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BIOFUELS ENVIRONMENTAL ZONING IN BRAZIL

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ABSTRACT

Many improvements towards the increase of sustainability on biofuels production have been recorded in Brazil since the country started the large-scale ethanol production from sugarcane 35 years ago. Among them it is a high growth in both agricultural and industrial yields, allowing a significant decrease of production costs, making ethanol economically competitive with gasoline.

At the same time, improvements of social and environmental legislation and regulations, both at federal and state levels have been implemented for biofuels.

Due to the expansion of sugarcane production in the recent years, concerns about the direct impacts of land use change have led governments to adopt policies to direct this expansion towards suitable areas for this crop.

The state of Minas Gerais launched its economic-environmental zoning in the year 2007. It combines social, economic and environmental information to identify regional vulnerabilities and potential new plantation areas.

In the state of São Paulo, the agro-environmental zoning, launched in September 2008, established constraints based on studies related to soil and climate, topography, water availability, air quality, existence of protected and biodiversity conservation areas.

The Federal Government launched, in September 2009, the national agro-economic zoning of sugarcane which forbids sugarcane cultivation in 92.5% of national territory, including the Amazon Forest, Pantanal wetlands and other native (and fragile) biomes. It also identified 64 million hectares that comply with environmental and productivity criteria. The zoning also addresses the zoning of oil palm crops.

Considering this experience, this paper discusses these processes of environmental zoning on biofuels in Brazil, aiming to share the lessons learned in the country with other developing countries, to allow the increase of the sustainable production of biofuels in such countries.

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1. INTRODUCTION

This concept paper on Biofuels Environmental Zoning in Brazil was prepared jointly by CENBIO and CENTROCLIMA for GNESD – Global Network for Sustainable Environment, as part of a group of policy papers on bioenergy in developing countries.

Brazil began its large-scale sugarcane ethanol program – PROALCOOL – in 1975, when oil prices raised with the world oil crisis. Since then, many developments towards a sustainable production system have been achieved. These have resulted in important increases in both agricultural and industrial productivity, with more than 3 % per year (GOLDEMBERG, COELHO and GUARDABASSI, 2008).

As a consequence, production costs fell rapidly, making ethanol economically competitive with gasoline. At the same time, improvements in social and environmental legislation have been achieved, both at the federal and state levels.

This is an important issue to be addressed, since biofuels are today under several controversies, mainly based on environmental and social concerns but used also as an economic tool.

Besides the fact that they can be used as an option for the reduction of GHG worldwide, replacing fossil fuels together with local environmental and social benefits, they are also seen by many studies as a negative option since they would promote deforestation and competition with food. Studies Fargione (2008), Pimentel (2003); Searchinger (2008), among others, claims that biofuels can present GHG emissions even higher than fossil fuels when they are produced in areas previously used as native forest and were deforested for bioenergy crops. Even considering that there are other studies showing that biofuels are not responsible for such impacts, mainly in the case of sugarcane ethanol (MACEDO, et al., 2008; NASSAR et al., 2010), several controversial issues are still being discussed.

This paper intends to present Brazilian policies already implemented in the country to guarantee the sustainable production of biofuels, mainly sugarcane ethanol, such as the environmental zoning of sugarcane and oil palm, introduced not only in Federal level, but also in state level, like the example of Sao Paulo and Minas Gerais states. Recently Mato Grosso do Sul also informed it was developed an economic environmental zoning protecting Pantanal wetlands and other fragile biomes in the state.

The paper presents initially a general overview on liquid biofuels in Brazil (both ethanol from sugarcane and biodiesel) and electricity from bioenergy (sugarcane bagasse cogeneration), followed by a discussion on sustainability issues (both environmental and social) and by the presentation of the policies on environmental-economic zoning of sugarcane.

Such policies discussed here can be an experience to be shared with other developing countries, mainly in Africa and Asia, which could benefit from the lessons learned in Brazil.

