DEVELOPING AWAY FROM SUSTAINABILITY? REGIONAL DEVELOPMENT AND GLOBALISATION IN THE BRAZILIAN SUGARCANE ETHANOL SECTOR.

Paper prepared for the Regional Studies Association conference, Leuven, 2009.

February 2009

Dr Peter Wells*
Ms Thaisa Faro

*Corresponding Author
Reader
Cardiff Business School
Cardiff University
Cardiff UK
CF10 3EU

wellspe@cardiff.ac.uk

DEVELOPING AWAY FROM SUSTAINABILITY? REGIONAL DEVELOPMENT AND GLOBALISATION IN THE BRAZILIAN SUGARCANE ETHANOL SECTOR.

ABSTRACT

Over the last 40 years or so the Brazilian sugarcane industry has been transformed by the growth of the market for ethanol, produced by the fermentation and distillation of sugarcane juice. Initially under the impact of the government Proalcool programme, more recently as a result of new flexible-fuel engines, the sugarcane ethanol sector flourished serving a local demand – generating wealth and jobs. Within the context of Brazil, the sugarcane ethanol sector had much to recommend it as an example of regional agri-industrial sustainability. It provided an escape from volatile and falling international sugar prices; it provided work (albeit difficult and underpaid) for many migrant rural workers; it generated distributed local wealth; and it provided macro-economic benefits most notably in terms of substituting for imported petroleum. As this paper explores, the danger now is that a previously sustainable example of regional industrialism is exposed to the forces of globalisation as never before, with the risk that in such a volatile market the sector will become unsustainable in economic, social and environmental terms.

KEYWORDS

Sustainable regions; bio-ethanol; sugarcane; Brazil; globalisation; transitions.

1. INTRODUCTION

Over the last 40 years or so the Brazilian sugarcane industry has been transformed by the growth of the market for ethanol, produced by the fermentation and distillation of sugarcane juice and used as a substitute for petrol in vehicles. Initially under the impact of the government Proalcool programme, and more recently as a result of new flexible-fuel engines, the sugarcane ethanol sector flourished serving a local demand – and simultaneously generating wealth and jobs within rural regions of Brazil. Land ownership structures remained largely unchanged, with traditional sugarcane plantation landowners benefiting greatly from technical considerations that resulted in micro-monopolies and an inability to achieve economies of scale in ethanol production. Within the context of Brazil, the sugarcane ethanol sector had much to recommend it as an example of regional agri-industrial sustainability or 'green jobs' (Annandale et al. 2004). It provided an escape from volatile and falling international sugar prices; it provided work (albeit difficult and underpaid) for many migrant rural workers; it generated distributed local wealth; and it provided macro-economic benefits, most notably in terms of substituting for imported petroleum. Indeed, the environmental benefits of sugarcane ethanol, particularly in terms of reduced carbon emissions compared with petroleum-derived fuels, were not a primary motivation for the initiation of the programme but have become important as time has moved on. Many other social, economic and even cultural factors can be said to have contributed to the growth of the sector domestically (Nardon and Aten, 2008), rather than a specific desire to nurture sustainable eco-industrialism, but this has become an outcome and a stated policy intention subsequently.

In more recent years, however, the sector has been propelled onto the international market as countries such as Japan and Sweden have sought to achieve their carbon reduction targets by, among other things, using imported Brazilian bio-ethanol in place of petrol. High level political support within Brazil has accompanied this drive. Investment funding, from the US and elsewhere, has been poured into the sector in a bid to expand, rationalise, professionalise and internationalise it.

The process of mechanisation of harvesting, needed for economic and environmental reasons, is already strongly underway with the result that the employment of unskilled harvest workers will fall dramatically. Infrastructures for exporting sugarcane ethanol are under development with new pipelines and harbour facilities. Markets outside Brazil are being cultivated. Many companies from within and outside Brazil are now competing to gain control over sugarcane ethanol production, including petroleum suppliers, investment houses, venture capitalists, agricultural products companies, sugar producers and more (Wells, 2009).

As this paper explores, the danger now is that a previously sustainable example of regional agri-industrialism is exposed to the forces of globalisation as never before, with the risk that in such a volatile market the sector will become unsustainable in economic, social and environmental terms. This has important implications for the theorisation of trajectories of sustainability and of system transitions.

The paper commences therefore with a discussion on the implicitly linear and spatially-intensive theories of transitions in socio-technical systems, from ‘less sustainable’ and towards ‘more sustainable’. It is very possible that it is necessary to take one step ‘backwards’ (or become in some respects less sustainable) in order to take two steps forwards (or become more sustainable). Moreover, in Brazil the characteristics of ethanol production require extensive eco-industrialism. Hence the politics of environmentalism could become complicated by temporal and spatial specificities where apparently detrimental changes are underway. Put another way, the transition phase may result in a qualitatively different sort of sustainability.

These themes are then explored through the empirical example of the evolution of the Brazilian sugarcane ethanol sector, its contemporary position, and likely future medium-term prospects given current knowledge.

2. LINEAR CONCEPTUALISATIONS AND THE SPATIAL FOCUS OF TRANSITIONS AND SUSTAINABILITY

In general terms, research and analysis into issues related to sustainability tend to have an implicit temporal trajectory; situations become progressively more sustainable on a step-by-step basis. Simultaneously, practices that are regarded as less sustainable fade away, usually under pressure from government regulation. Similar observations might be said to apply with respect to many of the technology ‘roadmaps’ produced by governments and companies alike over recent years. There has been an essential progressiveness about such perspectives, inevitably, which assumes that the fundamental quality of change is for the better. Within the realm of local eco-industrialism, there has been a focus on the identification of successful practice, and the replication of strategies and policies that might nurture more sustainable clusters in new locations. Equally, eco-industrial networks might be fostered through a process of continuous improvement whereby the inter-linkages become ever-deeper and mutually self-reinforcing. Typically, the literature is grounded in polar, spatially-intensive cases where the emergent best practice is centred on a single major industrial process contained within a singular plant – most classically of course in Kalundborg (Desrochers, 2002) but also in other instances (Kahn, 2005; Boons, 2008). This is clearly not the case for the dispersed structure of ethanol production described below, which can be understood as a specific case of dispersed or distributed energy economy (Mirata et al. 2005; Johansson et al. 2005).

