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Sugar and ethanol production as a rural development strategy in Brazil: Evidence from the state of São Paulo

Luiz A. Martinelli [a,*], Rachael Garrett [b], Silvio Ferraz [c], Rosamond Naylor [a]

[a] Program on Food Security and Environment, Stanford University, 616 Serra St. Encina Hall East, 4th Floor, Stanford University, Stanford, CA 94305-6055, USA
[b] Emmett Interdisciplinary Program in Environment and Resources, Stanford University, 473 Via Ortega, Suite 226, Stanford, CA 94305-6055, USA
[c] Departamento de Silvicultura, ESALQ, USP. Av. Pádua Dias 11, 13416-000, Piracicaba, SP, Brazil

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ABSTRACT

Sugar and ethanol production are key components of Brazil's rural development and energy strategies, yet in recent years sugar production has been widely criticized for its environmental and labor practices. This study examines the relationship between rural development and sugarcane, ethanol, and cattle production in the state of São Paulo. Our results suggest that the value added components of sugarcane production, which include sugar refining and ethanol production, may have a strong positive affect on local human development in comparison to primary agricultural production activities and other land uses. These results imply that sugar production, when accompanied by a local processing industry can stimulate rural development. However, this paper also highlights the significant environmental and social harms generated by the sugar industry at large, which may undermine its development benefits if not addressed.

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1. Introduction

Agriculture plays a critical role in Brazil's economy at both local and national scales (Moraes, 2009). The agricultural sector, including agribusiness, accounts for up to one-quarter of Brazil's GDP and over one-third of its total exports (Guilhoto, 2004; Barros, 2008; Guimaraes, 2008; Brazilian Trade Balance, 2008). Brazil currently runs a large trade surplus in agriculture and has become one of the largest global exporters of soybeans, sugar, coffee, oranges, poultry, and beef. As a result, the sector contributes substantially to the country's foreign exchange earnings (Abbey et al., 2006; Guimaraes, 2008; Barros, 2008; Embrapa, 2009). The growth of agribusiness, which encompasses agricultural transportation, processing, logistics, retail, and production, also generates increased investment in rural infrastructure and employment (Gasques et al., 2004; Chaddad and Jank, 2006; Barros, 2008). In terms of private (or financial) gains to the economy, one cannot overstate the importance of the agricultural sector (Damico and Nassar, 2007).[1]

The social (or economic) gains from Brazil's agricultural development are less straightforward. In some situations, agricultural expansion and industrialization has led to the concentration of land and wealth in fewer hands, resulted in dangerous working conditions, and been accompanied by rural violence (Ferreira et al., 2006; Abbey et al., 2006; Barros, 2008; Franko, 2007; Alves and Marra, 2009; Olivette and Carmargo, 2009; Ocampo, 2009; Canuto et al., 2010). Brazil's agricultural development process has also generated large social costs in the form of deforestation, loss of biodiversity, deterioration of water and air quality, increased use of toxic chemicals, and changes in nutrient (biogeochemical) cycles—all of which are well-cited in the literature but remain "un-priced" in the calculations of economic growth (Fearnside, 2001; Klink and Machado, 2005; Chomitz, 2007; Galloway et al., 2008; Martinelli and Filoso, 2008; Nepstad et al., 2009).[2]

While agriculture has been developing, Brazil has maintained very high levels of income inequality, with one of the world's highest Gini coefficients for income (0.55 in 2009) and one of the worst Gini coefficients for land distribution (0.85 in 2006) (IPEA, 2010).[3] The concentration of economic and political clout with respect to

* Corresponding author. Address: CENA, University of São Paulo, Av. Centenário 303, 13416-000 Piracicaba, SP, Brazil. Tel.: +55 19 34294074.
E-mail address: martinelli@cena.usp.br (L.A. Martinelli).

[1] The terminology follows the convention of referring to "financial" or "private" costs and benefits as those valued in market prices, and "economic" or "social" costs and benefits as those valued in market prices and also accounting for policy distortions and social and environmental externalities.

[2] The literature on environmental damages from agricultural expansion in Brazil as a whole is vast and too extensive to cite fully here; these are just a handful of papers that have examined this issue. In this paper we specifically focus on the environmental damages from the sugar industry.

[3] The Gini coefficient is a measure of inequality in wealth (income, land holdings) in which 0 represents total equality and 1 represents total inequality (the latter shows that an infinitesimally small fraction of the population—verging on just one person—controls 100% of the wealth).

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land ownership, is a serious challenge for Brazil, and continues to catalyze powerful social movements like the MST (*Movimentos dos Sem Terras*) aimed at land reform (Abbey et al., 2006). Despite progress in alleviating poverty through macroeconomic stabilization and the successful implementation of a conditional cash transfer program (Ravallion, 2010), over one-fifth of Brazil's population still lived below the official poverty line (less than 1/3 of the minimum wage) in 2008 (IPEA, 2010). Due to the continued problems of inequality and poverty in Brazil, it is important to examine whether pursuing agricultural expansion and industrialization as a rural development strategy actually results in meaningful gains to the poorest members of society, and whether the private benefits of agricultural development are actually reflective of the gains to society after taking into account government supports and environmental externalities.

Although we do not conduct a full cost–benefit analysis in this study, we take one step closer to a full accounting of the cost and benefits of agricultural development in one region in Brazil – the Southeast – by examining the case of sugar expansion and industrialization in São Paulo state. Specifically, we examine how human development indicators (HDIs) vary across municipalities with different levels of sugarcane production and cattle ranching (the two main agricultural activities in São Paulo), and with or without sugar mills for ethanol refining, while controlling for other important factors that might influence development.