2. CURRENT SITUATION AND PERSPECTIVES OF BIOENERGY IN BRAZIL

The use of bioenergy in the Brazilian energy matrix has been a reality for a long time. Ethanol production in Brazil was initiated in 1975 through a subsidized program but, over time, improvements in technology and economies of scale drove down production costs. By 2004, it had already become economically competitive with gasoline without subsidies (GOLDEMBERG et al., 2004).

Nowadays, Brazil is the world's second largest producer of ethanol (and the largest one on sugarcane ethanol) with 28 billion liters, after US producing ethanol from corn. In the last harvesting season there were 427 mills producing ethanol and sugar, in a planted area of 8.6 Mha of sugarcane. Related to agricultural yields, in 2010 the national average was almost 78 (metric) tonnes of sugarcane per hectare (tc\ha), with some regions reaching 100 tc\ha) (BRAZILIAN MINISTRY FOR AGRICULTURE LIVESTOCK AND SUPPLY, 2011).

Initially ethanol was available for ethanol-dedicated engines (hydrated ethanol, 96% ethanol) or as an octane enhancer (anhydrous ethanol, 99.5%), replacing lead and MTBE; there is a mandate from Federal government to blend anhydrous ethanol with gasoline in ranges from 20-25 percent.

Nowadays, instead of ethanol-dedicated vehicles, hydrated ethanol is used in flex-fuel vehicles; more than 90 percent of all new cars sold in Brazil are flex-fuel, which can run on any blend of gasoline or ethanol, allowing drivers to make price-driven fuel choices (ANFAVEA, 2010). In the domestic market, it replaces 41.5 percent of light duty transportation fuel in the country (DATAGRO, 2010).

Projections are expected to increase the ethanol production to almost 57 billion liters over the next 10 years (CONAB, 2011), due to the increase of 51.7 % on the total fuel consumption on ligth duty transportation.

Bagasse, the residue from sugarcane crushing, is used for combined heat and power generation (cogeneration) in the mills, both for self-consumption and for the sale of electricity surplus to the grid. The installed capacity in 2010 was almost 6,000 MW (CONAB, 2011).

In 2009/2010 harvesting season the total of electricity production from sugarcane bagasse was 20,031 GWh. In this scenario, 28.2% of the mills sell their surplus to the grid (CONAB, 2011).

Over the next 10 years, in the best scenario (considering higher pressure boilers installed - 99 bar, in all mills, for a sugarcane production of 1.04 billion of tones), electricity production from sugarcane bagasse is expected to increase up to 68,730 GWh (CONAB, 2011).

Related to biodiesel, Brazil is the world's second largest producer. By the end of 2010 the production was 2.3 billion liters and there were 68 plants registered with installed capacity of 6.198.68.000 liters (ANP, 2011). Soy is the mainly feedstock used for biodiesel production (counting for 80%), followed by animal fat (almost 13%) and others vegetable oils.

The domestic market of biodiesel is guided by the blending mandate of 5% biodiesel (B5) in all diesel sales in the country. In 2010, the use of B5 was anticipated (it was scheduled only for 2014) and there was a significant increase in biodiesel production.

The use of soy as the most important vegetable oil in the country is due to the fact that this oil is the by product of the soy (protein) export for animal feed in other countries. The increasing use of animal fat is due to the huge amount of cattle heads in the country mainly to provide meat export to industrialized countries.

3. SUSTAINABILITY ISSUES

3.1. Environmental aspects

3.1.1. Impacts to the air quality

Proalcool was created with the purpose of partially replace gasoline due to the high prices of imported oil in 1975 and also to the revitalization of the sugarcane industry (Moreira and Goldemberg, 1999).

Initially, lead additives were reduced as the amount of alcohol in the gasoline was increased and they were completely eliminated by 1991. Brazil was then one of the first countries in the world to eliminate lead entirely from gasoline.