While it is often recognised that the embedding of sustainability in a region, a sector, or even a single firm is indeed uneven and contested, it is not usually proposed that a currently sustainable situation might become less sustainable, or that the condition of sustainability might be a temporary state. That is, the focus tends to be on the identification and exploitation of those factors that are held to improve sustainability, in general or at the community level (Hampstead and Quinn, 2005), often under the rubric of Regional Sustainability Initiatives (Annandale et al. 2005). Similarly, when developing agri-industrial clusters are propelled onto the international state, the focus tends to be on the factors that contributed to enhanced sustainability (Perez-Aleman, 2003). From both a theoretical and policy perspective, however, it needs to be recognised that there may be instances when a situation becomes less sustainable. While this may be a case of taking one step back in order to take two forward, at a minimum an awareness of the situation is a pre-requisite to good policy. An aspect of relative sustainability, it is argued here, should be the physical, informational and other networks that connect the bounded region with other spaces (McManus, 2008). In short, we need to consider whether sustainability is consistent over different spatial scales.

Sustainability of course combines social, economic and environmental aspects. All three need to be viable over (a usually unspecified) long time period for a situation to be described as sustainable. Various metrics have been developed to help show that situation x is more sustainable than situation y, but it is rather more difficult to say that an absolute level of sustainability has been achieved. There are parallels with the literature on networks and innovation, and of course with respect to cluster theory. Consequently, forecasting cluster development is at best an inexact science that from a methodological perspective raises important questions about the relationship between theory, evidence and the advocacy of policy choices. The problem is that the character of future development, in this case with respect to the sugarcane ethanol sector, is not entirely knowable. Attempts have been made to develop methodologies to identify ‘microchanges’ in embryonic cluster development as a policy aid (Montana and Nenide, 2008) in recognition of the problem. Hence, we may only say with certainty that a situation got ‘better’ or ‘worse’ from a sustainability perspective after the event, by which time it may be too late to initiate remedial action or other changes.

3.THE EVOLUTION OF THE BRAZILIAN SUGARCANE ETHANOL SECTOR

The first sugarcane plantation in Brazil was founded in 1503, almost immediately after the country was colonised by the Portuguese. Conditions in parts of Brazil are naturally conducive to sugarcane: there is a combination of latitude, soil, topography, and climate that makes some regions especially favourable to large-scale cultivation of this crop. Within Brazil, production of sugarcane has long been concentrated in the State of Sao Paulo.

In the 1970s, when Brazil was ruled by a military dictatorship, the successive oil shocks occasioned by OPEC production cuts, along with chronically low prices for sugar, provided the circumstances and rationale for the initiation of the programme to convert sugarcane into ethanol to be used as fuel for cars (i.e. the ‘Proalcool’ programme). Brazil in any case had a long tradition of fermenting and distilling sugarcane to make ‘pinga’ or ‘cachasa’, an alcoholic drink of approximately 40% alcohol by volume that forms the basis of caipirinha.

The transformation of the sector from one that provided sugar, plus a modest volume of alcohol, into one that supplied sufficient volumes to supply most of the personal transport needs of the country was never going to be straightforward. An obvious requirement was to develop (or at least adapt) engines that could run on pure ethanol. In brief, the Proalcool initiative encompassed three phases (Zapata, 2009):

- First phase, established in 1975, put in place an E22 blend with petrol (i.e. 22% ethanol), to test the effect on engines and to start the transition to ethanol production;
- Second phase, starting in 1979 with the first ethanol-only vehicles on the market which reached a peak in 1986 when 96% of all vehicles sold were ethanol only (i.e. using E100 fuel);
- Third phase, starting in 1987, which saw the reduction of subsidies and other measures to promote ethanol use.

By the mid-1980s some 95% of new car sales were of a type designed to run on pure ethanol. However, falling oil prices, technical problems with the cars, issues with supply as sugar prices rose, and the withdrawal of government support all combined to undermine the market. Ultimately, the use of ethanol as a fuel for cars was almost moribund until the emergence of the twin circumstances of ‘flex-fuel’ engines (i.e. engines that could run on either ethanol or petrol or a mix of the two) and resurgent petrol prices (Louro, 2004). VW introduced the first flex-fuel model on the market (the Gol Total Flex) in March 2003; by the end of 2008 over 90% of all new car sales were of the flex-fuel type. In addition, even ‘petrol’ as sold in Brazil is actually 25% anhydrous ethanol. It is generally held that if oil prices are above about US$50 per barrel, then sugarcane ethanol is cost-competitive (Unica estimate US$70). Ethanol production in Brazil has a foundation demand in the domestic market, virtually assured by the total dominance achieved by flexible fuel vehicles in new car sales. The Brazilian Automotive Manufacturers Association estimates that by 2017 pure ethanol or flex-fuel vehicles could account for 80% of the total fleet of 37 million cars in Brazil (Carvalho, 2008). If the Proalcool initiative comprised the first three phases of development for the use of sugarcane ethanol in Brazil, then this market-led phase made possible by flex-fuel vehicles can be said to comprise the fourth phase, from 2003 onward. The sector is now on the verge of a fifth phase, in which changes in the sector are more strongly determined by the attempt to reach international markets.

4. SUGARCANE ETHANOL AND THE STATE OF SAO PAULO

The city and state of Sao Paulo comprise the wealthiest region of Brazil, and one of the most populous. It is the region that has the highest concentration of R&D but also a long tradition of agriculture (CGEE, 2008). It is also a region that is naturally endowed with a high potential for bio-energy (Goldemberg et al. 2008) by virtue of its latitude, climate, soil, water and topography. Government has been heavily involved in technology development, the supply of professionals, and the creation of a supportive context for the industry that has resulted in a continuous year-on-year cost reduction for ethanol production, such that since 2004 the fuel has been cost-competitive on a global basis with petroleum (Goldemberg et al. 2008 p23). While growth in output is expected to occur in other states such as Minas Gerais (Stefano, 2008), the region with retain its dominance overall.