We chose São Paulo as a case study for multiple reasons. For one, we see it as a critical case (Yin, 1989) in understanding the relationship between sugarcane expansion and industrialization and development, since it is the largest sugar producing state in the country and has experienced the most rapid growth in this industry over the last decade (IBGE, 2009). However, there are important differences between São Paulo state and other regions in Brazil that prevent generalization over the whole country, which we discuss in Section 3. Secondly, by studying São Paulo, we will have more explanatory power than if we had studied another state (or Brazil as a whole), since at the present time São Paulo has more data than any other location for human development indicators, sugar mills, and other critical variables.

The paper begins with some background information on agricultural development in Brazil, the environmental and social issues related to the sugar sector, and the socioeconomic and agricultural characteristics of São Paulo. We then turn to the detailed analysis of how various human development indicators differ across municipalities specializing in different agricultural land uses in São Paulo. The empirical results of this analysis, combined with evidence from existing literature, allow us to assess, in the final section of the paper, the full suite of social benefits and costs related to sugar and ethanol expansion in the state of São Paulo.

2. Agricultural development and the social costs of sugar production

Brazil has emerged as a leader in the global agricultural economy, a position that has resulted largely from investments in crop technology and rapid growth in the domestic and global demand for feed and fuel stocks. Embrapa – Brazil's agricultural research institution,[4] capitalized on the country's already abundant land resources and exceptional climatic conditions (which allow farmers to produce crops in many parts of the country all year around with minimal irrigation) by developing cultivars particularly suited to Brazil's longer growing season and poorer soils (Gasques et al., 2004; Alves et al., 2005; Abbey et al., 2006; Barros, 2008). As a result of Embrapa's efforts, Brazil has rapidly improved agricultural yields and total factor productivity (labor, capital, and land) over the past few decades (Gasques et al., 2004). On the demand side, the domestic market for higher valued products, such as meat and dairy, has expanded as a result of economic growth and the success of poverty alleviation programs (Barros, 2008). In addition, the Brazilian government's emphasis on the development of domestic renewable energy sources has created a new and sizeable domestic market for sugar cane ethanol (Goldemberg et al., 2004; Cerqueira Leite et al., 2009). Finally, the liberalization of Chinese and Russian trade policies and an increasing global meat demand have provided strong international markets for both livestock feeds, such as soybeans, and livestock products, such as chicken and beef (Gasques et al., 2004).

Brazil's agricultural development path has been influenced by a series of important policy reforms. The government initially focused on the direct subsidization of domestic staple crops to offset imports, but later reduced these subsidies during a period of widespread economic liberalization in response to the macroeconomic crises of the 1990s. In the wake of this liberalization there was a large increase in the production of export crops (Damico and Nassar, 2007). Despite these direct subsidy reductions, Brazilian farmers still retain important government supports in the form of subsidized loans and price guarantees, particularly for small farmers (Damico and Nassar, 2007). While direct producer supports in Brazil are now quite small in comparison to OECD countries (estimated at only 3% of total farm receipts), the government has been supporting agriculture in a different way: by investing billions of dollars in infrastructure improvements (Gasques et al., 2004; Abbey et al., 2006; Barros, 2008); subsidized loans (particularly on capital investments) and tax breaks on the production of export commodities (Abbey et al., 2006). The Brazilian government announced as recently as June 2010 that it will provide 100 billion Reais (US$ 54 billion) in loans for the major commercial crops in the coming season, 60% of which will be at below-market rates (Cortes, 2010).

The sugar and ethanol industries, in particular, have benefited from a long history of subsidy payments and price controls that have augmented their financial competitiveness in national and global markets (Seroa da Motta and Rocha Ferreira, 1988; Saint 1982; Sperling, 1987; Oliveira, 1991; Puppim de Oliveira, 2002; Baccarin et al., 2009; Puerto Rico et al., 2009).[5] While subsidies for the primary production of agricultural commodities have decreased during the last decade, subsidies to the processing industry are far from zero after accounting for the indirect incentives generated by the government's price controls on gasoline and the preferential loan conditions for sugar and ethanol mill infrastructure improvements (Torquato and Fronzaglia, 2009; Puerto Rico et al., 2009). For example, the price of gasoline in Brazil is kept artificially high, which makes the price of ethanol low in relation to gasoline, fostering the use of ethanol among consumers (Torquato and Fronzaglia, 2009). Export taxes on ethanol and internal movement taxes on goods and services (ICMS – *Imposto sobre Circulação de Mercadorias e Prestação de Serviços*) in some states of Brazil are also lower than those applied to crude oil (Brazilian Regional Science Association, 2010). These policies reflect a motive to remain self-sufficient in oil, but they have the added effect of favoring investment in the ethanol industry (Baccarin et al., 2009).

Arguably the most important agricultural policy tool in Brazil is subsidized credit. Given Brazil's exceptionally high lending rates and loan default rates among agricultural enterprises, a key policy

[4] Embrapa is Brazil's national agricultural research organization, similar to the US Department of Agriculture in production mandates but an order of magnitude smaller in annual budget (in 2009 Embrapa's budget was $650 million and USDA's budget was $95 billion) (Embrapa, 2009).

[5] It is important to note that although government supports made the industries competitive in private (financial) terms, they might not have been socially profitable. See note 1.

objective has been to provide credit at competitive costs with subsidized interest rates for commercial crops and ethanol, machinery acquisitions, and subsistence farming (Damico and Nassar, 2007).[6] A special line of credit exists for the sugar cane industry through the *Banco Nacional de Desenvolvimento Econômico e Social* (BNDES, the Federal Development Bank of Brazil); from October of 2008 to December 2009 the industry received nearly 14 billion Reais (US$7.6 billion) in development loans, 40% of which were specifically targeted for new sugar mills (BNDES, 2010).In addition to subsidized loans, the government has engaged in substantial loan forgiveness, amounting to hundreds of millions of dollars. For example, in 2009 Brazil's largest ethanol and sugar producer, Cosan, received new government loans despite large outstanding debts, and is now a member of the *Programa de Recuperação Fiscal* (Fiscal Reform Program), a federal program not exclusive to the sugar cane industry aimed to help companies repay large government debts. By joining this program Cosan was instantly alleviated of approximately 200 million Reais of their debt (Cosan, 2009). The government supports outlined above represent a cost to society in the form of opportunity costs (public funds that could otherwise be used for different social programs such as education or health) and taxpayer cost.

