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# Ethanol and food production by family smallholdings in rural Brazil: Economic and socio-environmental analysis of micro distilleries in the State of Rio Grande do Sul

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ABSTRACT

In light of the perspectives of ethanol from sugar cane industry in Brazil and the biofuelscurrent international debate, certain questions ought to be examined. The framework for future expansion of ethanol production, to meet with supply needs at national and international levels using the current production model, does not take into consideration the prospect of Brazil's regional and rural development. Although currently there are no impediments to the culture of sugar cane in Rio Grande do Sul (RS) State, Brazil's largest producer of biodiesel, it imports 98% of its demand for ethanol from São Paulo and other regions. The promotion of ethanol market in that State might pass for a productive model different from the practice in industrial monocultures, given their cultural and agricultural characteristics. The IFES (Integrated Food and Energy System) from COOPERBIO -n Cooperativa Mista de Produção, Industrialização e Comercialização de Biocombustíveis do Brasil Ltda., established on an experimental basis in the State, presents multiple economic, social and environmental benefits, potentializing the present food procuction by smallholders and favoring a sugar cane ethanol greater consumption in the inland of RS State. With a few tweaks and adequate governmental policies and instruments, the expansion of this model may even cover the current demand in the State. In addition to the production of energy and foods less dependent on fossil fuels, this model contributes for preservation of ecosystem services and for climate smart rural sustainable development.



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## 1. Introduction

### 1.1. Purpose of the work

This paper presents an analysis of the model of decentralized production of sugar cane ethanol in micro distilleries, integrated with food production, developed on an experimental basis by COOPERBIO (RS, Brazil), with direct involvement of rural smallholdings in the State of Rio Grande do Sul (RS), Brazil. In spite of the promissory aspects of the ethanol Brazilian production in the international biofuels debate, the goal of involving small producers in ethanol production, included in the initial design of National Alcohol Program (Proálcool), has not been achieved, resulting in an ethanol/sugar supremacy model concentrating capital and land, and not sufficiently labor-intensive. Sustainability of similar monocultural models is being questioned, because of its competition for natural resources with food production, land use change impacts, biodiversity threats, deforestation and other impacts (local and regional). Another questioned point is the smallholders inclusion in biofuels production chain, which has also not yet been achieved in National Program for Production and Use of Biodiesel (PNPB), as foreseen in its conception.

Considering the ethanol production expansion prospects in the coming years, for domestic and export supply, the tendency is the expansion of this model through the country, including in RS. This State is the biggest Brazilian biodiesel producer, but contradictorily produces only 2% of its ethanol needs, importing the rest from São Paulo State and other regions, at high economic and environmental costs, little benefitting from gasoline substitution by hydrated ethanol.

The study hereunder analyzes the economic viability of the COOPERBIO initiative, the problems encountered in its implementation, social and environmental benefits, in addition to opportunities for its possible expansion in the RS State, based on its specific socio-cultural configuration in light of possible impacts of climate change on agricultural geography in Brazil. With adequate government policies, the smallholders inclusion process in the ethanol production chain in RS might promote its desirable sustainable and climate-smart rural development. The following subsections examine the context, targets and rationale of the task at hand.

### 1.2. Liquid biofuels

During the 1990–2000 decade, the industrialized countries encouraged its national biofuels industries to substitute gradually the fossil fuels, looking for energy security and rural economy development [1]. The growing concern for climate change and its relation with the natural and human systems sustainability, in parallel with increasing price of petroleum and other geopolitical factors, heated the world demand for renewable, sustainable and less polluting energy sources [1–5]. In 2010, the renewable sources accounted for 16.7% of the final consumption of world energy [6]. In 2011, transportation needs consumed 27% of the final use of energy in the world, accounting for about 23% of the global emissions of $CO_2$ [7]. Use of liquid biofuels in this sector, though still small (2.3% in 2012 [8]) is expected to grow in the coming years. World production of liquid biofuels in 2011 was 107.5 $hm^3$ (86.1 $hm^3$ of ethanol and 21.4 $hm^3$ of biodiesel) [9]. In 2012, this production has not progressed much (110 $hm^3$), due to the high costs of raw feedstocks production and reduction of produced volume, mainly because of extreme climate conditions in key regions [8]. In 2011, the ten largest producers concentrated 93.7% of world production, led by E.U.A (53.5%, the largest producer of ethanol and biodiesel) and Brazil (23.8%, the second largest producer of ethanol) [9]. Projections indicate that ethanol and biodiesel production must double by 2021 [10] especially in the light of ongoing policies in the US (US Renewable Fuel Standard-RFS, 2007) and in the EU (EU Renewable Energy Directive-RED, 2009). However, the rapid growth in 1st generation liquid biofuels production worldwide has left many unanswered questions, as to its real GHG (greenhouse gases) mitigating capacity, its environmental and social sustainability and its economic viability, in long term [1]. This originated an intense international debate, briefly outlined in item 1.4 of this manuscript.