Sugar production in the State of Sao Paulo has grown from around 45 million tons in 1975/76 to 300 million tons in 2007/08 while ethanol production in the State has grown from about 7.5 million cubic metres in 1990/91 to 13 million cubic metres in 2007/08 (Goldemberg et al. 2007 p27 and p28). As such, at present the State of Sao Paulo accounts for about 62% of Brazilian production and 26% of global production of ethanol in terms of the situation in 2007 and 2008. Put another way, ethanol and bagaçe (the waste material from sugar production that may be subsequently burnt to produce steam and hence electricity) between them account for more than 25% of all primary energy in the State. Since the millennium, the land area devoted to sugarcane in the State of Sao Paulo has increased by about 7% per annum (op cit. p28), mostly by way of taking over grazing areas. The industrial base supporting the sugarcane sector comprises at least 100 companies making equipment, providing consulting services, etc. mostly centred on two poles: Piracicaba and Sertaozinho, both in the State of Sao Paulo. Table 1 illustrates the evolution of ethanol production in Brazil from the 1999/2000 season to the 2007/2008 season. These data are not exactly aligned with data on sugarcane production or sugar production, but the overall pattern is similar.

Table 1 Total ethanol production by State, 1999/2000 to 2007/08 (000s litres).

The employment of temporary workers as cane cutters in Sao Paulo region follows an annual cycle in which employment in summer (January) falls to almost zero while it peaks in winter (June). In 2007 this peak was over 50,000, a figure that has been increasing with time despite increased mechanical harvesting in the State (Goldemberg et al, 2008 p43) – mostly attributed to the increased area under production. Table 2 illustrates the top twenty ethanol production sites in Central-South Brazil, from which it can be seen that 17 are to be found in the State of Sao Paulo. UNICA, the source for the data, actually identifies 281 production sites in Central South Brazil (comprising Sao Paulo, Parana, Mato Grosso, Minas Gerais, Goias, Espirito Santo states), but there is a long ‘tail’ of sites that produce less than 100m litres per annum.

Table 2 The leading ethanol production sites in South Central Brazil, 2007/2008.

As can be seen from the data, sugarcane production does not exactly equate with sugar output or ethanol output (hydrous and anhydrous). Indeed, the total database reveals many instances where only sugar is produced, or only ethanol. Hence, there is significant movement of materials between various sites, particularly in respect of sugarcane.

5. CONTEMPORARY SUSTAINABILITY IN BRAZILIAN SUGARCANE ETHANOL

In 2008 a spokesperson from the United Nations caused a furore when he asserted that bio-fuels (in general) were being cultivated in place of food crops resulting in food supply shortages and price inflation to the detriment of billions of poor people around the world. This is a complicated issue and cannot be explored here, but steps were quickly taken within Brazil to demonstrate that such arguments did not apply to sugarcane ethanol production. The stimulus was useful, because it augmented the available data on the sustainability performance of the Brazilian sugarcane ethanol industry (see for example the work collected by (Carvalho Macedo, 2007; Goldemberg, et al. 2008; and Coelho, 2008). Moreover, at the political level it reinforced the drive to have sugarcane ethanol independently certified as sustainable, both for the major suppliers and for the small to medium companies that dominate the sector.

Aspects of sustainability

As a fuel source, sugarcane ethanol is a particular case of bio-fuel, which in Brazil has distinct productivity and eco-efficiency advantages (Chum and Arvizu, 2008 p49). The general case for the sustainability of the sugarcane ethanol sector rests on an examination of the process in its entirety.

As Table 3 illustrates, cane sugar ethanol confers a very low net CO_2/litre figure in production and use, and is much lower than gasoline (Wells, 2008). If burning prior to cropping is phased out as is proposed, the overall lifecycle emissions of CO_2 will be even lower per kilometre of travel in a car. Sugar cane yields 7,500 litres of ethanol per hectare of production compared with corn in the USA that yields 3,000 litres per hectare.

Table 3 The CO_2 cost (in kg) for 1,000 litres of Brazilian cane sugar ethanol.

There are many varieties of cane, with new ones being added all the time; at least 50 are in commercial cultivation and about 500 in use in all, all adapted to particular circumstances and requirements. Among the main sugarcane pests, the sugarcane beetle and the cigarrinha are biologically controlled, while ants, termites and other beetles are chemically controlled; the introduction of new varieties has been important in combating important viruses (Burnquist and Landell, 2007). According to the CGEE (Centre for Strategic Management and Studies, Brazil), in the 1970s typical productivity was 2,000 litres of ethanol per hectare, whereas by the mid-2000s it had reached 8,000 litres per hectare. The CGEE (Poppe, 2006) estimates that 70% of the production costs of ethanol arise in sugarcane cultivation, 25% in the industrial process, and 5% in management.

Other aspects of sustainability include a characteristic eco-industrialism in the process that allows the co-generation of electricity to drive the crushing mills, fermentation and distillation (and also to export to the grid) using the bagaçe or waste fibre from the crushed cane. Waste water from process is taken and added back to crops as liquid vinasse or fertilizer.

In 2007 and 2008 around 50% of the total sugarcane crop was used to produce sugar rather than ethanol; on this basis only half the land area devoted to the crop can be said to be for fuel rather than food. This proportion may change into the future as ethanol production increase. The crop is rotated every 5-10 years with soy bean, peanuts or corn –also of course food crops, thereby further diluting the proportion of land given over to ethanol production.