Another social cost of the development of the sugar industry has been the consolidation of sugarcane production and processing, and an increase in land concentration in the state of São Paulo during the last decade (Baccarin et al., 2009; Olivette and Carmargo, 2009). One mechanism for this consolidation occurs when a smaller domestic company's massive debt has led to acquisitions by larger international companies. For example, in February 2010, Cosan announced a joint venture with Royal Dutch Shell, in which Shell plans to invest 3 billion Reais in cash in Cosan and will assume the equivalent of 4.6 billion Reais of Cosan's debt (Shell, 2010).

Society incurs more direct social costs from sugar and ethanol expansion as well. For example, sugarcane production in São Paulo has had notoriously poor labor practices (Martinelli and Filoso, 2008).Although labor standards have improved considerably in the State of São Paulo in recent years, the modern sugar cane industry has frequently violated official labor laws by subjecting sugar cane cutters to egregious (and illegal) working conditions (Costa and das Neves, 2005; Rodrigues, 2006).

The burning of sugar cane has deleterious impacts on the atmosphere, soils, and the health of sugar cane cutters and local inhabitants (Martinelli and Filoso, 2008).Atmospheric pollution caused by burning sugarcane contains a high concentration of aerosol particles, nitrogen gases like NO_x, and carcinogenic products like polycyclic aromatic hydrocarbons (PAH) (Zamperlini et al. 1997; Lara et al., 2001; Azevedo et al., 2002; Santos et al., 2002; Pereira-Netto et al., 2004; Godoi et al., 2004; Allen et al., 2004; Lara et al., 2005; Machado et al., 2008; Umbuzeiro et al., 2009; Vasconcellos et al., 2008). This pollution reduces solar radiation (Codato et al., 2008) and is linked to respiratory illness, particularly among children and elderly people (Arbex et al., 2000; Arbex et al., 2007; Cançado et al., 2006; Uriarte et al., 2009; Mazzoli-Rocha et al., 2008). Sugarcane burnings also increase nitrogen deposition and hence the acidity of Brazil's already poor tropical soils (Lara et al., 2001; Krusche et al., 2003).

Finally, ethanol production generates a large volume of vinasse, an industrial effluent with high concentrations of nitrogen and potassium and a very high biological oxygen demand. In the past, this effluent was dumped into rivers and streams with serious consequences to aquatic life; now it is used frequently as a liquid fertilizer (Martinelli et al., submitted for publication; Gunkel et al., 2007). Continuous handling and transport of vinasse has led to several accidental spills, threatening the ecological integrity of São Paulo's rivers and streams. Compounding this problem is the fact that many rivers and streams adjacent to sugar cane fields are 1st–2nd order streams with low water volumes and lack the riparian vegetation reserve required by law, making them more vulnerable to soil erosion and vinasse spills (Martinelli et al., submitted for publication).

In light of this evidence, it is important to evaluate whether the expansion and industrialization of Brazil's sugar sector may have benefits to society that justify the social costs of government expenditures, poor labor practices, human health impacts, and environmental damages. To date, the social benefits side of this equation has been largely ignored in the literature on Brazil's sugar industry. In the following section, we provide a brief description of the socioeconomic and agricultural characteristics of São Paulo and present the results of our analysis of the sugar sector's influence on human development indicators in the state of São Paulo. This analysis is designed to show how the expansion of sugar production and ethanol refining compares with alternative patterns of land use—namely cattle production—in terms of improving society's welfare.

Table 1
Demographic, economical and social indicators of the State of São Paulo, Brazil and the Northeast region.

Parameter	São Paulo	Brazil	Northeast
GDP per capita – 2007 (Reais of 2000)[a]	12,970	8280	3860
Income Gini – 2009[a]	0.489	0.543	0.558
Land distribution Gini – 2006[b]	0.678	0.850	0.850
HDI 2000[c]	0.820	0.766	0.676
MDI 2007[d]	0.870	0.748	0.614
Lack of literacy (%) above 15 years old – 2009[a]	6	11	20
Number of average years in school – 2008[a]	7.9	6.9	5.4
Poor and very poor households (%) – 2009[a]	11	22	45
Life expectancy (years)[a]	72	69	–
Households with food security (%) – 2004[a]	73	60	41
Water supply – household connection (%) – 2007[e]	90	81	77
Sanitation – household connection (%) – 2007[e]	93	71	53

[a] IBGE (2007).
[b] IBGE (2006).
[c] SEADE (2006).
[d] FRIJAN (2007).
[e] IBGE (2008).

3. Agricultural development and human development in the State of São Paulo

The state of São Paulo is located in the southeast region of Brazil; it has an area of approximately 250,000 km^2 and contains 22% of the country's population (42 million people in 2010).[7] The state's gross domestic product (GDP) is equivalent to almost 35% of the country's GDP and is generated primarily by the services sector (68%), followed by industry (30%) and then agriculture (2%). It is important to note, however, that the revenue and employment generated from agricultural processing activities is captured by the "industry," not "agriculture" category.

Although São Paulo is by far the richest state in Brazil in terms of GDP, it still has a great deal of inequality. The state's Gini

[6] Brazil's lending rates in June 2010 were: 10.25% for SELIC (the Central Bank's overnight lending rate, comparable to the US Federal Funds rate); 26.3% for bank lending to corporations; and 41.1% for bank lending to individuals. Brazil also has a government-subsidized rate (TJLP) that allows certain companies to borrow at a discounted rate of 6% (COPOM, 2010).