### 1.3. Social inequality and food security

In addition to energy issues, the agenda includes facing the challenge of moving toward a more egalitarian and sustainable society [11]. Despite the social progress observed in recent years [12], the persistence of social inequalities between and within Nations [13], revealed by an estimation of almost 870 million individuals of the world's population to be in a state of malnutrition [14], strengthens criticisms made with respect to production and consumption models of contemporary society. The multiple dimensions of handling poverty problems of the world's populations (provision of water, food, energy and health, agricultural, educational, financial and informational requirements), in the light of the complex interrelationship between climate change, bioenergy production, food [4,5,15] and biodiversity [16,17] is a challenge to current civilization, in function of the risks posed on ecosystem services. Within the global context of crises directly related to agricultural policies, and taking into account the projections of world population (increase of 680 million people until 2021 [10]), the challenges in meeting future human needs are not only how to increase production and agricultural productivity, but making in a more sustainable and resilient to climate way [10,16,18].

### 1.4. International biofuels debate

The 2007–08 food crisis was associated with the biofuels production increase in global scale, launching an international critical debate concerning the biofuels threat to food security [5,19,20]. This association was recently reviewed in depth, identifying other vectors in the process [19,21–23]. However, in medium and long terms, the dispute for natural resources, labor and other inputs, and their impacts on the biofuels and food prices, is almost unavoidable in the context of the market forces. China and India, e.g., highly populated countries, are directing their policies in order to avoid biofuels production from food crops [1,24], matter which is also under debate. The crop productivity increase, defended solution to minimize the conflict between energy and food [16,25,26], has to be prudent, because it can lead to resources degradation and exhaustion [1,27], specially regarding water availability [5]. Although the increase of foreign lands acquisition by many corporations and governments, after the food crisis, has not been exclusively due to the biofuels wave, it has to be carefully followed up, mainly in countries with social and environmental weak governance and where agricultural productivity can be strongly enhanced by technological investments [19,28,29]. In face of potential threats involving 1st generation liquid biofuels, it has been given priority to a more intensive use of biofuel feedstocks that do not compete with food for land and water, such as wastes, residues, cover crops, and forest thinning [5,16,26,30,31], using advanced technologies (2nd and 3rd generations). Nevertheless, even if these technologies reach sufficient scale for future demands, the bioenergy competition with food (land, prices) in the long run is uncertain [1,20,24] and also may incur in GHG emissions (transport) and other impacts [19,32].

The land use impacts resulting from biofuels production, interlinked with food security, may undermine the expected GHG mitigation [30,33,34] and threaten biodiversity [26.31,33,35], either by direct conversion (LUC) of certain land types (e.g., rainforest and peatland), or indirect one (ILUC), when energy crops displace food crops to native areas [16,26,35,36], besides possible change of commodities prices [26,37]. Although the biodiversity may be beneficiated by the feedstock crops and degraded and abandoned lands [1,20,31,38], the temporal quantification of these benefits and the climate change effects on biodiversity [2,20,39] and on water availability [40], are very uncertain. Moreover, besides the eventual pressure on the local communities [24,41], one doubts about the real availability and economic viability of producing in such lands [30]. It should be noted that the biofuels ILUC account is still under controversies, because the use of different methodologies [30] and spatial and temporal uncertainties [38,42]. Another point of discussion is the feedstock efficiency (yield per unit of land) and the energy balance of productive systems. Some raw feedstocks are moderately efficient, but require heavy direct subsidies from the governments, like corn (ethanol in U.S.) [1,43] and rapseed (biodiesel in EU) [1]. Other ones are more efficient and with favorable energy balance, like sugar cane (ethanol in Brazil) [43] and oil palm (biodiesel in Malaysia and Indonesia) [44,45], economically viable without direct subsidies, but with questioned sustainability.

Sustainability of bioenergy production is beeing intensily discussed in several certification schemes (especially in EU countries) and voluntary patterns (private initiatives) [1,7,20,44]. The certifications present limitations as they do not interrelate the different aspects of sustainability [1,20,44]. The RED methodology, e.g, based on life-cycle assessment (LCA) approach, excludes many critical issues [42]. The social impacts are the weakest point in several biofuels studies [3,24,45] and are mentioned in most certifications schemes only in minimum requirements (infantile labor, minimum wage, land and lost resources compensation, national laws and international conventions compliance) [1,19,46]. Issues such resources management, human health implications, poverty reduction and smallholders inclusion normally are not discussed [1]. The geographical coincidences of extreme poverty and biodiversity hot spots, concentrated in rural areas, should receive an empirical treatment, not only theoretical, in search of “win-win” solutions (biodiversity conservation and poverty traps mitigation) [17,47]. The proliferation of monocultural agroenergy systems where the rights of rural properties are not guaranteed [1,25,40] may cause significant social impacts, both direct (mainly water and food insecurity) and indirect (e.g., smallholders displacement and cultural uprooting, lack of land access because of its growing prices), these latter ones not encompassed in EU directives [19,41,48–50]. The more intense demand for raw feedstocks and agricultural residues for biofuels advanced generation may also affect directly poor rural people who still depend on biomass traditional uses for cooking (2.6 billion, in 2012 [51]) [1,49], mainly in Sub-Saharian Africa [41]. The smallholders, fundamental actors, if properly trained, in a less aggressive management of natural resources and subjects with legitimate aspirations [16,17,50] are often considered as mere feedstocks producers [3,19] and do not take part in the discussions. Moreover, the certifications are practically out of their reach, because of their high costs, lack of information access and management expertise required in their implementation [50,52], favoring the big enterprises [1]. On the other hand, certifications may become a barrier to smallholders productive inclusion [41,52]. Depending on circumstances and productive scale, payments for ecosystems services preservation or mitigation rewards for biofuel use [17,26,49] may be more viable alternatives than certifications [44], mainly when production is not destined to exporting [41]. The rural sustainable development in underdeveloped areas depends basically on strong sectorial policies, avoiding inclusively the deepening of power asymmetries between agro-industrial oligarchies and smallholders [46], rather than processes and patterns orienting criteria [3,50]. However, smallholders involvement in certifications is relevant, e.g., when bioenergy is explored in sensible areas, like oil palm production in Amazon region [3,19] or in Thailand [52], because of deforestation risks.

