margin for both non-tradable inputs as indicated above. The cost of agricultural land in India is primarily the land rent which is nominal and paid on annual basis, and cannot be considered as the true opportunity cost of land (Gulati and Kelly, 2000). In the present study, the rent paid to land was not accounted in cost computations (private and social prices).

In this study, the social prices of tradable inputs nitrogen, phosphorus and potash, weighted average NPC of 0.59, computed by Gulati and Narayanan (2003) and for farm machinery (tractors) NPC of 1.24, computed by Kalra and Gulati (1992), were used.

It was assumed that sweet sorghum is not internationally tradable due its bulkiness (stalk). Hence, its domestic price and world reference price were assumed to be the same, implying no distortions in the product market.

Domestic Resource Cost

The DRC was computed as:

$$DRC_i = \frac{\sum_{j=1}^{n} A_{ij} P_j}{\left(Y_i * P_i\right) - \sum_{k=1}^{n} A_{ik} P_k} \qquad \ldots(3)$$

where, i^{th} commodity refers to sweet sorghum; DRC is the resource cost of saving a unit through the production of one unit of the i^{th} commodity; A_{ij} is the quantity of the j^{th} non-traded input required to produce a unit of commodity i; P_j is the social price (computed shadow price) of the j^{th} non-traded input; Y_i is the yield of the i^{th} commodity; P_i is the market price of the i^{th} commodity; A_{ik} is the quantity of the k^{th} traded input required to produce a unit of commodity i; and P_k is the private price of the k^{th} traded input.

Nominal Protection Co-efficient (NPC)

The NPC for tradable inputs is computed as:

$$\mathrm{NPCI}_i = \frac{{}^{p}P_i}{{}^{s}P_i} \qquad \ldots(4)$$

where, NPCI_i is the nominal protection coefficient of tradable input of to produce commodity i; ${}^{p}P_i$ is the private price of the tradable input to produce commodity i; and ${}^{s}P_i$ is the social price (shadow price) of the tradable input to produce commodity i.

Effective Protection Coefficient (EPC)

The EPC was calculated:

$$\mathrm{EPC} = \overset{D}{V}_A / \overset{R}{V}_A$$

$$= \left[\overset{D}{P} - \sum_{J=1}^{K} A_{ij}\overset{D}{P}_j\right] \Big/ \left[\overset{R}{P} - \sum_{J=1}^{K} A_{ij}\overset{R}{P}_j\right] \qquad \ldots(5)$$

where,

$\overset{D}{V}_A$ = Value added at domestic prices;

$\overset{R}{V}_A$ = Value added at international prices;

$\overset{D}{P}$ = Domestic price of the output;

$\overset{R}{P}$ = Reference price of the output;

A_{ij} = Share of the jth input used in the production of one unit of the ith output;

$\overset{D}{P}_j$ = Domestic price of the jth input; and

$\overset{R}{P}_j$ = Reference price of the jth input.

Results and Discussion

The resource utilization pattern in cultivation of sweet sorghum at project locations viz. Medak district of Andhra Pradesh and the Nanded district of Maharashtra are presented in Table 2. The major tradable inputs utilized in cultivation of sweet sorghum are fertilizers, plant protection chemicals, and machine labour (tractor), while non-tradable inputs utilized are labour, farmyard manure and irrigation.

The private and social costs on cultivation of sweet sorghum in Maharashtra and Andhra Pradesh are presented in Table 3. The yield of sweet sorghum in Maharashtra was higher by 50 per cent than in Andhra Pradesh. The value of output realized was also higher

Table 2. Resource utilization pattern in production of sweet sorghum in Medak (Andhra Pradesh) and Nanded (Maharashtra) districts: 2010

(per hectare)

Inputs	Type	Andhra Pradesh	Maharashtra
Labour (humandays)	Male (hired)	11	19
	Male (family)	40	1
	Female (hired)	49	40
	Female family	21	5
Total labour (humandays)		122	65
Bullock pair (days)	Bullock (hired)	2	1
	Bullock (own)	7	13
Tractor (hours)	Hired	5	3
	Family	0	2
FYM (100kg)	Own	13	0
	Purchased	1	16
Seed (kg)	Own & purchased	5	7
Total fertilizer (kg)		204	257
Sprayer(hired & owned) (hours)	Hired	0	2
Spray (litres)		0	11
Irrigation/Machinery (hours)		0	0
Threshing (hours-hired & family)		0	0