[7] Data for these next two paragraphs come from *Fundação Sistema Estadual de Análises de Dados*–São Paulo State Foundation on Data Analysis (SEADE, 2006).

Table 2
Percentage cover of sugarcane, corn, orange, soybean and coffee in relation to the total arable land area of the State of São Paulo and percentage of the economic value of the production of these crops in relation to the total economical value of agricultural production of the State of São Paulo (IBGE, 2009). Production value is obtained by multiplying the crop production of each municipality by the average price of that crop during the year.

Year	Arable area (%)						Production value (%)					
	Sugarcane	Corn	Orange	Soybean	Coffee	$\sum_a$[a]	Sugarcane	Corn	Orange	Soybean	Coffee	$\sum_v$[b]
2000	43	19	11	9	4	86	45	9	8	5	5	71
2001	44	19	10	9	4	86	43	6	18	4	3	74
2002	45	18	10	10	4	86	44	7	20	5	4	80
2003	45	18	10	10	4	87	43	8	20	6	3	79
2004	46	17	9	12	3	87	38	8	20	7	4	78
2005	46	16	9	12	3	86	44	7	18	5	4	78
2006	51	15	8	10	3	88	50	5	21	3	4	83
2007	57	13	9	7	3	89	49	6	19	3	4	81
2008	60	13	8	7	2	90	49	7	17	4	4	81

[a] Sum of arable area of sugarcane, corn, orange, soybean and coffee.
[b] Sum of production of sugarcane, corn, orange, soybean and coffee.

Table 3
Criteria used to grouped municipalities of the State of São Paulo in five classes according to the presence of sugar mills, sugar cane area and number of cattle heads. In brackets the number of municipalities in each class.

	MILL (90)	SUGAR (97)	CATTLE-SUGAR (142)	CATTLE (212)	NON-RURAL (104)
Mill	Yes	No	No	No	No
Sugar cane (ha)		>1200	>1200	<1200	<1200
Cattle (animals)		<13,200	>13,200	>5500	<5500

coefficient for income was 0.49 in 2009 and 0.68 for land distribution in 2006 (the only dates for which there are data). Both of these coefficients are very high, indicating a significant degree of inequality, but slightly lower than the Gini coefficients of the Northeast region (the other major sugar producing region in Brazil) and the country average (Table 1). The State of São Paulo also performs better than the Northeast and country average with respect to per capita incomes, inequality measures, education, sanitation, and the Human Development Index (Table 1). Another important difference between the state of São Paulo and the rest of the country is the high degree of urbanization. Approximately 95% of the population lives in urban centers and 95% of the formally employed are classified as having urban versus rural jobs (IBGE, 2007). These urban centers (particularly São Paulo city) serve as important markets for the state's sugar and ethanol products.

Historically, coffee was the main crop of the State of São Paulo; however, today pasture accounts for almost 50% of the agricultural land use in São Paulo, followed by sugarcane (27%), oranges (3.5%) and corn (3.3%) (CATI, 2008).Today the state has 324,600 farms encompassing about 80% of the state's total area.[8]

As mentioned earlier, the amount of land devoted to sugarcane cultivation in São Paulo has increased faster than any other state in Brazil over the past two decades, and São Paulo now accounts for half of the sugar cane area in Brazil (IBGE, 2009). While in 2000 sugarcane was responsible for 43% of all cropland area in São Paulo and 45% of all primary agricultural production value, in 2009 sugar cane was responsible for 64% of all cropland area and for 55% of all primary agricultural production value (IBGE, 2009; Table 2). The expansion of sugar cane area was accompanied by a decrease in the area occupied by corn, orange, soybean, coffee, and pasture (IBGE, 2009; Rudorff et al., 2010). The scale and speed of the sugar industry's development in São Paulo and it's large land use impact make understanding the impacts of the sugar industry in this state critical, although not sufficient, for understanding the overall impacts of the rapid industrialization and expansion of the sugar industry in Brazil.

3.1. Methods and data

To evaluate development indicators for the two key agricultural sub-sectors in São Paulo—sugar and beef—we grouped the State's 644 municipalities according to the following variables: the presence of an ethanol plant, hectares of sugar cane harvested, and number of cattle in each municipality. The only municipality that was excluded from this analysis was São Paulo because it is strictly urban and has a disproportional number of inhabitants and wealthy people compared with the other municipalities. The sugar cane harvested area and number of cattle for each municipality were obtained from the Brazilian Institute of Geography and Statistics' Municipal Agricultural Survey and Municipal Livestock Survey. Because these variables did not follow a normal distribution, we used the median values and the lower quartile (25%) from 2000 to 2007 to define five different classes of municipalities. The median sugar cane area was 4600 ha and the lower quartile was 1200 ha. The median number of cattle was 13,200 and the lower quartile was 5500.

The five land classifications were defined as follows. Due to the importance of sugar mills in generating revenue and employment opportunities beyond that of agricultural production, we grouped municipalities that have a sugar mill as one distinct class MILL, no matter how much area they had under sugar or cattle production. Municipalities without a sugar mill that had moderate to high levels of sugar cultivation and below average levels of ranching (a sugar cane area larger than 1200 ha and less than 13,200 cattle heads) were grouped under the class SUGAR. The third class called CATTLE-SUGAR included municipalities that both moderate to high levels of sugar planted area and an above average herd size (a sugar cane area larger than 1200 ha and more than 13,200 cattle heads). Municipalities with a low level of sugar and moderate to high level of cattle (less than 1200 ha of sugar and more than 5500 cattle heads) were denominated CATTLE. Finally, municipalities with low levels of sugar and cattle (less than 1200 of sugar cane and less than 5500 cattle heads) were designated NON-RURAL. Table 3 summarizes all these criteria and the number of municipalities in each class, while Table 4 summarizes basic average demographic and social information for land-use each class.