In principle, biofuels projects implementation aimed at exporting should be in large scale in order to be competitive [22,41], noting that their associated costs relative to social and environmental damages have not yet internalized in economic assessements [1,31,53,54]. It is believed that the challenge of governments would be the adequate planning of such systems, advancing in their social and environmental limitations [19], counterbalancing (geographically, temporally and socioculturally), however, with the implementation of small (household and local use) and also medium scales systems. The government support for the integration of small producers and less-favored groups in biofuels chain [22,25,36] may guarantee energy and food security [1,41], avoid the known poverty traps [17] and favor the ecosystems services maintenance [16]. Developing countries governments that would succeed in these management possibilities in their territories, might have their export productions priorized, as an additional requirement in certifications. Finally, without strong and consistent additional national policies and economic instruments that regulate market failures in exporting and importing countries [36,55,56], not just focused in energy supply security [19] and that integrate small producers in the biofuels value chain, certification will not be sustainability guaranty [1,3,25,32]. It is also worth noting the need to incorporate in planning the complexity of climate change influence on agricultural and ecosystems services [16,57].

### 1.5. *Brazilian ethanol production and sustainability aspects*

Within the panorama of liquid biofuels, there are exceptions such as the sugar cane ethanol in Brazil, where, at least, the costs are low and the reductions in emissions of $CO_2$ seem to be substantial [7,22,38,58–60], in spite of uncertainties in the assessements [43]. Brazilian ethanol provides energetic security, foreign exchange saving, employment and air pollution reduction, not depending on more subsidies to be competitive [61], being recognized as an advanced biofuel (reduction of at least 50% of GHG emissions, compared to gasoline) by EPA (Environmental Protection Agency of US) [21]. The production of ethanol in Brazil came to prominence with the Proálcool, created by federal Government in 1975, as a response to high oil prices on the market [62,63], initially supported by strong subsidies and regulated market. Following an unfavorable production period in the mid-80's, factors such as deregulation of the market, efficiency gains and lower costs of production revitalized the ethanol industry in the 90's, especially in São Paulo[1] State [64]. In 2012, the ethanol production reached 23.5 $hm^3$, 9.7 $hm^3$ of anhydrous ethanol and 13.8 $hm^3$ of hydrated ethanol [65]. It is expected to reach 63.1 $hm^3$ in 2020 [66]. The flex fuel technology (2003), the introduction of which was determinant for the ethanol production increase in the country, guarantees a high share of biofuel use in transport sector (20.1%, in 2010), compared to other countries (4.4% in US and 4.2% in EU, in 2010) [8]. In 2012, 51% of the total fleet of light vehicles in the country were flex fuel [65]. The proportion should attain the 74% mark in 2020 [66], thereby accompanying the growth of ethanol market.

The country, currently the greatest exporter of sugar cane ethanol, and the second in soybean production, is in the center of biofuels debate [21,68], mainly for deforestation and land-use change (LUC and ILUC). Deforestation is the main source of GHG emissions in Brazil (61% of total emissions, in 2005) predominantly in the Amazon region [69], problem which affects also Indonesia [68] and India [16]. Deforestation is being fought by federal government with positive results [69], through satellite monitoring developed at the National Spatial Research Institute (INPE) [68]. Efforts of public sector, enterprises and civil organized society to upraise ethanol sustainability can not be denied [21,54,68,70–72]. In 2008, the Brazilian Government launched the agroecological zoning plan of sugar cane (ZAE), as an indicative document linked to government planning strategies to provide conditions for obtaining credits from sector agencies [73]. The sugar cane monoculture expansion in Brazil, in spite of being done mainly in pastures and other crops areas (LUC) [54,60,63,74], could push them to forest zones (ILUC) [1,33,35]. Different studies, however, do not confirm this possibility. Reduction of pasture areas in South-Center region is attributed to productivity increase of cattle ranches through intensification, what also may liberate more areas for sugar cane crops [21,43,60,72,75–77]. However, spatial and temporal dynamics of these impacts should be constantly controlled, in face of ethanol production increase and other vectors in the socioeconomic dynamics of the country (e.g., production costs, demand and prices of land for grain production, meat and other export products) [2,29,48]. Other examples of Brazilian initiatives towards sustainability of the production of sugar cane are the requirement of phasing out of biomass burnings (SP, 2002) and the Agro-environmental Protocol (SP, 2007), covering critical points of production [78]. As to discussions on fuel versus food, even with the increase in sugar cane production from 2003 onwards, data from food production in Brazil has shown a consistent growth path, confirming the idea that ethanol development did not (until 2008) cause instability in food supply at national and world level [58,79].