Sugarcane, once cut, is able be transported relatively short distances because of the value / cost equation relative to weight, and cannot be stored for long periods because it starts to decompose into compounds unsuited to the sugar-making process. Manually-harvested cane lasts longer, because the cane is not chopped into small pieces, but it is not so easy to get as much into a truck load compared with mechanically-harvested cane which generates small pieces that pack more tightly. Cane is usually analysed as it comes to the mill, and (independent) growers are paid according to the sucrose content. The entire process runs on a just-in-time basis for about 8 months of the year. All this limits the capacity of the industrial plant and the area of land that one plant can serve: production economies of scale are difficult to realise beyond an optimum of about 2 million tons per annum crushing capacity. Hence, at least in terms of production, sugarcane ethanol and the associated processes are inherently spatially distributed.

6. THE TRANSITION AWAY FROM SUSTAINABILITY?

How far can current developments be characterised as a transition away from sustainability? In some respects, this goes to the heart of the sustainability dilemma in the terms that are usually adopted because the economic rationale for expansion and ‘development’ of the sector appears to compel globalisation: of markets, of investment sources, of regulatory frameworks and trade agreements, and of the participating companies. Globalisation may, in consequence, actually act to undermine the existing regional sustainability. As Ehrenfeld (2005) has pointed out, economic development has no presumption of simple sustainability; indeed sustainability may in fact preclude economic development as normally understood. Expansion of the sugarcane ethanol sector in the State of Sao Paulo is by no means unproblematic (Martinelli and Filoso, xxxx) even within narrowly environmental concerns. In a wider concept of sustainability, the concerns are also wider. Of course, there are multiple and often conflicting views on the future trajectory of the sector within Brazil as a whole and for the State of Sao Paulo, but in general terms if expansion occurs of the type that the mainstream view appears to contemplate, then the following issues with respect to (un)sustainability may be pertinent. The forecast from the CGEE (Poppe, 2006) is a useful starting point to understand the scope for change in the sector.

Table 4 Productivity in the sugarcane ethanol sector

As can be seen from Table 4, it is anticipated that productivity per tonne of cane or per area of land is expected to grow substantially in the period to 2020, with a large part of that growth accounted for by the application of cellulose processing technology that will allow a greater proportion of the energy content of the cane to be extracted and converted into ethanol. Inevitably, technology like this, as well as that associated with mechanisation, new variety development and crop management systems will require large investments. In turn, the investment requirements could be a decisive factor in re-shaping the sector and helping to create economies of scale.

Table 5 Projections for the future of the Brazilian bio-ethanol sector to 2021

Table 5 illustrates one perspective of the growth prospects for the sector as a whole, in which it can be seen that exports play an increasingly important part. In the period to 2020/21, UNICA anticipate that overall output will increase three-fold, but also that the share taken by exports will rise from 16% (2007/08) to 24% (2020/21). This level of internationalisation can be made viable if transport systems, particularly pipelines, are developed to move ethanol from the more remote (and newly emerging) production regions to the ports on the coast. Again, the investment requirements are large and it means that economies of scale in distribution could become critical in allowing consolidation within the sector, thereby breaking the de-centralised pattern of ownership and control. Indeed, an examination of the business model of Cosan shows precisely this strategy; consolidation through the purchase of existing mills, plus new sites, but with an overall focus on downstream integration to capture more of the value chain (Cosan, 2008c).

Employment

According to UNICA the sector grew in employment by 100,000 over the period from the year 2000, and many of these jobs are high quality technical, managerial and professional jobs. The mechanisation and professionalization of the sector is part of the trend towards the application of scientific or precision agriculture in which the bio-sciences are brought to bear on the management of the sugarcane crop. In addition, processing of sugarcane into ethanol (or subsequent by-products such as ethyl plastics) is in the early stages of development, a factor that is likely to bring further skilled workers into the broader sector as a whole. The continued growth of the sector will presumably add further to this type of employment. In comparison, the unskilled and migrant cane cutters are more likely to become ‘victims’ of the development of the sector. Currently, a single mechanical harvesting machine may be expected to cut 80 tones per day; the typical expected average for a man is 8 tons per day. Hence for a given crop, one machine can replace 10 unskilled workers.

The mechanisation issue is closely tied to that of employment and of sugarcane burning. Cane is burnt to allow manual harvesting; it is not generally necessary (though does occur) for mechanical harvesting. The cane cutters have been described by some as 'Brazil's ethanol slaves: the 200,000 migrant workers who prop up the renewable energy boom' (Phillips, 2007). The State of Sao Paulo has enacted legislation to provide a timetable for the phased reduction of burning, with all such burning banned by 2014 on land considered suitable for mechanical harvesting (slope less than 12% and / or fields larger than 150 ha). For land considered unsuitable for mechanisation, which constitutes about 12% of the cropped land area, burning is due to cease by 2017 (Goldemberg et al. 2008 p101).

Local control and ownership

The immediate competition is for control over the linear supply from the plantation onwards to the pumps supplying consumers (Wells, 2009). For many reasons, this is essentially an area of business open to influence from a wide range of potential parties including:

- Existing sugarcane plantation owners, who also have distilleries. These are often relatively small-scale, single-plant operations but have the advantage of economies of scope and greater flexibility of operation than the bigger operations;
- Sugar producers that want to expand into ethanol, including producers from outside Brazil;
- The emergent consolidators such as Cosan that are seeking economies of scale by purchasing smaller, less efficient businesses, and driving up per unit revenues by capturing more of the downstream operations (in April 2008 Cosan purchased Exxon's assets in Brazil for US$826 million);
- Traditional petroleum businesses that want to diversify their portfolios and leverage their expertise and assets in distribution and retailing. These include the investment of US$60m by British Petroleum to create Tropical BioEnergia with joint venture partners Santaelisa Vale and Maeda Group, and the entry by the state monopoly petrochemical company Petrobras;
- The equipment and production process consultancy companies, that in some cases can now offer a turnkey operation to those wishing to enter the sector for the first time;
- Investment vehicles, banks, hedge funds and venture capitalists, often motivated by the twin aims of high returns and sustainability, and that act either as consolidators or bring into being new capacity;
- Scientific agriculture companies from the bio-technology sector (such as the US group Amyris Biotech joint venture with Crystalsev to produce sugarcane diesel, and global leaders such as Monsanto), exploiting the fact that compared to other agricultural products sugarcane is relatively under-represented with such approaches;
- International trading houses such as Mitsui and Itochu, that have sought to secure long-term supply by entering into joint-venture investments and other arrangements;
- International agri-business companies such as the American giants ADM and Cargill, that see sugarcane ethanol as having the potential to be a new world commodity;
- Chemicals and plastics companies such as Solvey and Dow, that are just bringing on stream major new investments that will turn ethanol into plastic,

mostly for sale at a premium to Japan, Europe and the US. The automotive industry is a significant potential market for bio-plastics.