We analyzed municipalities by land-use class to see if they had statistically different levels of economic and social development as defined by two sets of variables: human development indicators and Gini coefficients. For the human development indicators, we used data from the São Paulo State Government's Social Responsibility Index (SRI) recorded for the years 2000, 2002, 2004 and 2006

[8] The most recent land use and composition data are for the period 2006–2008.

Table 4
Median values of socioeconomic parameters by municipality class (given years).

Variable	MILL	SUGAR	CATTLE-SUGAR	CATTLE	NON-RURAL
Average area (ha)	43,400	19,809	46,200	25,800	14,400
Total area (million ha)	4.5 (18%)[a]	2.3 (9%)	7.6 (31%)	7.9 (32%)	2.5 (10%)
Average population – 2000 (ha)	28,255	8444	9740	6717	34,000
Total population – 2000 (million)	4.4 (17%)[a]	2.1 (8%)	4.4 (17%)	5.9 (22%)	9.7 (36%)
Population density (inhab. per km^2)	98	91	58	75	388
Gini income – 2000	0.518	0.504	0.517	0.525	0.538
DHI – 2000	0.800	0.780	0.780	0.766	0.788
Gini land – 2006	0.700	0.664	0.684	0.669	0.637

[a] Percentage in relation to total of the State of São Paulo.

(SEADE, 2006). The SRI is divided into three different major categories of social welfare—wealth, longevity, and education—which we summed and weighted equally to create an index comparable to the United Nations' Human Development Index.[9] We also used the Municipality Development Index for the years 2000, 2005, 2006 and 2007, which was created by the Industry Federation of the State of Rio de Janeiro (FRIJAN, 2007). The MDI like the SRI is divided into three different major categories of social welfare – employment and revenues; health, and education.[10] Finally, we also used the State of São Paulo's Human Development Index (HDI) (equivalent to the United Nations index), which is calculated for each municipality in the State on a decadal basis (SEADE, 2006). The aggregate SRI and the HDI for São Paulo municipalities are significantly correlated (Spearman rank correlation = 0.65), as are the MDI and the HDI (Spearman rank correlation = 0.55).

Finally, we tested to see whether the 2000 Gini coefficient for income and the 2006 Gini coefficient for land distribution differed among classes of municipalities (since these were the only years for which we had data). Data for the Gini coefficient for income were obtained from the State of São Paulo's *Informações dos Municípios Paulista* (Municipality Information) portal and data for Gini coefficient for land were obtained from the state government's *Levantamento Censitário das Unidades de Produção Agropecuária do Estado de São Paulo* (Survey of the Units of Agricultural Production) (CATI, 2008).

Most of the variables we analyzed followed a non normal distribution and were adjusted by using a Box Cox transformation. We applied ANCOVA followed by the Tukey Honest Test for unequal variance. A series of control variables (covariates) were used in our ANCOVA model to minimize the amount of influence we erroneously attributed to our variables of interest – the land use classes. We used the municipality area, its population and the gross domestic product of services (GDP services)[11] as our first three controls. Using a geographical information system we estimated the distance of the main city of each municipality the closest major road and to the city of São Paulo, which is the major market of the State. We then used both of these variables as two more covariates. Although the area of other crops in São Paulo are small in relation to sugar cane, we used the area of corn and oranges as covariates, since they are the next largest land uses in the state (Table 2). Finally, in an attempt to capture the historical levels of development of the municipalities before the recent sugar cane area expansion, we adopted the total tax generated in each municipality in 1993 (the oldest series available)[12] as the final covariate.

[9] For full details on the categories within the SRI, see Appendix A.
[10] For full details on the categories within the MDI, see Appendix B.
[11] Area and population data for the year 2000 were obtained from *Informações dos Municípios Paulista* (Municipality Information for the State of São Paulo) available at *Fundação Estadual de Análise de Dados* (São Paulo State Foundation on Data Analysis) (SEADE, 2006).
[12] Data obtained from *Informações dos Municípios Paulistas* (Municipality Information of the State of São Paulo) (SEADE, 2006).

It is important to note that the MILL category includes a few municipalities that have a strong urban component, such as Piricicaba, and that including these municipalities in this category runs the risk of capturing non-mill related industrial or service activities that might also influence development. However, we felt it was important to include these municipalities in the MILL, rather than the NON-RURAL class because they also have a significant amount of land devoted to sugar production, and the synergy between sugarcane production and sugar refinement is an integral component of their economy. Additionally, the problem of urbanization levels in this category is mitigated through the use of GDP services as a control variable in the ANOVA analysis, because those municipalities that have high urban components also tend to have higher levels of GDP in the category of services.

3.2. Results

Our analysis led to four general sets of results. First, the area data indicated a distinct pattern of land use change favoring the growth of sugar over cattle during the last 4 years (Fig. 1).[13] Specifically, relative areas with sugar cane observed in the classes MILL, SUGAR, and CATTLE-SUGAR increased, while the median number of cattle decreased in all classes of municipalities. This trend bodes well for the development process, because the second main result—focused on human development indicators—was that the HDI was significantly smaller for the CATTLE class than all other classes, while the HDI was higher in the MILL class than in the others, even the NON-RURAL class. This trend followed for both aggregate socioeconomical development indexes – the Social Responsibility Index (SRI) and the Municipal Development Index (MDI) as well; the CATTLE class was significantly smaller than all other classes, and the MILL class was significantly higher than the class NON-RURAL (Tables 4 and 5).[14]

Within the SRI and MDI sub-categories, wealth was statistically lower in the CATTLE class in comparison to all others, while wealth was statistically higher in the MILL class in comparison to all others, especially after 2000. The education and longevity trends of the SRI and MDI were different than the wealth component. Education was consistently lower in the class NON-RURAL in relation to the other classes.[15] However, the longevity component was not statistically different among municipality classes for the SRI or the MDI index. Finally, in terms of income distribution, the analysis shows that the income Gini coefficient was not different among municipality classes. The land distribution Gini coefficient was significantly lower in the NON-RURAL class in relation to all others, since other forms of capital tend to be more concentrated in non-rural areas (Tables 4 and 5).