Although the undoubted economic sustainability of Brazilian cane ethanol [21], environmental problems persist inherent to its monocultural model. The GHG emissions of the ethanol chain are highly affected by nitrogenous fertilizers (like in all Latin America plantations [25]) and by burnings, which also jeopardize carbon stocks and reduce soil nutrients [80], besides causing human health local problems [21,43,81]. The mechanical system for planting sugar cane presents serious problems of soil compaction that can be improved by traffic control and reduced or no-tillage farming, e.g. Refs. [21,43,72]. The mechanized harvest (used in 65% of sugar cane crops in São Paulo [82]) dispenses burning, but may compact the soil [21,38,43]. The production chain of sugar cane has the great potential for saving fertilizer by the recycling of nutrients (vinasse, filter cake and ashes), but only vinasse (relevant for volume produced and polluting potential) has legislation on its disposal and only in São Paulo [21]. Bagasse (burned to supply heat and electricity, for plant self sufficiency and surplus for network) increasing use favors the GHG emissions reduction [26,59,76,81]. Transport of raw materials and ethanol distribution are also significant items in energy costs (mainly big diesel trucks) resulting also in GHG emissions [21,76]. As to water demand, Brazil has the advantage of needing low crop irrigation, differently from countries like India, Australia, Peru and South Africa [1], but the current plants in São Paulo are relatively inefficient water users [21]. The intensive application of fertilizers and other chemical inputs in farming can degrade soils and water bodies (acidification, eutrophication) [38]. High rates of industrial effluents and residues may cause local pollution (water eutrophication, terrestrial and fresh water ecotoxicity and human toxicity) [37,83]. Because of high plants concentration in some São Paulo regions, the installation and operation of new ones have to follow specific legislation within the State (water uptake and wastewater treatments), reducing social and environmental constraints [21]. At last, the agricultural intensification and landscape simplification, typical of large scale agricultural production, do not favor the preservation and/or expansion of biodiversity several components [47,84].

The sugar cane harvest, where not yet mechanized, displaces large contingents of rural workers and farmers in various regions of Brazil. Working conditions in the sugar cane industry may be

[1] São Paulo is the largest producer of sugar cane in Brazil, accounting for 54.2% of the production of the crop in 2012–13 [67].

precarious or even degrading [3,19,63,85,86], especially in Northeast [46], in spite of verified desaceleration of slave labor in 2010, caused by official "National Pact for the Eradication of Slave Labor " (2005) [48,71]. On the other side, the mechanized harvesting undoubtedly improves labor conditions, although it reduces jobs in the sector, especially for less qualified workers [24,46,63]. Studies in sugar cane producing municipalities in São Paulo show socio-economic indicators comparatively high to the rest of the country [76]. But, scale economy and land concentration [14], not only related to expansion of ethanol production (and not only in Brazil) have benefited, and tend to keep on benefiting, major producers and industrialists [22,54,87]. Small producers, in general vulnerable in the agribusiness forces game [17,24,40,46], have not participated in the sugar-alcohol benefits [3,22,87], many loosing land property and migrating to big urban centers. Brazilian government created new ministries to deal with these issues: social exclusion (Ministry of Social Development & Fight against Hunger) and small farmers inclusion (MDA-Ministry of Agrarian Development) [87], with immediate measures of income transfer to urban and rural poor people and perspective for productive inclusion in the long run.

Nations with similar natural conditions who plan to enter in the world ethanol market (mainly of Sub-Saharian Africa and some of Latin America) [27,63] may take the Brazilian experience of more than 30 years for reflection. Although considered a technical and commercial success, the ethanol production concentration in rural areas [78] may aggravate the regional inequalities within countries [24], with differentiated effects on urban and rural people [40].

### 1.6. *Brazilian inequalities, family smallholdings[2] and PNPB*

Brazil is the fourth in income distribution inequality in Latin America, in spite of its world sixth GDP (Gross Domestic Product), having 110 million people living in slums [89]. According to agricultural census of 2006 [88], 4,367,902 units were identified as rural family smallholdings (84.4% of country's total), together occupying an area of 80.25 million hectares (24.3% of the total area). These results demonstrate that the high concentration of agrarian activities in Brazil [22,90,91] is basically the same as it was in the middle of the last century [92]. Although family farming produces between 60% and 70% of internally consumed food [93], this sector comprises the greatest extreme poverty concentration, specially in Northern and Northeastern regions [92].