Thus far, the sector remains fragmented. In mid-2008 there were some 387 distilleries, and about 30 more are being added each year. The majority are single-distillery businesses. The former market leader, Cosan, has just 9% of the total business while the top five suppliers control less than 20%. In 2008, the co-operative group Copersucar became a limited liability company, and secured for itself the leading position in the sector - with aggressive expansion plans. Copersucar is responsible for 33 mills, accounting for 14% of all the sugar and 14% of all the ethanol sold in Brazil in 2008. The company also buys sugar and ethanol from independent producers, a business model of quasi-consolidation that is becoming more widespread in the sector.

The Brazilian company Petrobras, in July 2008 announced the formation of a joint venture with Mitsui and Itaruma with the intention of exporting ethanol to Japan, the US and Europe (Lampinen, 2008b). This is just one example of how in recent years Japanese companies have substantially increased their investments in the sector (St John, 2008), and have become key to resolving logistical barriers to exports (Watkins, 2008). US sources of funds have also been significant (Anon, 2007; WSJ, 2008) and have contributed to a situation where an estimate of up to 17% of the capital in the sector comes from outside Brazil. Riveras (2008) is typical of the business and economic journalists following the sector, with an analysis that predicts even greater capital inflows, significant expansion of output largely attributable to export markets, and industry consolidation.

It seems therefore that the beneficial aspects of eco-efficiency that might be associated with the professionalization of the sector come at the cost of the erosion of the traditional pattern of small-scale local ownership and control in the sector, with the distinct possibility that much of the value added and profits generated by the sector will flow back to the sources of funding in the US, Europe, Japan and elsewhere.

Commodification

The Brazilian government and sector representatives, along with some key companies, have been assiduous in searching out export opportunities – efforts that have met with some success (Lampinen, 2008a). In September 2008 the US Senate approved 'The Western Hemisphere Energy Compact' that aimed at co-operation with Brazil on bio-fuels; earlier in the year there had been talk of Brazil taking the US to the World Trade Organisation over the imposition of tariffs on imported ethanol (Lampinen, 2008c). According to the consultants McKinsey, by 2020 the global traded market for ethanol could grow from 6.5 billion litres (2006) to reach 50 – 200 billion litres by 2020 (Assis et al. 2007). In 2007 sugar and alcohol combined accounted were the 4th largest product area by value for agricultural exports from Brazil, accounting for 11.3% of the total exports (Anuario Exame, 2008 p122).

Advanced industrial nations like Japan, dependent upon imported petroleum and keen to reduce their national CO_2 emissions, are beating a path towards Brazilian ethanol. Japan has a target to reduce fossil fuel dependency by 20% by 2030. The country uses some 60 million k/l of gasoline each year; by contrast in 2006 actual ethanol production was just 30 k/l. In July 2007 Japan and Brazil reached an agreement to expand output and exports of ethanol to Japan, with the Japan Bank for International Cooperation funding new ethanol plants, storage tanks, pipelines, port facilities and tankers to export the bio-fuel to Japan. Within Brazil, similar steps are being taken with for example the announcement in March, 2008 of a joint development by Cosan, Copersucar and Crystalsev (three of the larger companies in the sector) to put in place a pipeline linking some key distant production locations with the port of Santos in the State of Sao Paulo (Cosan, 2008a; 2008b).

Behind these inter-governmental initiatives, corporations have also taken steps. For example, in mid-2007 Mitsubishi Corporation signed a 30-year contract for the supply of bio-ethanol with a subsidiary of Grupo Sao Martinho of Brazil, one of the world's largest producers of sugar cane and ethanol, in a deal large enough to account for 15% of Japan's ethanol needs each year. Similarly, and also in 2007, both Mitsui and Itochu Corp. signed separate deals with the monopoly supplier Petrobras to import large quantities of ethanol.

Moreover, Brazil is now starting to export its expertise in bio-ethanol production, notably to countries such as the Congo where an agreement was reached in December 2007 to provide finance, expertise and technology in sugar cane and palm oil use for bio-fuels. Similar discussions are underway with South Africa. Experts within the industry interviewed in the course of the research contended that it would be beneficial to Brazil were other countries to embrace sugarcane ethanol production, and start supplying world markets (see also Jenk, 2008 for the UNICA perspective). This commodification would, in their view, give greater confidence to purchasing nations such as Japan that hitherto were reluctant to rely on a single source (i.e. Brazil) that could be disrupted by economic changes, by political manipulation, or even by a bad harvest year.

Land and water use

Two land issues are of potential concern for the sustainability of the expansion of sugarcane ethanol production: the expansion of the area of land given over to sugarcane, and the impact of the crop on soil condition and water consumption. Worldwide, soil loss is becoming seen as a critical issue for long term sustainability in many locations, including with respect to bio-mass energy.

The crop is generally held to be better for soils than other crops such as corn or soybean, and its cultivation is likely to improve the soil condition in most cases (Donzelli, 2007 p142). The same is largely the case with soil erosion; according to Donzelli (2007 p143) soil loss is 62% greater under soybean and 2.35 times greater under castor oil plants compared with sugarcane.

Brazil has instituted an agricultural zoning policy termed ZAECana (Sugarcane Agro-Ecological Zoning) in a partnership between the Federal Ministry for the Environment and that for Agriculture, which once validated by the State Legislative Assembly level will identify priority areas for expansion of the crop and, in contrast, those areas specifically excluded by reason of environmental concerns.