[13] Farm sizes are divided into 14 classes followed by the number of farms in each class and the total area under that size class. For more details, see CATI (2008).
[14] The only year that this relationship was not statistically significant was in 2006.
[15] The only exception again was the year 2006, when the education component was only significantly lower in class NON-RURAL than in the class SUGAR.

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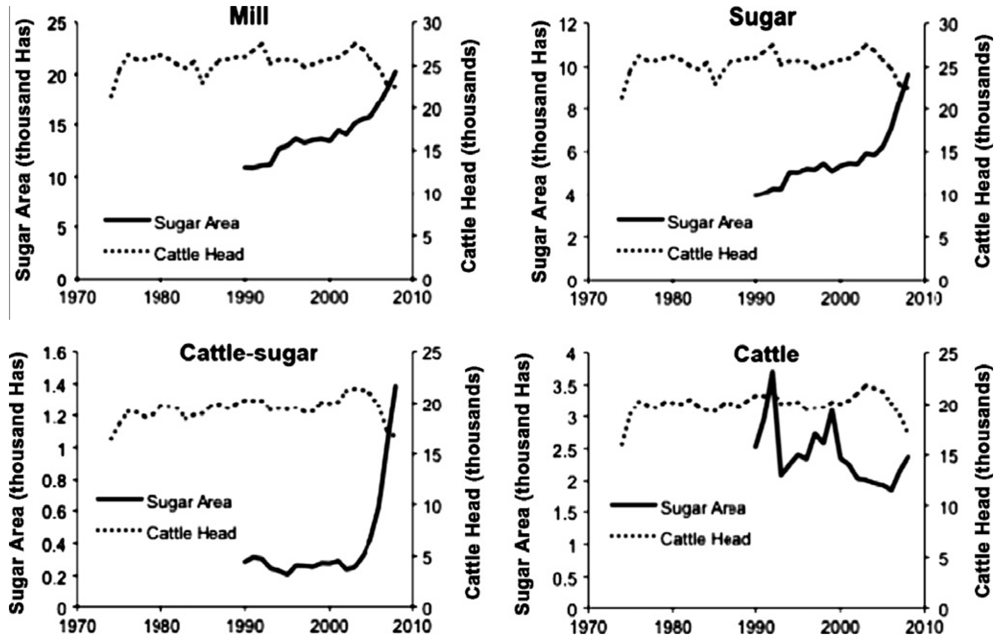

Fig. 1. Variation of relative proportion of sugar cane area and number of cattle heads in four classes of municipalities: mill, sugar, sugar, and cattle.

Table 5
Significant statistical differences ($p < 0.005$) by municipality class for socioeconomic parameters. Letters indicate municipalities classes as follows: "M" for MILL; "S" for SUGAR; "CS" for CATTLE-SUGAR; "C" for CATTLE, and "NR" for NON-RURAL. Relationships hold for all years when data are available unless otherwise specified.

Variable	Significance
Area (ha) 2000	M, CS > S, C > NR
Population 2000	M, NR > S, CS, C
Gini income 2000	Non significant
Gini land 2006	M, S, CS, C > NR
Average area per farm 2006 (ha/farm)	M > CS, C, NR and S, CS > C, NR
Corn area (ha)	S, CS, C > M
Orange area (ha)	M, S, CS > C, NR
DHI 2000	M > S, CS, C, NR and S, CS, NR > C
SRI-total	
2000–2006	M, S, CS, NR > C
2000–2004	M > NR
MDI-total	
2000	M, CS > C
2005–2007	M > S, CS, C and S, CS, NR > C
SRI-wealth	
2000	M, NR > S, CS, C
2002–2006	M > S, CS, C, NR and S, CS, NR > C
MDI-wealth	
2000	M, CS > C
2005–2007	M > S, CS, C and S, CS, NR > C
SRI-education	
2000–2004	M, S, CS, C > NR
2006	Non significant
MDI-education	
2000, 2005–2007	M, S, CS, C > NR
SRI-health	
2000–2006	Non significant
MDI-health	
2000, 2005–2007	Non significant

3.3. Discussion

The class MILL had the highest overall levels of economic and social development across the five land cover classes, while the class CATTLE had the lowest overall levels of economic and social development. The class NON-RURAL performed better than the other classes on a few of the economic development indicators such as wealth and on the Gini coefficient for land distribution, but worse on most other indicators. Based on these results we conclude that municipalities with a sugar mill have performed better on average on human development over the past decade than municipalities without a sugar mill. Additionally, municipalities with high levels of sugar, but no sugar mill, have still performed better on average than municipalities specializing in cattle production. Overall, municipalities with high levels of cattle and low levels of sugar performed significantly worse than every other agricultural class on nearly every indicator. However, the cattle municipalities still performed better than non-rural municipalities, suggesting that municipalities that have not developed any strong agricultural activities have also not developed an economic alternative to agriculture to increase the income, longevity, and educational attainment of the poor.[16]

Because our data begin in 2000, we cannot rule out the possibility that the municipalities with sugar mills had higher levels of economic development than the other municipalities before the arrival of the sugar mill. In fact, it is possible that the municipalities with better economic conditions attracted the interest of sugar mill developers because they already had better financial and physical infrastructure. If so, it might not be the industry that determined the economic and social fate of the municipality, but other historical reasons that are beyond the scope of this study. On the other hand, the use of the total tax generated in 1993 before the sugar boom of this decade as a control variable (covariate) give us some confidence that the prior level of development was not the main cause of the better performance of municipalities with sugar mills, nor was the existence of transportation infrastructure since distance to São Paulo's major highways was also used as a control variable.