In this framework and seeking to avoid social problems generated by Proálcool [78], the PNPB (2004) was designed with the initial premise to include 225,000 family farmers in the biodiesel production chain, stimulating the use of more suitable crops for these farmers, such as castor beans in semi-arid Northeast and palm oil in North, regions focused by the program [3,94–96]. Biodiesel would be mixed to petrodiesel in growing percentages (5% or B5 reached in 2010), allowing structuring of smallholders supply chain [96,97]. To reach such targets, MDA instituted SCS instrument (social fuel seal, 2005), consisting of contracts between biodiesel producers and smallholding farmers. Among several arrangements, SCS guarantees minimum prices, capacitation, training, technical assistance and good quality seeds supply to smallholders, as well fiscal benefits, financing and preference in national biodiesel auctions organized by National Agency of Petroleum, Natural Gas and Biofuels (ANP) to companies that buy certain raw feedstocks percentages from smallholders [3,21,94]. SCS underwent several changes with soybeans oil entry in the chain and with several difficulties of smallholders, such as lack of production and technical assistance, precarious flow logistics, low productivity and production rates, resulting in non competitive prices and low income generation for smallholders [3,29,98]. The soybeans oil (soybean complex by-product) is offered in great amounts and low prices, thus its easy flow to PNPB [99]. This opportunity was also embraced by modern smallholders, mainly in the Southern region (greater number of smallholders and better organization in co-operatives) and in the Center-Western region (greater family land plots and bigger production volume) [3,29,94,96]. Crops like peanut, sesame and sunflower have no significant participation in PNPB, because they have better market prices than in PNPB, thus generating higher income for smallholders [97]. As a result, soybeans participation in SCS acquisition matrix in 2010 was 94%. In 2011, soybean was responsible for 80.6% of country total production, followed by animal fat (13.4%, also by-product of Brazilian cattle herd [29,94]) and by cotton (3.1%) [100], putting the country in fourth position in the world in biodiesel production [6]. For its importance in Brazilian exports, soybeans must be maintained as the main raw material of the program for many years [101]. There has not been sufficient time for the planned regional production decentralization neither for feedstocks diversification, more sustainable than soybeans (e.g., castor beans, sunflower and rapeseed) [94,98], compatible with country agricultural land extension and edaphoclimatic diversity. It is also to be noted that one can not conclude on Brazilian biodiesel economic viability, once its production and commercialization are still highly subsidized focused on its processing and industrialization [21,29,94,98]. In spite of noticeable family farmers growing participation in program, PNPB presents weak results, in quantitative terms (up to 2010, 100,371 family farmers were included [97]), as well qualitative ones (inexpressive inclusion of family farmers from poor regions) [3,94]. It is expected that other governmental policies be adopted in this recent program, so as not to have convergence of PNPB with Proálcool [63]. Finally, the unprecedented PNPB social conception reveals the importance of large and everlasting policies and investments in structural poverty fight [3,29,40], which takes time to produce results.

### 1.7. *The IFES (Integrated Food-Energy Systems) approach*

Within sustainability challenges of biofuels scale economies (also food), mainly concerning pressure on smallholders,

[2] The definition used here refers to the classification of "Family Farmer" used by the IBGE (law n°11,326-jul/2006) [88], observing the following requirements: (i) does not own, under any title, an area greater than 4 (four) tax modules; ii) uses predominantly family's own labor in economic activities of his establishment or enterprise; iii) has family income mainly derived from economic activities linked to the establishment or enterprise; iv) runs his establishment or enterprise with his family.

studies point to integration of food and energy production as strategy to improve countries food and energy security, to alleviate poverty in a climate smart way and to reduce risks associated with land conversion (LUC and ILUC), deforestation and forest degradation [1,37,49,52,102,103]. These systems (IFES), suggested even by FAO (Food and Agriculture Organization of the United Nations), have scales and configurations which vary in function of their goals and contexts. They may operate in household or at local level (small scale systems) for energy self-sufficiency or adjusted to industrial operations, both benefitting mainly smallholders in developing countries, where energy and food securities are basic requirements for poverty reduction and rural development [102].

A traditional example of IFES is anaerobic digestors for biogas production (cooking, lighting) and bioslurry (byproduct applied to crop fields), in integrated systems of crops-livestock-fish, found in various shapes, sizes and compositions, disseminated mainly in China and Vietnam [49,104]. Other recent IFES experiments, which link biofuels production to smallholders wellbeing and poverty alleviation are: industrial production from cassava as opposed to maize-based industry na Tanzania [105]; inclusion of small and medium producers in the sugar cane ethanol chain of Caña Brava company in Peru, in outgrowers scheme [52]; small scale production of Jatropha to provide fuel for household use and to make soap in Malawi and Mozambique [27]; and large scale production of biodiesel from Jatropha, with outgrowers associated to a private company in Ghana and Zambia [27]. In general, these systems present several limitations which do not yet favor their dissemination. In the case of food and cane ethanol integration in family farming systems, focus of this manuscript, studies have already been presented in the 80's decade (e.g., in Refs. [106–108]), with arguments and results quite timely and reinforced by some recent researches. Agostinho and Ortega [53], e.g., conclude through different methodologies the energetic-environmental advantage of IFEES (Integrated Food, Energy and Environmental Services, in that approach) when compared to large-scale ethanol production, in São Paulo.

It is to be noted that studies on integrated systems advantages, in contrast with industrial production specialized systems, are not necessarily related to bioenergy and not only to developing countries. As an illustration there is the Diversified Farming Systems (DFS) (see Refs. [84,109–111]), which emphasize biodiversity function in spatial and temporal scales in maintenance of ecosystem services, essential for the agricultural production (e.g., pollination services, water quality and availability, soil conservation, pest and disease control), close connected to multifunctional, organic (or low-input farming) and local agricultural systems. Another study presents the importance of agricultural biodiversity in agricultural production and productivity, indicating that higher diversity is actually more effective in increasing productivity than higher management intensity [112]. At last, integrated approach and diversification in agricultural system, with emphasis on sustainability, is seen as an important component in GHG mitigation and also adaptation, once diversification increases its resilience to climate change [16,49].