Table 3. Private and social costs of sweet sorghum cultivation in Maharashtra and Andhra Pradesh: 2010

Costs	Revenues	Tradable costs	Non-tradable costs	Profits
		Maharashtra		
Private costs	31,790	5,604	15,800	10,386
Social costs	31,970	6,298	23,917	1755
Divergence		-694	-8,117	
		Andhra Pradesh		
Private costs	12,600	5,948	15,992	(9,340)
Social costs	12,600	5,141	9,184	(1,725)
Divergence		807	6,808	

in Maharashtra than in Andhra Pradesh due to high opportunity cost of land. The farmers in Maharashtra were paid ₹ 1200/ tonne of sweet sorghum stalk by the distillery, while in Andhra Pradesh, they were paid only ₹ 800/ tonne. The divergence of both social and private costs of sweet sorghum cultivation was high in Maharashtra than in Andhra Pradesh. The private and social costs computed were used to work out PAM coefficients. The gross revenue was computed by considering only the value realized for the stalk (main product) and the by-product grain was not included in computations as the stalk was harvested before grain maturing in Maharashtra.

The findings of the PAM framework constructed for sweet sorghum and the coefficients of EPC, DRC and NPCI for sweet sorghum are presented in Table 4.

The values of EPC show the combined impact of policies in product market (price enhancing) and input policies (cost reducing). The EPC nets out the impact of protection on inputs and outputs, and reveals the degree of protection accorded to the value-added process in the production activity of the relevant commodity. The EPC computed in the study reflected the divergence due to inputs only. The divergences between private and social costs for both tradable and non-tradable inputs for cultivation of sweet sorghum were found positive in Andhra Pradesh and negative in Maharashtra.

For cultivation of agricultural crops, the inputs like fertilizers, plant protection chemicals, electricity for pumping irrigation water are subsidized in India. The amount of subsidy computed varied from crop to crop. For example, the fertilizer subsidy alone amounted to 32.2 per cent in cultivation of paddy and 6.3 per cent in sugarcane as compared to 2.8 per cent for a rainfed crop like sorghum during 2001-02 (Sharma and Thaker, 2009). Though the inputs utilized in the case of sweet sorghum were also subsidized, the amount of subsidy (mainly for fertilizers and machine labour) was nominal as sweet sorghum is a rainfed crop and is not resource-intensive compared to other agricultural crops (for example, sugarcane and paddy are water-intensive crops and the high subsidy provided for irrigation results in higher negative distortions). Further, sweet sorghum is relatively a new crop for farmers and the EPC coefficient of 0.89 in Andhra Pradesh and 1.03 in Maharashtra showed that cultivation of sweet sorghum was largely not protected by policies.

Table 4. Indicators of protection co-efficient for sweet sorghum in Maharashtra and Andhra Pradesh: 2010

PAM coefficient	Maharashtra	Andhra Pradesh
EPC	1.03	0.89
DRC	0.94	1.23
NPCI-Tradable	0.89	1.16
NPCI-Non-tradable	0.66	1.74
NPCI	0.71	1.53

The value of NPCI coefficient was lower in Maharashtra than in Andhra Pradesh. The NPCI value of less than one in Maharashtra indicated that policies were reducing input costs for cultivation of sweet sorghum. A comparative input utilization pattern in both the states showed that fertilizers, plant protection chemicals and seed were used in higher proportions in Maharashtra than in Andhra Pradesh.

The estimated DRC value was less than unity for Maharashtra and marginally higher at 1.23 in Andhra Pradesh. Both the private and social profits of sweet sorghum cultivation were negative in Andhra Pradesh, indicating inefficient production. A low DRC value in Maharashtra indicates that it has comparative advantage in cultivation of sweet sorghum as compared to Andhra Pradesh. A study conducted by the authors to identify the growing domains for sweet sorghum has also indicated the agro-ecological zones in Maharashtra to be the potential regions for cultivation of sweet sorghum. The zones were identified based on the agro-ecological characteristics using district level data. The agro-ecological zones were grouped using dominant soil types, climate, length of growing period, normal rainfall and soil fertility. Of the five identified sub-regions, majority (6.1, 6.2 and 6.3 sub-regions) were located in northern and south-central Maharashtra (Appendix 1). Further, in 2007, nearly 53 per cent of the sorghum area in India was concentrated in Maharashtra. The relative economies of sweet sorghum cultivation augurs well in the agro-ecological regions of Maharashtra. Given that grain sorghum area under rainy season in Maharashtra has declined in the previous 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.