Additionally, the land use patterns we examined in our study over the past decade have a longer historical basis (Fig. 2; IBGE, 2006; Brannstrom and Oliveira, 2000), which supports the linkages

[16] In a more limited study of land classifications and time periods, Carmargo and Toneto, 2009 found a similar trend for the State of São Paulo.

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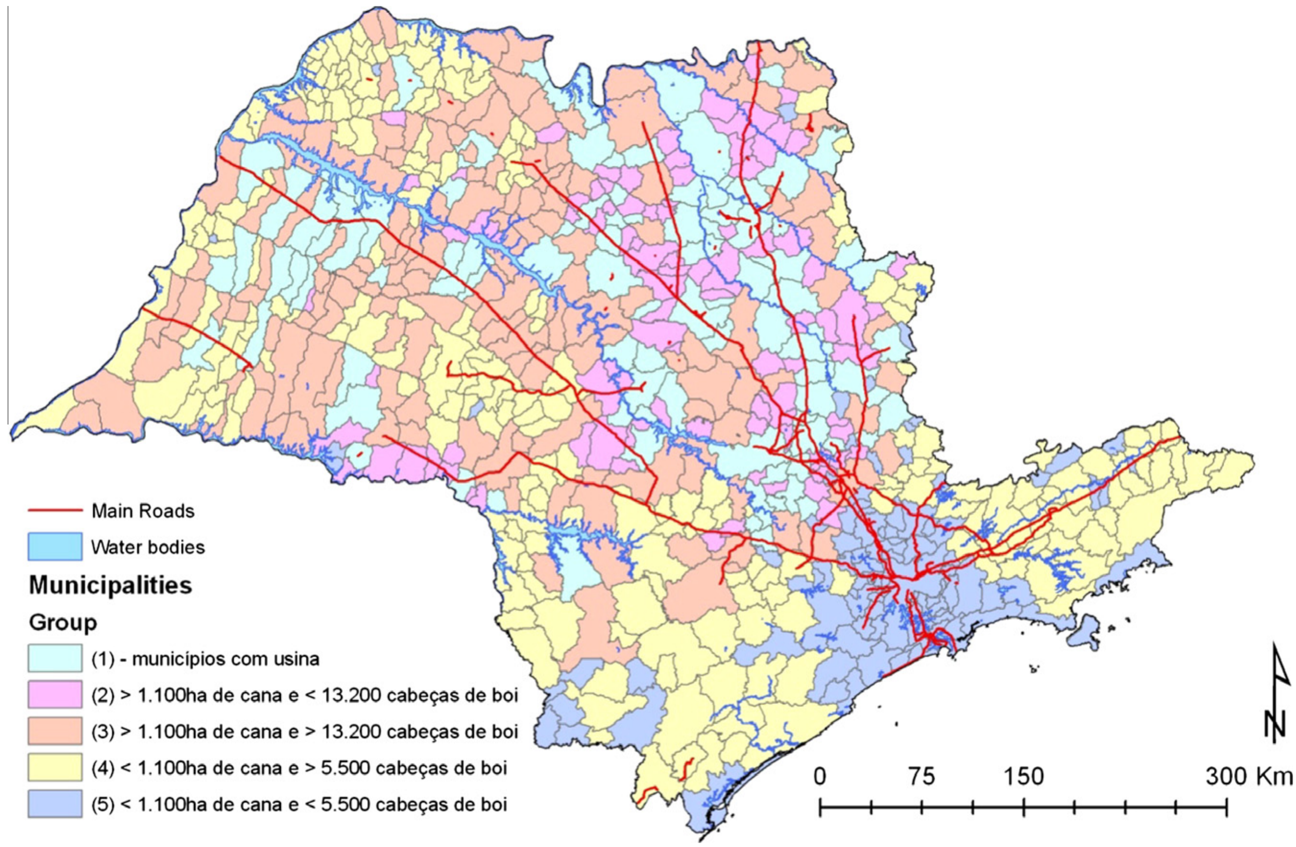

Fig. 2. Municipalities of the State of São Paulo grouped according to the classes mill, sugar, sugar, cattle, and non-rural.

we have drawn between present day agricultural specialization patterns and overall development levels. While the municipalities in the MILL and SUGAR classes have seen an increase in sugar cane area alongside the growth of the ethanol industry in the region, they were both specializing in sugar for at least a decade prior to the arrival of the new sugar mills. Thus, while specialization in sugar was a constant across the two classes, the development of new processing facilities in the municipalities in the MILL class was a new event during the study period that may explain the different development levels across the two classes. Similarly, we see that all classes have had a fairly constant number of cattle over the past four decades, but the CATTLE-SUGAR and CATTLE classes don't increase their level of sugarcane production until after 2005–2006, which may explain their poorer performance on the development indicators prior to that period. Thus, while it is inherently hard to identify the direction of causality in the relationship between development and agriculture (Carmargo and Toneto, 2009), it is likely that the long history of sugar and cattle production in each of the municipalities has influenced its development trajectory.

Consequently, there is strong evidence that municipalities that specialize in sugarcane have higher rates of economic and social development than those with cattle, likely through the generation of employment opportunities and improved infrastructure (Dias de Moraes, 2007; Shikida, 2008; Montagnhami et al., 2009). For instance, between 2005 and 2006 job opportunities in the sugar industry increased 20% – the highest relative growth among agricultural activities of the State of São Paulo (Petti and Freddo, 2009). In terms of employment opportunities, sugarcane demands annually eight workers per 100 ha, while cattle demands only two workers per 100 ha (Petti and Freddo, 2009). Additionally, it was estimated that in the northwest region of the State of São Paulo, for each job created in the sugar industry, approximately 2.4 jobs are created through a multiplier effect in other activities in the same region (Montagnhami et al., 2009).