The aromatic hydrocarbons (such as benzene), which are particularly harmful, were also eliminated and the sulfur content was reduced as well. In pure ethanol cars, sulfur emissions were eliminated. The simple addiction of alcohol instead of lead in commercial gasoline has dropped the total carbon monoxide, hydrocarbons and sulfur transport-related emissions by significant numbers.

Also, ethanol hydrocarbons exhaust emissions are less toxic than gasoline's, since they present lower atmospheric reactivity.

One of the drawbacks of pure ethanol combustion is the increase in aldehyde emissions as compared to gasoline or gasohol. Total aldehyde emissions from ethanol engines are higher than gasoline ones, but it must be observed that these are predominantly acetaldehydes and for gasoline they are mainly formaldehydes. Also, aldehyde ambient concentrations in São Paulo present levels quite below the reference levels found in the literature.

Besides the increase of acetaldehyde, there is also concern about the increase on peroxyacetyl nitrate (PAN) concentration, caused by the combustion of ethanol when compared to gasoline. PAN is an eye irritant noxious to plants, which is a byproduct of combustion.

Several studies were conducted to determine air quality impact of ethanol blends. One of these studies, conducted in California noticed a small increase on acetaldehydes and PAN concentrations with ethanol blends, and the conclusion of a study conducted in Canada is that the risks of increased aldehyde pollutants are insignificant (IEA, 2004). Some studies concluded that the impacts on pollution levels are quite similar for high level (E85) and low level blends (IEA, 2004).

Nowadays NOx and VOCs (frequently referred as hydrocarbon) may have negligible or even null increase with ethanol. Modern vehicle technology allows efficient NOx control, reducing ground-level ozone. Depending on engine characteristics, reduction of exhaust emission of VOCs, potent precursors of photochemical smog and noxious substances, can also be accomplished.

The most obvious pollution reduction effects associated to blends containing up to 10% ethanol by volume (E10 blends) include reduction of carbon monoxide (CO), harmful hydrocarbons (such as benzene and 1-3 butadiene that are known carcinogens), sulfur oxides (SOx) and particulate matter (PM). However, modern catalytic converters help significantly in the reduction of emissions (Coelho et al, 2006). Carbon monoxide (CO) transport-related emissions were drastically reduced: before 1980, when gasoline was the only fuel in use; CO emissions were higher than 50 g/km and they went down to less than1 g/km in 2000.

The use of E10 blends to reduce harmful wintertime CO emissions has proven to be a very effective strategy in the USA. Tests at the National Center for Vehicle Emissions Control and Safety at Colorado State University document a 25% to 30% reduction in CO when automobiles burn E10. It is important to note that CO, in addition of being an important air pollutant by itself, also contributes to the formation of photochemical smog. Therefore, the reduction of CO may actually contribute to lower formation of ground-level ozone (Coelho et al, 2006).

3.1.1.1. Air emissions in sugarcane and ethanol production

3.1.1.1.1. Air emission in the ethanol production process

As already mentioned, all the energy needs in the sugar/ethanol process are supplied by the sugarcane bagasse (30% of sugarcane in weight). In the past, the bagasse was burned very inefficiently in boilers. However, old boilers of low pressure (21 bar) are being replaced by new and more efficient ones (up to 80 bar) and new plants have high efficiency boilers.

Emission from bagasse boilers are mainly particulate matter (PM) and NOx. These emissions are controlled by the São Paulo State Environmental Agency (CETESB) and a Resolution from the National Council for the Environment (CONAMA number 382/2006) has established limits for such pollutants.

3.1.1.1.2. Air emissions due to sugarcane burning

Sugarcane burning before harvesting is a practice used to facilitate the manual harvest of the stalks and also repel poisonous animals, such as spiders and snakes. On the other hand, cane burning can damage the cell tissue of the cane stem, and thus increase the risk of diseases in the cane, destruction of organic matter, damage to the soil structure due to increased drying, and increased risks of soil erosion. Harvesting method of burning sugarcane results also in risks for electrical systems, railways, highways, and forest reserves. Beside these impacts there are harmful atmospheric emissions such as CO, CH_4, non-methane organic compounds (NMOC) and particulate matter. The burning of sugarcane is also responsible for the increase of troposphere ozone concentration in sugarcane producer areas.