## 2. Methodology

The research tool adopted was the "case study", reflected through literature review on related themes and based on *on-the-spot* observation of the experiment in progress of COOPERBIO, enabling the gathering of technical data and survey information from the stakeholders involved in the initiative. The case selection was based on originality and promising aspect of the experiment, also hypothesized by Sachs in 2007 [113], subject of several specific (see Refs. [114–119]) and related (see Refs. [120–124]) studies and seriously taken ahead by the implementing team.

### 2.1. COOPERBIO

COOPERBIO, an initiative of MPA (Smallholding Farmers Movement), was established in 2005 at Palmeira das Missões (Rio Grande do Sul, Brazil) and operating in north-western region of this State in about 63 municipalities. This cooperative arrangement has the main objective of bringing together small and medium-sized farming enterprises, to produce raw materials and to store, manufacture and market biofuel products. Its main strategic objectives are: the combination of food and fuel products to the best benefit of the community as a whole; farmers participation in all stages of the production chain, aimed at income increase; management of the natural resources system, aimed at the conservation and maintenance of biodiversity, water and soil; and feasibility of logistic system for ethanol production through the implementation of small-scale equipment (alcohol micro distilleries, crushers, dryers and community grain silos), to permit recycling of community biomass to its agro-ecosystem [125]. The Cooperative has a partnership with EMBRAPA, EMATER, UFSM (Universidade Federal de Santa Maria) and URI (Universidade Regional Integrada), universities involved in technological validation and systematization of the initiative, as well as agreements concluded with ELETROSUL and PETROBRAS.

The coverage area of the COOPERBIO (Fig. 1) is characterized by high incidence of family agriculture. The production units with up to 50 ha (small and medium-sized properties) represent 95.07% of total establishments, but the large landowners concentrate 43.87% of the land [88]. The region, therefore, faces the same difficulties as does the country's agriculture [126].

### 2.2. COOPERBIO system: food-energy-environmental services production

Aimed at concrete implementations for the achievement of its strategic goals, COOPERBIO signed in October 2006 a contract with PETROBRAS in the amount of R$ 2,318,362.00, for implant and technological validation of 09 micro distilleries producing ethanol-food from the family farm, through small agro-industrial processing units with a nominal capacity of 600 L of alcohol per day (L/d) each, interconnected and managed collectively. A central production unit was also installed, with nominal capacity of 5000 L/d, which would use different raw materials in the production of ethanol (sugar cane, manioc and sorghum) and would also have the function of rectifying


**Fig. 1 – Geographical location – COOPERBIO. Source: Adapted from [126] and [127].**

the alcohol produced in micro distilleries, in different municipalities in the north-western region of Rio Grande do Sul. Fig. 2 shows the scheme of the units in the original design.

In the project design, each unit of 600 L/d would need raw materials produced in about 2 hectares (ha) of smallholding land (average area per smallholding is 13 ha), with an average of 13 families per unit, plus 29 families on the central unit (5000 L/d), with full involvement of about 150 families. Two forms of transportation would be contemplated for taking the raw material to the micro-stills: i) cane carried by trucks or lorries and unloaded manually in the micro-still; ii) transportable mills (powered by tractor) taken to cane grinding location and transportation of resulting broth (already decanted and ready for fermentation) to the micro-stills. The first form would result in the use of bagasse in boilers of power generation micro distilleries and the second would make the tips and cane bagasse available for making up a formulation of feedstock and a supplementary ration for animal kept at the