Conclusions

In January 2003, the Government of India launched the Ethanol Blended Petrol Programme (EBPP) in nine states and four Union Territories promoting the use of ethanol for blending with gasoline and the use of biodiesel derived from non-edible oils for blending with diesel (5% blending). Due to ethanol shortage during 2004-05, the blending mandate was made optional in October 2004, and was resumed in October 2006 in 20 states and 7 Union Territories in the second phase of EBPP. These ad-hoc policy changes continued until December 2009 when the Government of India came out with a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy Sources (MNRES) (GoI, 2009). However despite efforts, the EBPP has not taken-off successfully due to unsustainable ethanol production from molasses. Hence, to meet the targeted blending requirements, alternative feedstocks will have to play a more important role to fill the current and future gap between demand and supply of bio-ethanol.

This study has assessed the competitiveness of cultivation of sweet sorghum as feedstock for ethanol production and has provided evidence based policy support for its promotion. The study has shown significant potential for sweet sorghum cultivation in the agro-ecological regions of Maharashtra. In Andhra Pradesh, the regions where sorghum is predominantly cultivated, sweet sorghum can be grown efficiently as has been indicated by DRC coefficients.

In the current market context, policy support for the production of a biofuel crop primarily depends on mutual/simultaneous co-existence of producers and processors to promote alternative feedstocks. For growers, it is the relative profitability of bio-ethanol crops vis-a–vis competing crops and assured buy-back at pre-determined prices that are important factors determining allocation of land for these crops. For industry, the raw material’s conversion efficiency, its continuous supply for at least 5-6 months in a year, the economics of establishing multi-feedstock production units and the purchase price of ethanol by oil companies are the critical factors.

Hence, the existing National Policy on Biofuels requires a re-look to specify a clear road map for bio-ethanol production from alternative feedstocks like sweet sorghum besides molasses. This will aid in sustainable production of bio-ethanol and will benefit all the stakeholders in the biofuels supply chain besides accelerating the pace of biofuel production in the country to meet the blending mandates.

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Appendix 1

Agro-ecological characteristics of selected AEZ for up-scaling sweet sorghum

AEZ sub-region	Physiographic	Number of districts	Climate	Growing season (days)	Normal rainfall (mm)	Rainy season sorghum area ('000 ha)	Post-rainy season sorghum area ('000 ha)
3	Deccan Plateau	5	Arid	60-90	592	102.03 (5.23)*	209.62 (8.62)
6.1	Deccan Plateau	8	Semi-arid (dry)	90-120	686	219.15 (2.58)	2499.30 (25.53)
6.2	Deccan Plateau	13	Semi-arid (moist)	120-150	885	569.78 (8.02)	1325.05 (10.31)
6.3	Deccan Plateau	6	Semi-arid (moist)	120-150	935	452.70 (15.94)	46.70 (1.40)
6.4	Deccan Plateau	9	Subhumid (dry)	150-180	1079	164.17 (5.37)	766.54 (9.92)
7.1	Deccan Plateau	2	Semi-arid (dry)	90-120	677	6.01 (1.29)	68.85 (9.40)
7.2	Deccan Plateau	8	Semi-arid (moist)	120-150	860	102.85 (2.91)	64.36 (1.52)
8.2	Deccan Plateau	10	Semi-arid (moist)	120-150	954	56.74 (1.77)	15.56 (0.47)
8.3	Eastern Ghats & Tamil Nadu Uplands	1	Semi-arid (moist)	120-150	697	1.22 (0.23)	0.00 (0.00)
10.2	Deccan Plateau	2	Subhumid (dry)	150-180	1193	32.50 (2.99)	3.90 (0.17)
12.1	Eastern Plateau	2	Subhumid (moist)	180-210	1524	7.00 (1.18)	19.10 (1.47)

Note: *Figures within the parentheses indicate per cent sorghum area to gross cropped area of the sub-region