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Research paper

Risk analysis of using sweet sorghum for ethanol production in southeastern Brazil

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ABSTRACT

Our objective is to evaluate the economic feasibility and the risks associated with the utilization of sweet sorghum as a raw-material for the production of ethanol at a representative sugar mill in São Paulo State, Brazil. The economic payback of the working mill is compared with and without sweet sorghum. A sensitivity analysis of sweet sorghum yield is made to empirically estimate the risk associated with adding sweet sorghum in an ethanol mill during the sugarcane off season. The results of a Monte Carlo simulation analysis indicate that the addition of sweet sorghum on 20% of the sugarcane land can increase net present value and average annual net cash income and reduce the relative risk for net income and net present value. Given current yields for sweet sorghum in the study area, risk averse decision makers would have a risk premium benefit of about R$4.5 million per year in average annual net cash income. The analysis suggests that adding sweet sorghum to the crop mix will reduce the costs for a mill by spreading fixed costs across more ethanol. Also, an addition of sweet sorghum would increase ethanol receipts more than the variable costs of cultivating and harvesting the crop plus the costs of producing ethanol. Despite the profitability and risk reducing benefits of sweet sorghum, wide spread adoption has not occurred in southeastern Brazil. The uncertainty about yields and effects on labor scheduling may be factors in the slow rate of adoption. Improvements in sweet sorghum yields would likely increase the rate of adoption.

1. Introduction

Over the past 30 years, there has been a global movement to develop energy sources that could reduce the dependence on petroleum products. In this sense, biofuels, especially ethanol, have gained prominence in the world energy market [1]. In Brazil ethanol, as a fuel, has gained importance as result of historical processes. Historically political and institutional factors have converged such as the Pro-Alcohol program. The relatively high prices of oil and derivatives in Brazil also made an alternative fuel attractive. Finally, the nation had a natural physical and technological potential for the cultivation of sugarcane [2].

In spite of this importance and the recent measures taken by the Brazilian government, the expectation is that the Brazilian production of ethanol is enough to supply the internal market for the coming years [3]. The demand for "green" ethanol from sugarcane by California and the EU offers Brazilian ethanol a unique opportunity to export ethanol to meet the demand for cane-based ethanol. From a technical point of view, one possibility for increasing ethanol production would be the use of other biofuel feedstocks. Among the candidate biofuel feed stocks is sweet sorghum, which can be harvested between sugarcane harvests. During December to March there is a seasonal decrease in ethanol production, which raises ethanol price to the final consumer [4].

There has been increased interest in utilizing sweet sorghum for ethanol production with multiple studies confirming their technical and economic viability [5–8]. Sweet sorghum has shown potential as a raw material for fuel-grade ethanol production due to its rapid growth rate and early maturity, greater water use efficiency, limited fertilizer requirement, high total value, and wide adaptability [9]. In addition, other factors are leading producers and mills to consider sorghum as a means to increase the supply of ethanol. Cutz et al. [10] suggested that using sorghum between harvests may have a secondary benefit of providing a means to

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Acronyms list

CDF	Cumulative Distribution Functions
CE	Certainty Equivalent
GRKS	Gray, Richardson, Klose, and Schuman Distribution
MVE	Multivariate Empirical Distribution
NCI	Net Cash Income
NPV	Net Present Value
SERF	Stochastic Efficiency with Respect to a Function
TRS	Total Recoverable Sugar
VHP	Very High Polarization

produce a year round electricity surplus by burning bagasse.

Due to its short growth period, sweet sorghum can be planted and harvested within a maximum of 120 days between harvest and replant, thus offering farmers an income source during the sugarcane off-season. Sweet sorghum can be planted on sugarcane land in renovation. This must occur every 5-years. As a result, about 20% of the sugarcane land is available each year. Another strong economic incentive for using sweet sorghum is the opportunity for using the same equipment for harvest and industrial processing as sugarcane, thus spreading fixed costs for the mills over more tons of biomass and ethanol production. Therefore, it may be possible to achieve better utilization of the industrial facilities during the year by producing ethanol in a seasonal period of shortage and higher prices, and improve a mill's profits over a strictly sugarcane production option.

The objectives of the present study are to evaluate the economic feasibility and risks associated with using sweet sorghum as an additional raw-material for the production of ethanol at a representative sugar mill in São Paulo State, Brazil. Initially, the economics for the representative mill is compared with and without the addition of sweet sorghum to the feedstock. A sensitivity analysis of sweet sorghum yield is included to compensate for the lack of yield data for sweet sorghum in commercial operations.