According to UNICA (Jenk, 2008) sugarcane in total accounts for 2.2% of arable land use in Brazil, while ethanol accounts for just 1%. In contrast, almost half is given over to pastures, principally extensive grazing for cattle. This is the land that has been identified as most appropriate for the expansion of sugarcane production. Goldemberg et al. (2008 p79), citing work by the Agricultural Economics Institute, estimate that the land area given over to sugarcane production in the State of Sao Paulo will grow from 4 million ha in 2006/07 to nearly 7 million ha by 2015/16. By that time, the proportion of the crop given over to ethanol (rather than sugar) could be between 52% and 66%, but the share of the Brazilian total ethanol production accounted for by Sao Paulo is likely to fall from around 61% in 2006 to 55% in 2015 as other locations come on stream. Inevitably, large areas of sugarcane are hardly conducive to wildlife diversity and this form of monoculture does not provide an ecological space for other plants, insects or animals.

While water consumption and conflicts over water resources are considered important issues at the global level, and issues that have come to the fore with respect to the importation of 'hidden' water in products (Chapagain and Orr, 2008), Brazil is in the fortunate position of having excess water supply relative to demand. Sugarcane production itself is largely conducted without irrigation (apart from ferti-irrigation) while the processing of the cane into ethanol has been considerably improved in terms of water efficiency. Surveys in Sao Paulo state have shown a consumption rate of 1.23m3 of water per tonne of sugarcane, and UNICA has expressed a target of 1 m3 / tonne. In specific locations however water use, agro-chemicals and subsequent effluent remain problematic (Martinelli and Filoso, xxxx).

7. CONCLUSIONS

The characterisation of change in a region as being more or less sustainable is inevitably difficult and ultimately judgemental. This paper has sought to show that in some respects the sugarcane ethanol industry found in the Sao Paulo region of Brazil could be characterised as having reached a certain peak of sustainability, and is facing the real prospect of being less sustainable in the future medium term. Whether or not something is sustainable somewhat depends upon the spatial scale under consideration: Brazil might be considered to have a sustainable sugarcane ethanol industry serving local needs, but it must be questioned whether this sustainability is still valid at the global scale. To put it another way, this case demonstrates that a region cannot readily 'export' its sustainability for the benefit of others.

As is often the case with issues related to sustainability, contradictory forces are at work here. For example, from an environmental perspective it is desirable to phase out the burning of the sugarcane crop prior to harvesting. To do this, manual harvesting must be replaced by mechanical, and ultimately this demands large capital investments in cane cutting and ancillary equipment. The 'price' of that investment funding may well be loss of local level control, and greater integration into world markets.

ACKNOWLEDGEMENTS

The research on which this article was based was partly funded by the Centre for Business Relationships, Accountability, Sustainability and Society (BRASS), itself funded by the UK Economics and Social Research Council (ESRC). The authors would like to thank the many individuals and organisations within Brazil who helped this research, in particular: Marcelo Poppe, CGEE; Alfred Szwarc, UNICA; Bautista Vidal; Jose Goldemberg; the staff at Novamerica and Pyles distilleries; and Horus Magalhaes.

REFERENCES

Annandale, D.; Morrison-Saunders, A.; and Duxbury, L. (2004) Regional sustainability initiatives: the growth of green jobs in Australia, Local Environment, 9(1), 81-87.

Anon (2007) The money flying down to Brazil, Business Week Online, http://www.businessweek.com/magazine/content/07_25/b4039079.htm, June 18th. Accessed 3rd October 2008.

Anuario Exame (2009) Os maiores mercados para o Brasil, Anuario Exame, p122-123.

Arrigoni, E. B. and Almeida, L. C. (2007) Agrochemicals (pesticides and others), Chapter 8.2, pp149-156 in Macedo, I. C. (2007) (Editor) Sugar Cane's Energy, Sao Paulo: Unica (Sao Paulo Sugar Cane Agroindustry Union).

Assis, V.; Elstrodt, H. P. and Silva, C. F. C. (2007) Positioning Brazil for biofuels success, The McKinsey Quarterly Special Edition: Shaping a new agenda for Latin America, 1-6.

Burnquist, W. L. and Landell, M. G. A. (2007) Varieties and protection from diseases and pests, Chapter 10.2 pp179-183 in Macedo, I. C. (2007) (Editor) Sugar Cane's Energy, Sao Paulo: Unica (Sao Paulo Sugar Cane Agroindustry Union).

Boons, F. (2008) Self-organisation and sustainability: the emergence of a regional industrial ecology, Emergence, Complexity and Organisation, 10(2), 41-49.

Carvalho, A. (2008) Flex cars win over consumers, Economico Valor Especial – Biocombustivies: A forca do verde, November, 31.

CGEE (2008) Brasil: A economia natural do conhecimento, Brasilia: Centro de Gestao e Estudos Estrategicos.

Chapagain, A. and Orr, S. (2008) UK water footprint: the impact of the UK's food and fibre consumption on global water resources, London: World Wildlife Fund.

Chum, H. L. and Arvizu, D. E. (2008) Liquid biofuels as a viable alternative to fossil fuels: technology and sustainability considerations, Revista brasileira de bioenergia, 2(3), 48-53.

Coelho, S. T. (2008) Ethanol and food: what lies behind the polemics, Revista brasileira de bioenergia, 2(3), 5.

Cosan (2008a) Cosan announces ethanol pipeline project, Cosan Press Release, 18th March 2008. Copy obtained from www.cosan.com.br/ir, 10th October 2008.

Cosan (2008b) Investor and analyst presentation, APIMEC 2008, 26th August. Copy obtained from www.cosan.com.br, cosan_apresentacao_APIMEC_20080826_en.pdf.