Besides the reduction of local pollutant emissions, the mechanical harvesting of green cane also reduces carbon emissions, avoiding the emission of 183.7 kg of carbon per year per square kilometer (Cerri, 2007).

Harvesting burning practices, which result in intense air pollution, are being phased-out, resulting in energy benefits of mechanization due to higher surpluses of electricity that can be produced from sugarcane by products corresponding to 30% more in terms of biomass availability (State Law 11,241/2002). Also, harvesting burning practices are controlled/authorized by São Paulo State Secretary for the Environment according to atmospheric conditions.

In 2007, the São Paulo Secretariat for the Environment and UNICA (Sugarcane Agro industry Association) signed a voluntary environmental agreement, which aims at reward good practices in the sugarcane sector. As of February 2011, 149 out of the 196 ethanol plants have adhered to this agreement. It represents more than 90% of total cane crushing in the state. One of the main guidelines of this agreement is to anticipate the timetable for sugarcane burning phase-out – following the Protocol timetable, in 2010, 60% of the sugarcane was harvested green in the State of São Paulo, and until 2014 the use of fire must be banished in mechanizable areas.

Preliminary results obtained estimate that by 2012 all mechanizable areas will phase-out harvest burning, anticipating the legal deadline of 2021. For non-mechanizable areas the legal deadline of 2031 will be anticipated to 2017.

Despite the high investment costs – each harvesting machines costs about R$ 1 million (US$ 600,000.00) – the operational costs are reduced and productivity gains obtained.

Mechanical harvesting will prevent releases of 3.9 thousand tonnes of particulates (~28% of emissions from diesel vehicles in the Sao Paulo Metropolitan Region – SPMR); 45.3 thousand tonnes of carbon monoxide (12% of diesel emissions in SPMR) and 6.5 thousand tonnes of hydrocarbons (11% of diesel in SPMR). Riparian forests defined to be protected were around 400 thousand hectares (~10% of cultivated land). Results are verifiable through satellite images.

There are initiatives for the banishment of sugarcane burning in many states. Furthermore, the Brazilian sugarcane zoning establishes national targets and timetables for the phase-out of this activity.

3.1.2. Water

In the production of sugarcane and ethanol water is used in the sugarcane crops (agricultural demand) and in the industrial operations.

Water consumption decreased rapidly due the environmental legislation and the imminent billing for the use of water.

3.1.2.1. Agricultural demand

The use of crop irrigation is very small in Brazil, mainly in Northeastern region, due to the dry climate. Sugarcane production is mainly rain-fed in the rest of Brazil.

The evapotranspiration (transpiration that occurs in the leaves, corresponding to the water losses; higher evapotranspiration means higher losses) of sugarcane is estimated at 8-12 millimeters/tonnes of cane and the total rainfall required by sugarcane is estimated to be 1,500-2,500 millimeters/yr, which should be uniformly spread across the growing cycle (Macedo, 2005).

Nearly all São Paulo sugarcane production does not make use of irrigation (Matioli, 1998).So, unlike other parts of the world, sugarcane irrigation is a minor problem in Brazil. (Rosseto, 2004).

3.1.2.2. Industrial demand

Conversion of cane to ethanol requires large amounts of water. The total use of water is calculated to be 22 m^3/tonne of cane. However, it does not mean the amount of water withdrawn, because most of the processes occur in close looped circuits, leading to low net withdrawal from water bodies (ANA, FIESP, UNICA, CTC, 2009).

Water consumption and disposal for industrial use have substantially decreased in the last years, from around 5.6 m^3/ tonne of sugarcane collected in 1990 and 1997 to 1.83

m^3/ tonne of sugarcane in 2004 (figures from a sampling in São Paulo). The water reuse level is very high, and the release treatment efficiency is more than 98 %.