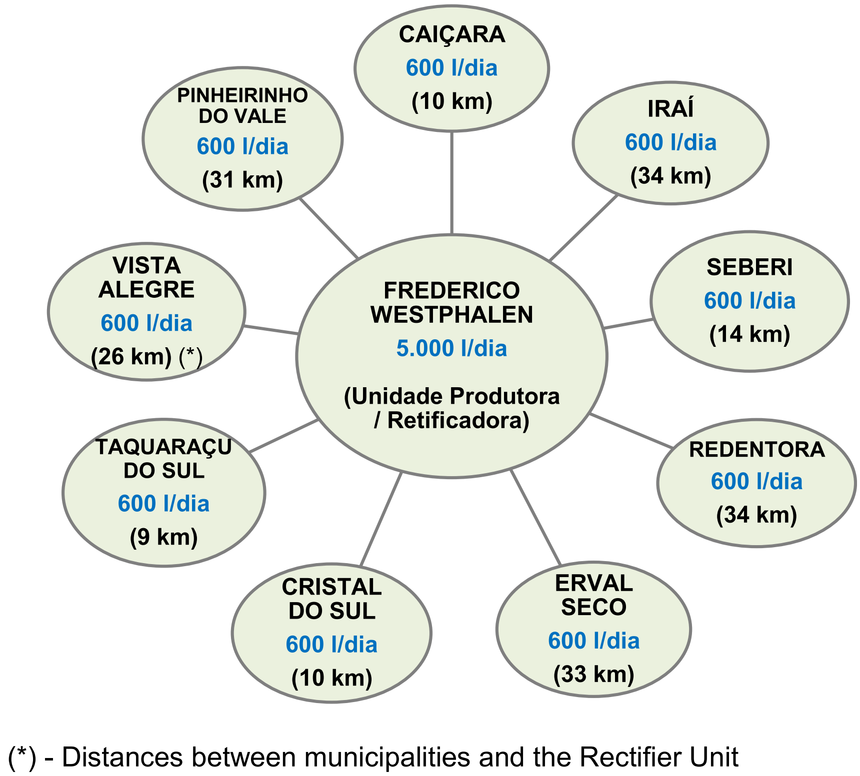


**Fig. 2 – COOPERBIO – decentralized production system hydrated ethanol – original design.**

individual properties. Production of milk is a significant factor in resource management of small producers in the South. Vinasse obtained from micro-stills would be used in feeds, directly by the animals or still in the crop fertiirrigation of sugar cane and other crops [116,125].

The micro distilleries were implanted under a leasing arrangement, remaining the cooperative responsible for marketing and technical assistance. Alcohol produced would serve primarily for the consumption of the co-ops in so-called Supply Points[3] with the surplus disposal from the central unit guaranteed by PETROBRAS. For trading between producers, the COOPERBIO has a special regime through Declaratory Act DRP no 2009/106 issued by the Secretary of the State Treasury Department of RS.

### 2.3. Problems encountered in project implementation and the current situation

Given the experimental nature of the initiative, some delays have occurred in implementation of the project. According to information obtained directly from the cooperative's technicians, the Environmental Licensing was designed specifically for the small scale licensees, with special norms and standards, taking a time not foreseen in the project, also delaying the license issue for water use in the major unit. Delays also occurred with technological tests, possibilities of intercropping and crop rotation and tests with different cane varieties adaptable to the region, resulting in consumption of time and resources not previously planned. The municipality of Pinheirinho do Vale (Fig. 2) had no three-phase electricity supply for the installation of the micro distillery, a problem now solved with the *Luz para Todos* Federal Government Program. In addition to previous facts, problems in production organization, heavy rains, delays in crops, conflicts and improbity in the agreement with community leaders, resulted in: i) loss of a micro distillery (Redentora) and the need to deactivate another one (Vista Alegre), now being installed in another community; ii) absence of funds for keeping the original timetable in the Cristal do Sul and Taquaraçu do Sul units, due to retention of part of the resources agreed with PETROBRAS, because of delays. The recent change of the president of PETROBRAS resulted in one more obstacle to the consignment of the remaining resources, not received until December 2013. Finally, the technology for one of the units (Seberi) is only suitable for production of cachaça and sugar.

The sum-total of the above drawbacks means that the system has currently 04 micro distilleries (Caiçara, Iraí, Erval Seco and Pinheirinho do Vale) and the central unit, all completely installed. The off-line Vista Alegre unit will be reinstalled, according to the technicians, in the municipality of Ametista, 35 km from Frederico Westphalen town. Micro distilleries have different technologies. The best test results

[3] Resolution ANP no12, 21.3.2007 [128] regulates the functioning of the Supply Point's installation for cooperatives with hydrated ethanol production facilities, where only powered mobile equipment, ground vehicles and others, operating on behalf of co-ops can be supplied, with proof documentation available at installation. No form of marketing, loan or exchange is authorized, the product being intended solely for consumption by the holder of the premises.

were obtained by "Orsy Ribeiro", as will be seen below. This resulted in yet another modification to the original idea: the hydrated alcohol produced by the Orsy Ribeiro technique does not require the originally planned rectification to achieve the minimum alcoholic strength specified in the ANP Resolution no 7, 9.2.2011 [128].

## 3. Results and discussion

### 3.1. Technical analysis

COOPERBIO tested 04 alcohol production technologies in the units. The "Marcelo Guimarães" technology, initially tested in prototype and later in the final unit (Redentora), operates by a batch distillation column, steam-heated by small boilers. Simple, easy operation and similar to brandy production systems, this technology is widely known by farmers. To obtain an alcoholic graduation of about 90°, the distilled alcohol would be taken by tanker trucks to the rectifier unit to meet the ANP standard. The nominal capacity achieved is 400 L/d, lower than the original project. Besides Redentora, the technology was also installed in Vista Alegre, in 2007, replaced in 2008 because of problems. The biggest disadvantage of that technology is its very low efficiency (0.351) [117], therefore excluded from the options list.

The "Jack Eliseu Crispim" technology (Seberi, Vista Alegre), with better performance than the previous system [117], operates in a continuous process using three distillation columns: fermented wine heating, alcohol-water separation and condensation of the alcohol to 90°, also requiring rectification. The nominal capacity meets the 600 L/d and, as an advantage, the technology allows for the production of spirits and alcohol using the same hardware, favoring the profitability of the agro-industrial unit.