Cosan (2008c) Cosan infrastructure – beyond crushing capacity. October, 2007. Copy obtained from www.cosan.com.br, Cosan_Infrastructure.pdf

Desrochers, P. (2002) Regional development and inter-industry recycling linkages: some historical perspectives, Entrepreneurship and Regional Development, 14, 49-65.

Donzelli, J. L. (2007) Soil used for sugar cane growing in Brazil: expansion trends, Chapter 7.2 pp140-146 in Macedo, I. C. (2007) (Editor) Sugar Cane's Energy, Sao Paulo: Unica (Sao Paulo Sugar Cane Agroindustry Union).

Ehrenfeld, J. (2005) The roots of sustainability, Sloan Management Review, 46(2), 22-25.

Goldemberg, J.; Nigro, F. E. B. and Coelho, S. T. (2008) Bioenergy in the State of Sao Paulo, Sao Paulo: Imprensa Oficial, Governo de Sao Paulo, Secretaria de Desenvolvimento.

Hampstead and Quinn (2005) Sustainable community development and ecological economics: theoretical convergence and practical implications, Local Environment, 10(2), 141-158.

Jenk, M. (2008) Biofuels update in Brazil: ethanol dynamics, Presentation to 4th World Biofuels Symposium, Beijing, 20th October. Copy obtained from www.unica.com.br

Johansson, A.; Kisch, P. and Mirata, M. (2005) Distributed economies – a new engine for innovation, Journal of Cleaner Production, 13, 971-979.

Kahn, J. (2005) The importance of local context in the planning of environmental projects: examples from two biogas cases, Local Environment, 10(2), 125-140.

Lampinen, M. (2008) Petrobras to begin E3 sales this year, www.automotiveworld.com, 18th June. Accessed 3rd October 2008.

Lampinen, M. (2008b) Mitsui, Petrobras and Itaruma form biofuel joint venture, www.automotivworld.com, 8th July. Accessed 3rd October 2008.

Lampinen, M. (2008c) US Senate Foreign Relations Committee approves bio-fuel co-operation bill, www.automotiveworld.com, 25th September. Accessed 3rd October 2008.

Louro, R. (2004) The flex-fuel revolution in Brazil, www.automotiveworld.com, 10th June. Accessed 3rd October 2008.

Macedo, I. C. (2007) (Editor) Sugar Cane's Energy, Sao Paulo: Unica (Sao Paulo Sugar Cane Agroindustry Union).

Martinelli, L. A. and Filoso, S. (xxxx) Expansion of sugarcane ethanol production in Brazil: environmental and social challenges, Ecological Applications, 18(4), 885-898.

McManus, P. (2008) Mines, wines and thoroughbreds: towards regional sustainability in the Upper Hunter, Australia, Regional Studies, 42(9), 1275-xxxx.

Mirata, M.; Nilsson, H. and Kuisma, J. (2005) Production systems aligned with distributed economies: Examples from the energy and biomass sectors, Journal of Cleaner Production, 13, 981-991.

Montana, J-P. and Nenide, B. (2008) The evolution of regional industry clusters and their implications for sustainable economic development: two case illustrations, Economic Development Quarterly, 22(4), 290-xxx.

Nardon, L. and Aten, K. (2008) Beyond a better mousetrap: a cultural analysis of the adoption of ethanol in Brazil, Journal of World Business, 43, 261-273.

Perez-Aleman, P. (2003) Decentralised production organisation and institutional transformation: large and small firm networks in Chile and Nicaragua, Cambridge Journal of Economics, 27(6), 789-805.

Phillips, T. (2007) Brazil's ethanol slaves: the 200,000 migrant workers who prop up the renewable energy boom, GuardianOnline, http://www.guardian.co.uk/world/2007/mar/09/brazil.renewableenergy. 9th March. Accessed 3rd October 2008.

Poppe, M. (2006) Opportunities for sustainable bio-ethanol, Centre for Strategic Management and Studies, Presentation obtained from www.cgee.org.br, 10th October 2008.

Riveras, I. (2008) Brazilian ethanol industry feels the winds of change, International Herald Tribune Online, http://www.iht.com/articles/2008/05/27/business/ethanol.php, May 27th. Accessed 3rd October 2008.

Stefano, F. (2008) A nova fronteira do etanol, Anuario Exame, 36-38.

St John, J. (2008) Biofuels roundup: Brazilian ethanol gets Japanese boost, GreentechMedia, http://www.greentechmedia.com/articles/biofuels-roundup-brazilian-ethanol-gets-japanese-boost-1505.html 30th September. Accessed 3rd October 2008.

Veja (2008) Veja, 19th March 2008, p106-7)

Watkins, E. (2008) Bottlenecks ahead as Japan pushes Brazil's ethanol industry, Oil and Gas Journal Online, http://www.ogj.com/display_article/340522/7/ONART/none/Prong/1/Bottlenecks-ahead-as-Japan-pushes-Brazil's-ethanol-industry/, 24th September. Accessed 3rd October 2008.

Wells, P. (2008) Too sweet to last? The future of the Brazilian ethanol industry, **Automotive Environment Analyst**, 155, 33-34.

Wells, P. (2009) Competition for the future of Brazilian bio-ethanol, **Automotive Environment Analyst**, forthcoming.

WSJ (2008) Brazilian sugar cane ethanol – private equity investors move in: investment challenges and opportunities, Wall Street Journal Online, http://www.marketwatch.com/news/story/brazilian-sugar-cane-ethanol--/story.aspx?guid=%7B9ECE4C4F-E031-4214-A5C1-6AEA3801885E%7D&dist=hppr, 1st October. Accessed 3rd October 2008.

Zapata, C. (2009) The Brazilian experience with biofuels, Chapter 7, unpublished PhD thesis, Cardiff: Cardiff University.

Table 1 Total ethanol production by State, 1999/2000 to 2007/08 (000s litres).