The São Paulo Agro-Environmental Protocol establishes goals for reducing water withdraw to 1m3/t of sugarcane in non-stressed areas, and in areas of the state where water is scarce policy limits consumption to 0.7 m^3/t of sugarcane. These targets were defined by the government after consultations to UNICA and the Sugarcane Technology Center (CTC); the 1m3 of water /t of sugarcane target is achievable with basic engineering, however lower levels will require the implementation of new technologies such as dry cane cleaning process.

Also, a dry cane washing process is replacing the standard wet cane washing process, which uses 5 m^3 of water/tonne of cane. The dry washing process recycles most of the water representing a much lower net water use (Macedo, 2005).

Modern agricultural practices include the recycling of washing water and ashes to the crops via fertirrigation, together with the vinasse (pollutant by-product from ethanol distillation).

3.1.2.3. Water pollution

Environmental problems related to water quality, which result from irrigation (water run-off, with nutrients and pesticides, erosion) and industrial use, have not been reported in São Paulo. Regarding wastewater issues, there is the problem of organic and inorganic pollutants.

The main liquid effluents of ethanol production are: the vinasse and the wastewaters used for cleaning sugarcane stalks.

The vinasse disposal represents the most important potential impact due to the large amounts produced (0.011 to 0.014 m^3 per m^3 of ethanol), its high organic loads and pH of 4 to 5 (Rodrigues and Ortiz, 2006).

Also, a number of studies on leaching and possibilities of underground water contamination with vinasse indicate that there are in general no damaging impacts for applications of less than 30,000 m^3 of vinasse/km^2. A technical standard by CETESB (2005) regulates all relevant aspects: risk areas (prohibition); permitted areas and adequate technologies.

Ways to reduce the amount of organic pollutants in wastewater include mechanical removal of suspended particles, aerobic treatment, anaerobic treatment and recycling (Smeets, 2006).

Agrochemicals such as herbicides, insecticides, mitecides, fungicides, maturators, and defoliants are inorganic pollutants applied in ethanol production. There is adequate Federal legislation, including rules and regulations from production to use and disposal of materials. Moreover, pesticide consumption per square kilometer in sugarcane crops is lower than in citrus, corn, coffee and soybean crops, as well as the low use of insecticides and fungicides

Genetic researches allowed the reduction of sugarcane diseases through the selection of resistant varieties, such as the mosaic virus, the sugarcane smut and rust, and the sugarcane yellow leaf virus (SCYLV). Genetic modifications (at field test stage) have also produced plants resistant to herbicides, fungus and the sugarcane beetle (Macedo, 2005). In fact, there are more than 500 commercial varieties of sugarcane.

The most important factor is the nutrient recycling through application of industrial waste (vinasse and filter cake), considering the limiting topographic, soil and environmental control conditions. So, substantial increases in productivity and in the potassium content of the soil have been observed. Nutrient recycling is being optimized, and the trash utilization is yet to be implemented.

3.1.3. Land Use

3.1.3.1. Expansion of sugarcane

The main concerns related to expanding the amount of land under cultivation for energy or any other use is the irreversible conversion of virgin ecosystems and the competition of food crops. None of these have been observed in the case of new sugar cane areas since they have mostly been planted on degraded land where there is little competition for food.

Sugarcane growth does not seem to have impact on food. Looking across the country the area used for food crops has not decreased. Within the state new sugar cane crops were planted in degraded lands that were previously used as pasturelands.

In Brazil, the expansion of sugarcane is limited by the quality of the soil; pluviometric precipitation and logistics.

Sugarcane is not a particularly demanding crop in terms of soil, adapting reasonably to soils of average fertility and high porosity / permeability - sandier soils. More fertile soils implicate in higher productivity levels, and/or smaller demand for costly fertilizers and corrective products, but high grade soils are more expensive due to the many other competing agricultural demands for land and thus usually not cost effective.