2. Data and methods

The sugarcane model, SUCROSIM, is a Monte Carlo simulation model to simulate the annual production, marketing, and financial activities of a representative commercial sugar mill and ethanol plant in Brazil [11]. The model uses data from many different sources to simulate a ten-year planning horizon. Risk faced by sugar mills and ethanol plants in Brazil are explicitly included in the model by using probability distributions to simulate random values for prices, yields, costs, rates of inflation, and asset values. For the analysis proposed in this paper, SUCROSIM was expanded to include sweet sorghum as a feedstock for ethanol production.

The model was programmed in Microsoft Excel using the Simetar© add-in, following a general architecture for Monte Carlo simulation modeling used by Richardson et al. [12]. This methodology provides numerous options for analyzing different scenarios without re-programming the model.

Few studies exist showing the results for sorghum yield in commercial operations, so four scenarios were simulated which include three distributions for sweet sorghum yields and a base scenario without sweet sorghum (Table 1). The average sweet sorghum yields reported in the literature are 40 and 80 tonnes ha^{-1} [13,14]. For scenario 2, we assumed a minimum sweet sorghum yield of 40 tonnes ha^{-1} and a maximum of 80 tonnes ha^{-1}. For scenarios 3 and 4, the simulated yields for scenario 2 were increased 140% and 180%.

Table 1
Scenarios analyzed.

Scenarios	
1	No sweet sorghum
2	With sweet sorghum – Yield equal 100% of GRKS (40,55,80)
3	With sweet sorghum – Yield equal 140% of GRKS (40,55,80)
4	With sweet sorghum – Yield equal 180% of GRKS (40,55,80)

2.1. Inclusion of sweet sorghum in the SUCROSIM model

This section of the paper presents an overview of the model, including the modifications to add the sweet sorghum as a raw material. See Rezende and Richardson [11] for a detailed description of the equations in the model. The model starts each year by simulating stochastic values for annual cane and sweet sorghum yield and the monthly total recoverable sugar (TRS) content for both. These variables are stochastic in the model because they are largely dependent on weather during the growing season which is out of the control of the sugar mills.

For cane yield, the climate of São Paulo State enables sugarcane production in two periods known as “one-year cane” and “1.5-year cane.” The one-year cane, planted in September–October, grows most rapidly between November and April. Growth slows after that due to weather conditions and is harvested within 11–14 months. The 1.5-year cane, planted between January and March, has its initial growth during the first rainy season (February through April). An accelerated growth is triggered during the second rainy season (October through April). Although it is not harvested within the year it was planted, it produces almost twice as much as the one-year cane. After the first harvest, the clump is left which has buds (nodes) that produce new shoots for growth and subsequent harvests each year. Each subsequent harvest has lower mean cane production [15]. For this reason, the mills in São Paulo have preferred five sugarcane harvests [16]. After the fifth harvest the cane is replanted and a new regrowth/harvest cycle is initiated. Because sweet sorghum is an annual crop with a short production cycle, it has been planted during the period between the fifth harvest and the replanting of sugarcane. In the present study area, the mills use owned and leased land. Sweet sorghum also can be planted on land that is not being used for sugarcane in the normal rotation. The model considers the area planted with sweet sorghum as a fraction (about 20%) of the area planted with sugarcane. This is the equivalent fraction to the land which has been harvested the fifth time and would be replanted in the spring.

To simulate the yield of sugarcane, it was assumed that each parcel planted was harvested for five years in succession before replanting. It was also assumed that the first harvest could be made at 1 or 1.5 years. This way, the cane was harvested at one year or 1.5 years on through the fifth year for a total of five harvests. For the simulation, it was assumed that the relative variability of cane production would be the same in the future as it has been in the past. Historical annual cane yield data for the regions (from 2001 to 2012) were used to estimate a multivariate empirical probability distribution for annual cane yields for each year (1–5) in the cane production/replant cycle.

The sweet sorghum yield (tonnes ha^{-1}) is simulated using a GRKS function, according to Equation (1). (In this paper, all random variables are denoted in bold with a tilda.) The GRKS distribution was developed by Gray, Richardson, Klose, and Schuman, and was chosen because of the absence of historical data on sweet sorghum in the same area. As input, the GRKS distribution uses three parameters (minimum, a mid-point, and a maximum) and then