4. Conclusion: weighing social benefits and costs

The data and results presented in this paper call attention to the linkage between sugarcane processing and rural development. The positive relationship between various socioeconomic indicators and the presence of a sugar mill across municipalities in São Paulo highlights the role of processing industries in expanding employment opportunities, public services, and infrastructure development. Indeed, a successful agribusiness sector—with its multiplier effects in industry and services—may be essential for ensuring that investments in commodity crops actually bring benefits to the rural poor, rather than just generating foreign exchange and further concentrating wealth.

Nonetheless, because our results have only shown a statistically significant relationship between the presence of a strong sugar and ethanol industry and higher levels of economic and social development—rather than proof of causality—there is a clear need for more research to elucidate the mechanisms by which processing activities may improve livelihoods and equality in rural Brazil. Understanding the link between development and sugar/ethanol production is critical for determining whether the private benefits of the government's promotion of the sugar industry in Brazil justify its high social costs. Additionally, due to a lack of data we were not able to study human development indicators in other parts of the country where some temporary sugar laborers reside when they are not working in São Paulo. Thus we are still lacking an understanding of how the sugar production in São Paulo affects other regions of Brazil. We also include the caveat that the study

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conducted here represents only one important, though not sufficient, case regarding the overall relationship between development and the sugar industry in Brazil. The State of São Paulo is more developed than other parts of Brazil in several aspects (Table 1) and much closer to the largest national markets for ethanol and sugar products. Thus, lower initial development levels and distance to national markets may influence the way the sugar industry's development plays out in terms of social benefits in other regions. Therefore, the results of this study should not be extrapolated for other regions of Brazil with out further study.

The results of this study also underscore the relatively low levels of economic and social development in municipalities dominated by cattle ranching in the State of São Paulo.[17] Considering that cattle ranching occupies roughly 200 million hectares of land in Brazil—more land than any other agricultural sub-sector—a switch from ranching to high value commodity farming could well lead to additional gains in rural development per unit of agricultural land. The data already show a trend toward sugar over cattle in São Paulo (Fig. 1). However, gains in economic development associated with a decline in cattle must be weighed against potential welfare losses incurred from additional environmental degradation associated with intensive agriculture, and possible effects on livestock small holders.

The latter point on environmental damages is particularly important in terms of how the Brazilian government conceptualizes and implements future agricultural development strategies. It is possible, for example, that if the economic burden of respiratory illness from sugar burning was subtracted from the estimates of income and wealth in the municipalities with sugar cane, their economic development performance would fall below municipalities specializing in cattle production. Similarly, placing an economic value on air and water pollution from sugar production and the mishandling of vinasse would lower the net benefits from the sugar and ethanol industries substantially.

In recent years, a few important steps have been taken at the state and federal levels to reduce the environmental impact of sugar cane. In the state of São Paulo, zoning for sugar cane expansion has been introduced to prohibit production in environmentally sensitive areas, and the government has agreed with the Brazilian Sugarcane Growers Association (UNICA) to end burning by 2014 (Ethanol Verde, 2010). Beyond São Paulo the federal government currently prohibits sugarcane cultivation in the Amazon and Pantanal to prevent environmental degradation in these ecologically critical biomes (Manzatto et al., 2009). Finally, UNICA and multinational corporate investors have stressed their commitment to environmentally sensitive and socially just practices as part of their social responsibility platform (M. Jank, President of UNICA, personal communication to L.A. Martinelli, May 19, 2010). Such positive measures, particularly when influenced by corporate leadership, imply that profitability and social responsibility need not be mutually exclusive.

Brazil is at an important crossroads in terms of supporting agribusiness that leads to social welfare gains for its population as a whole, rather than promoting private gains for the privileged few. Our work suggests that social benefits from sugar and ethanol expansion in São Paulo during the past decade—as measured by human development indicators and income distribution—are larger than commonly perceived, especially compared to cattle ranching. The real test remains: whether growth in agribusiness can go hand in hand with improving, not diminishing, environmental and labor conditions in other areas of Brazil. If so, public financial support for agriculture and agribusiness will have paid off in social returns.

[17] This conclusion is also supported by the findings of Sparovek et al. (2007).

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Appendix A

Variables and respective weights used to estimate the three main components of the Social Responsibility Index created by the government of the State of São Paulo (SEADE, 2006).

Wealth	
Domestic electricity energy consumption	44%
Non domestic electricity energy consumption	23%
Average income	19%
Gross Domestic Product per capita	14%
Health	
Perinatal mortality	30%
Mortality <5 years	30%
Mortality 15–39 years	20%
Mortality >60 years	20%
Education	
Percentage of young people (15–17 years) that finished intermediate level	36%
Percentage of young people (15–17 years) with <4 years in school	8%
Percentage of young people (18–19 years) that finished high school	36%
Percentage of children (5–6 years) in pre-school	20%

Appendix B

Variables and respective weights used to estimated the three main components of the Municipality Development Index created by the Federation of Industries of the State of Rio de Janeiro. Source: http://www.firjan.org.br/data/pages/2C908CE9229431C9-0122A3B25FA534A2.htm (accessed 01.11.10).

Wealth	
Creation of formal employment	30%
Number of formal employment	35%
Average income of formal jobs	35%
Health	
Perinatal visit to clinics	33%
Mortality <5 years	33%
Mortality by non well defined causes	33%
Education	
Rate of registration in elementary schools	20%
Rate of abandonment from elementary schools	15%
Rate of distortion between age and grade	10%
Percentage of teachers with college degree	15%
Average hours of daily classes	15%
Score of the Elementary Education Development Index	25%

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