The problem could be indirect pressure through the expansion of existing crops / cattle areas in the above regions. Most expansion on sugarcane existing crops is taking place on degraded and pasture lands (Lora et al, 2006). Through intensification of cattle production the São Paulo state's cattle population has increased in density from 1.28 heads/ha (2004) to 1.46 heads/ha (2010) (IEA, 2011) while at the same time releasing 0.88 million hectares of pasturelands to other crops, especially sugar cane.

The Brazilian environmental legislation is based on the National Forestry Code (Federal Law 4,771/65), and the Environmental Crime's Law (Federal Law 9,605/98), there is also legislation to licensing and recovery projects. A legal reserve of 80% is required for rural properties in the Amazon region, 35% in the Amazonian Cerrado (savannas) and 20% for the rest of the country, including São Paulo state.

So, sugarcane plantations (or other crops) in São Paulo must guarantee at least 20% forestry cover on native trees (or reforested with native trees) and São Paulo state Decree 50,889 from June 16th, 2006, which establishes rules to the execution of the legal reserve in the state. São Paulo has also special requirements on riparian forests maintenance for environmental licensing.

3.1.3.2. Land competition: ethanol versus food crops

In the 70's and 80's ethanol caused a shift in land use patterns from food crops to sugarcane. In São Paulo from 1974 to 1979 the expansion replaced food crops. Maize and rice had the biggest decrease, of which the planted area declined by 35% (Saint, 1982 in ESMAP, 2005). Nevertheless, sugarcane growth does not seem to have impact in food areas, since the area used for food crops has not decreased. The expansion in the state is taking place over pasturelands.

Besides the expansion of sugarcane area, the increase on ethanol production in the state was also due to the growth of overall productivity (both agricultural and industrial) in the country.

Brazil has achieved sugarcane agricultural productivity average around 65 tonne/ha. In the State of São Paulo the productivity can be as high as 100-1100 tonne/ha. An enhancement of 33 % in the State of São Paulo since Proalcool started can be related to the development of new species and to the improvement of agricultural practices.

Also, genetic improvements allow cultures to be more resistant, more productive and better adapted to different conditions. Such improvements allowed the growth of sugarcane production without excessive land-use expansion.

3.1.4. Soil

The sustainability of the culture increases due the protection against erosion, compacting and moisture losses and correct fertilization. In Brazil there are soils that have been producing sugarcane for more than 200 years with ever-increasing yield.

According to Smeets (2006) the prevention of soil erosion and nutrient depletion can be reduced through special management procedures related to: erosion, avoiding plantations on marginal or vulnerable soils, or with high declivity, monitoring soil quality and nutrient balance.

The sugarcane culture in Brazil is in fact well-known for its relatively small soil erosion loss mainly when compared to soybean and corn (Macedo, 2005).

3.1.5. Biodiversity

Direct impacts of sugarcane production on biodiversity are limited, because new cane crops are established mainly in pasturelands. As mentioned, these areas are far from important biomes like Amazon Rain Forest, *Cerrado*, Atlantic Forest, and *Pantanal* (Smeets, 2006).

According to the state Secretariat for the Environment there are 1 million hectare of degraded riparian areas in São Paulo, of this total, 235 thousand should be recovered by the sugar/ethanol sector.

3.2. Social Aspects

Regarding socioeconomics impacts of the agribusiness, the most important is attached to job and income creation for a very wide range of workface capacity building programs, with the flexibility to support local characteristics using different technologies.

Brazil’s labor legislation is well-known for its advances in workers protection; the labor union is developed and plays a key role in employment relationships. For sugarcane, the specific aspects of employment relations in agriculture are better than other rural sectors, with formal jobs mainly in São Paulo state. Compared to the Brazilian 40% mean rate of formal jobs, the sugarcane industry’s agricultural activities now has a rate of 72.9% (from the 53.6% of 1992), reaching 93.8% in São Paulo (2005) and only 60.8% in the North/Northeast Region.