STATE	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
ACRE	0	0	0	0	0	0	0	0	0
RONDONIA	0	0	0	0	0	0	0	0	0
AMAZONAS	0	3,854	1,703	3,889	4,375	4,671	6,009	5,650	8,264
PARÁ	11,344	19,081	10,945	9,749	4,316	6,175	8,194	9,120	9,528
TOCANTINS	0	0	0	0	0	0	110	2,125	NA
MARANHÃO	13,734	8,026	9,383	6,224	5,609	8,715	22,287	20,570	47,119
PIAUÍ	8,958	8,198	13,169	11,602	4,347	4,327	8,486	11,299	9,525
CEARÁ	2,435	783	1,186	976	317	153	1,022	1,002	571
R. G. NORTE	27,459	60,998	33,273	50,336	48,990	41,354	22,838	24,466	39,632
PARAIBA	104,099	105,514	138,774	133,754	151,160	181,275	158,819	178,685	187,782
PERNAMBUCO	185,758	132,979	141,516	152,297	166,259	135,919	120,957	118,349	274,327
ALAGOAS	218,078	313,943	244,713	312,048	444,234	410,716	333,712	333,512	469,674
SERGIPE	27,750	37,152	24,296	28,294	31,851	36,113	28,634	22,590	18,742
BAHIA	29,470	19,564	21,514	16,314	18,985	17,920	19,128	28,638	54,544
MINAS GERAIS	269,785	204,914	193,003	303,945	411,874	446,441	562,317	690,590	1,199,765
ESPIRITO SANTO	37,522	49,200	54,721	81,355	62,290	80,929	68,513	53,540	77,211
RIO DE JANEIRO	47,562	39,597	40,832	64,543	68,313	101,644	84,601	58,026	93,320
SÃO PAULO	4,692,539	2,884,080	2,879,691	3,101,115	2,885,197	3,791,387	4,827,784	5,645,705	8,398,776
PARANÁ	625,749	536,935	598,063	580,900	735,306	784,997	692,703	892,264	1,480,184
SANTA CATARINA	0	0	0	0	0	0	0	0	0
R. G. SUL	0	0	5,306	6,411	6,045	4,823	3,338	5,686	6,818
MATO GROSSO	224,365	195,743	304,120	330,393	313,081	371,547	474,501	443,601	512,184
MATO GROSSO DO SUL	191,247	175,605	171,320	214,707	260,820	326,403	311,251	433,690	662,562
GOIÁS	185,866	175,905	183,408	198,907	273,286	356,709	353,244	439,094	749,818
REGIÃO CENTRO-SUL	**6,274,635**	**4,261,979**	**4,430,464**	**4,882,276**	**5,016,212**	**6,264,880**	**7,378,252**	**8,662,196**	**13,180,638**
REGIÃO NORTE-NORDESTE	**629,085**	**710,092**	**640,472**	**725,483**	**880,443**	**847,338**	**730,196**	**756,006**	**1,119,708**
BRASIL	**6,903,720**	**4,972,071**	**5,070,936**	**5,607,759**	**5,896,655**	**7,112,218**	**8,108,448**	**9,418,202**	**14,300,346**

(Source: UNICA)

Table 2 The leading ethanol production sites in South Central Brazil, 2007/2008.

Ranking	State	Site	Sugarcane production (t)	Sugar production (t)	Ethanol productio	
					Anhydrous	Hydro
1º	SP	DA BARRA	6,815,821	489,723	193,903	
2º	SP	SÃO MARTINHO	6,762,247	361,580	155,910	
3º	MT	ITAMARATI	5,775,081	266,242	143,305	
4º	SP	VALE DO ROSÁRIO	5,717,163	386,460	93,089	
5º	SP	EQUIPAV	5,383,570	285,201	150,165	
6º	SP	SANTA ELISA	5,166,420	317,636	120,045	
7º	SP	COLOMBO	5,003,431	390,627	0	
8º	SP	CLEALCO	4,683,488	389,245	0	
9º	SP	COLORADO	4,551,827	345,336	27,820	
10º	SP	MOEMA	4,538,707	300,942	85,005	
11º	MG	VOLTA GRANDE	4,204,327	264,935	120,749	
12º	SP	CRUZ ALTA	4,168,067	475,664	13,414	
13º	SP	BONFIM	4,132,634	345,775	54,144	
14º	SP	CATANDUVA	4,005,476	227,396	60,429	
15º	SP	COSTA PINTO	3,989,362	312,902	63,590	
16º	SP	DA PEDRA	3,878,452	187,795	86,597	
17º	SP	NOVA AMÉRICA	3,790,257	309,819	117,159	
18º	MG	DELTA	3,762,517	365,071	9,694	

19º	SP	BARRA GRANDE	3,707,544	261,627	94,524
20º	SP	ALTA MOGIANA	3,681,114	320,666	66,626

(Source: UNICA)

Table 3 The CO2 cost (in kg) for 1,000 litres of Brazilian cane sugar ethanol.

Item	Emissions	Absorption
Farming of cane	173	
Cane growth		7,464
Burning and transport	2,940	
Production of ethanol	3,140	
Use in car engine	1,520	
Net	309	
Gasoline	3,368	

(Source: Veja, 19th March 2008, p106-7)

Table 4 Productivity in the sugarcane ethanol sector

Technology	2005		2015		2025	
	l / t cane	l / ha	l / t cane	l / ha	l / t cane	l / ha
Conventional	85	6,000	100	8,200	109	10,400
Hydrolysis	-	-	14	1,100	37	3,500
Total	85	6,000	114	9,300	146	13,900

(Source: Poppe, 2006)

Table 5 Projections for the future of the Brazilian bio-ethanol sector to 2021

Item	2007/08	2015/16	2020/21
Sugarcane production (mt)	496	829	1.038
Cultivated area (m ha)	7.8	11.4	13.9
Sugar production (mt)	31.0	41.3	45.0
Sugar internal market use (mt)	18.9	34.6	49.6
Sugar exports (mt)	18.6	29.9	32.9
Ethanol production (bl)	22.5	46.9	65.3
Ethanol internal market use (bl)	18.9	34.6	49.6
Ethanol exports (bl)	3.6	12.3	15.7

(Source: Jenk, 2008)