In São Paulo, non-specialized workers (sugarcane cutters) wages correspond to 86% of agricultural workers in general, and 46% of industrial workers. The average family income of those workers was higher than the income of 50% of all Brazilian families.

The formal direct jobs in the industry are now increasing in number (18% from 2000 to 2002) and reached 764,000 in 2002, while jobs in agriculture decreased. People having studied for less than 4 years represent 37.6 % of workers, 15.3 % being illiterate (4% in the Center-South).

This means that the workers in sugarcane industry are becoming more skilled and receiving higher wages.

According to (Neves, Trombin, & Consôli, 2009), in the year 2008, the sugarcane sector accounted 1,283,258 formal jobs, being 37.5% in agricultural activities. However due the seasonality of sugarcane crops, 54% of these jobs are temporary. Even though, there was a positive balance of 588,826 jobs. Nevertheless, one must account informal jobs, that despite being reduced still exist, thus achieving 1.43 million jobs. Considering that each direct job is responsible for other 2 indirect ones, one can achieve a great amount of 4.29 million jobs associated to the sugarcane production chain.

In São Paulo state, the same legislation that established the mandatory mechanized harvesting of green cane includes a program of professional re-qualification to those rural workers who used to harvest sugarcane and were replaced by the mechanical harvesting.

Despite the reduction of jobs in the crops due the phase-out of sugarcane burn, the expansion of the sugarcane culture in the period enabled the creation of new positions; maintain the number of employs constant.

Regarding the size of sugarcane producers in Brazil, almost 75% of the sugarcane land is owned by large producers. However, there are also around 60 thousand small producers in the Midwest-Southern Regions, organized in cooperatives with an increasing negotiation power. A payment system based upon the sucrose content in sugarcane has been used for a long time and has promoted significant growth in agricultural productivity.

Despite the fact that most sugarcane producers are quite large, there are two different situations. In São Paulo State, in most cases the sugarcane planted area belongs to large producers. A different situation is found in Paraná State (Southern region, one of the highest sugarcane producers in the country) where most sugarcane producers are small and members of cooperatives.

In the Center-South, the income of people working in sugarcane crops is higher than in coffee, citrus and corn crops, but lower than in soybean crops (highly mechanized, with more specialized jobs). In the North-Northeast, the income in sugarcane crops is higher than in coffee, rice, banana, manioc (cassava) and corn crops, equivalent to the income in citrus crops, and lower than in soybean crops. However the payment is always based on the amount of sugarcane harvested.

The workers in São Paulo receive, an average, wages that were 80 % higher than those of workers holding other agricultural jobs.

Their incomes were also higher than 50 % of those in the service sector and 40% of those in industry (Macedo, 2005).

According to Smeets (2006), the Gini's coefficient[1] for the sugarcane and ethanol production sector is low compared to the national average and other sectors.

Brazilian government signed ILO's recommendations which forbid most precarious ways of children labor and define the minimum age of 18 years to hard job. Also Brazil has intensified inspection on working conditions in sugarcane sector (Rodrigues and

[1] a measure for the income distribution. It is a number between 0 and 1, where 0 corresponds to perfect equality (e.g. everyone has the same income) and 1 corresponds to perfect inequality (e.g. one person has all the income, and everyone else has zero income).

Ortiz, 2006). Nevertheless, the inspection is still not sufficient and some worker right violations have been reported, not only in the Northeast region.

In 2006, the inspection from Brazilian Public Ministry was stricter, which resulted in over 600 fines on São Paulo State (Primeira Página journal, December 2006). The inspections were focused on work condition and environmental issues.

Mechanism of family compensation for the loss of family income from child labor, where parents are compensated for the costs of education, is calculated to increase the ethanol costs by 4% can minimize it (Smeets, 2006). However, even with these incentives 3% of workers in sugarcane and ethanol production sector are younger than 17 years old.

Despite the improvements on working conditions achieved in the last decade more progress is still needed.

4. ENVIRONMENTAL ZONING OF SUGARCANE

Due to the expansion of sugarcane production in the recent years, concerns about the direct impacts of land use change led federal and state governments to adopt policies for determining suitable areas for this crop.

The state of Minas Gerais was the pioneer in this process and launched its economic-environmental zoning in the year 2007. The zoning is based on social, economic and environmental information that shows regional characteristics, potentialities and vulnerabilities. It is an orienting tool that can support policy makers and entrepreneurs from different sectors.

In the state of São Paulo, the agro-environmental zoning, launched in September 2008, was conducted by the State Secretariat for the Environment, based on studies related to soil and climate restrictions, topography, water availability, air quality, existence of protected areas and biodiversity conservation areas, identified by the Biota Program/Fapesp (Research Program on Characterization, Conservation and Sustainable Use of São Paulo State Biodiversity) (Joly et al., 2010).

Another decisive new step was taken by the State Secretariats for Environment and Agriculture, and the President of the Sugarcane Producers Union (UNICA) in 2007, with the launch of the Agro-environmental Protocol (SMA, 2008). The text stipulates a set of measures to be followed, anticipating the legal deadlines for the elimination of sugarcane harvest burning and immediately halting burning practices in any sugarcane harvests located in expansion areas. It furthermore targets the protection and recovery of riparian forests and water springs in sugarcane farms, controls erosion and content water runoffs, implements water conservation plans, stipulates the proper management of agrochemicals, and encourages reduction in air pollution and solid wastes from industrial processes.

The Federal Government launched, in September 2009, the national agro-ecological zoning for sugarcane and, in 2010, for oil palm.

This zoning identified the areas where sugarcane crop expansion can take place. The zoning forbids sugarcane cultivation in 92.5% of national territory, including the Amazon Forest, Pantanal wetlands and other native biomes. It identified 64 million hectares that comply with environmental and productivity requirements, mainly from the intensification of cattle rising, currently very inefficien.

The Federal zoning was an intense program led by Embrapa Solos, involving dozens of institutions and researchers of agricultural and environmental issues. In this process maps were produced showing soils, climate and rainfall, and topography.

Land was classified and delimited by determining the areas of highest yield potential in detail (1:250.000), based on minimum productivity, with respect for the environmental regulations and which areas should be preserved, as well as trying to reduce competition with areas devoted to food production.

According to these studies, there are in Brazil about 650.000 km2 available for sugarcane and 300.000 km2 for palm, without undesirable impacts. On Embrapa Solos website many reports, maps and methodological issues can be easily accessed. Unfortunately, all relevant documents are available just in Portuguese.

Nowadays other states like Mato Grosso do Sul launched their environmental economic zoning not only for sugarcane but also for eucalyptus plantations for pulp and charcoal production, mainly in degraded areas previously used for cattle.

5. CONCLUSIONS

The Brazilian experience on agro-economic environmental zoning is an interesting experience to be shared with other developing countries mainly in Africa (mostly Sub-Saharian countries) and Asia. Competition of food and fuel productions and the deforestation of native fragile biomes can be avoided through the implementation and enforcement of policies based upon such zoning tools, coupled with incentives (e.g. certification) of overall sustainability aspects of biofuels production chain.

To achieve the implementation of such policies, adequate capacity building at national, regional and local levels (on technical, environmental and economic dimensions) is required, together with the dissemination of lessons learned.

The Brazilian experience also shows the interest of complementing command and control type of policies, such as zoning laws, with the use of economic incentives. The access to soft loans from public development banks can be conditioned to meeting zoning criteria. Similarly, funding from international agencies can play a similar role, like the on-going experience of the Cogen for Africa Project[2], funded by GEF – Global Environmental Facility, through UNEP-Nairobi, and by the AfDB (African Development Bank).

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