The "Orsy Ribeiro" technology, also of continuous process and reaching 600 L/d, operates with two distillation columns, a boiler and a cooling tower. Initially, this technology was tested in prototype by UFSM presenting unsatisfactory results [117]. This experiment served for subsequent optimization of technology (manufacturers and University), allowing its definitive installation in Caiçara, Iraí and Erval Seco. As today, there are no concrete data analysis by UFSM, regarding its current technological stage, due to the financial agreement expiration with COOPERBIO. However, according to COOPERBIO, this technology achieves the alcohol proof standardized by the ANP (95–96° GL). Besides, it shows reasonable energy efficiency index and mass balance, if compared to those obtained in the prototype. It was therefore adopted in three units. Direct information obtained from producers at Caiçara and Iraí, visited by the author in May 2012, confirmed the satisfactory results achieved. New tests on site must, however, be made to verify improvements or technological adjustments and to check the final quality of the alcohol produced against the ANP specifications.

The "Limana Poliserviços" technology installed in Frederico Westphalen, has a nominal capacity of 5000 L/d and operates a continuous process in two interconnected columns. It has equipment for sugar cane processing (mini-still) and for distillation of pre-ready alcohol (2500 L/d). That technology was also tested by UFSM, but under unfavorable conditions for a correct assessment [117]. However, a study on a 5000 L/d mini distillery (in Minas Gerais State, Brazil) done by Santos [121] revealed a positive energy balance (output/input = 5.01). From 2010 on, this unit was not operating, due to the scarcity of resources and the limited number of qualified personnel to work on it (mobilization of about 70 families in the sugar cane cultivation and ethanol production monitoring) and also due to other tasks. It is expected to be activated along 2014. Anyway, the alcohol rectification is to be waived; for a consistent assessment, the system, however, must be tested in its alcohol production future function.

It should be noted that, more than the technological efficiency, the critical factor in terms of earned revenue of industrial alcohol distilleries is agricultural productivity and raw material quality [21,81,117]. The main factors that affect the sugar cane quality and productivity are the variety and the growing conditions [117]. Another issue is the use of sugar cane beyond the recommended maturation period, and loss of sugars remained in the bagasse. These problems were encountered in the first analysis made by the UFSM, but easily solved as the processes reached maturity. According to EMATER/RS [129], there are no technical impediments to productivity growth in Rio Grande do Sul. In 2012/13 yield, an average of 60 metric ton of sugar cane per hectare ($t_c$/ha) [66] was achieved and up to 120 $t_c$/ha in assisted localities. The analysis done by Nogueira [120] of sugar cane varieties also confirms the great potential for its cultivation in RS. Productivity achieved at first COOPERBIO deployment was 60 $t_c$/ha, intercropped with beans, in Redentora, but values ranged over the past 5 years, depending on the climatic conditions. A reasonable average value for future sizes is 70 $t_c$/ha (value adopted in sub-item 3.2, below), according to COOPERBIO and EMATER/RS, which virtually coincides with the expected average productivity of 69.96 $t_c$/ha for the 2012/2013 yield, in Brazil [66]. Finally, special attention should be given to the transportation of raw materials to the micro and mini distilleries. Rather than transportable mills, it may be preferable to use the raw cane transport system to units, thus avoiding possible post-harvest losses of sucrose [21,130] and problems with mechanical adjustment of mill equipment [114]. In this way the bagasse from each property can return back to it using the same vehicle. The bagasse use in the individual property seems more advantageous than its use for energy production at the micro distilleries [116,123], if we consider the firewood production in the properties as contemplated in the project design.

### 3.2. Economic feasibility

Given the uncertainties as to the full operation of the system in the future, and the absence of concrete data regarding the central unit of 5000 L/d, it has been decided to analyze the economics of only one Micro Distillery with 600 L/d capacity using Orsy Ribeiro technology. Ideally, the configuration of a central mini distillery would be interesting because it would serve as a political and informational integration point for producers, an essential factor in productive inclusion of rural workers [10]. In a possible expansion of the system in the region, it may be advisable to implement individual units which could be expanded gradually from the results of the studies recommended previously. Additionally, the spontaneous interest of producers from other regions could reduce management problems COOPERBIO has been facing.

Payback (period of recovery of the initial investment) has been adopted as an economic feasibility tool for analysis of a 600 L/d unit. This gives easy visualization and interpretation, since no investment alternatives are involved, but only the economic prospect of the initiative, serving mainly the producers interested in diversifying their production adhering to the project. Table 1 presents production data of the micro distillery adopted in the analysis. Excel spreadsheets were used to demonstrate accounts for the initial investment, fixed and variable costs, cash flow forecasts (12 years), expenses and income generated from the production of sugar cane up to ethanol sale, among other items. All values considered were obtained, updated for 2012 or set in agreement with the COOPERBIO.

Of course, one cannot compare the ethanol price received by small producers with the price received by producers of São Paulo (R$ 1.06/L in July 2012) [82], at least not for a long period of micro distillery operation, remembering that the current performance of the ethanol industry of that State was achieved after 37 years, at the expense of large government subsidies. To ensure a reasonable profit margin for family producers and a price interesting to consumers, the applied sale price of ethanol (R$ 1.80/L) took into account the average selling price of ethanol in RS State in July 2012 (R$ 2.41/L) – the country's highest price [82]. Table 2 presents the costs and revenues involved in the analysis set down as fixed costs presented in simplified form. It assumes that producers would take the loan at PRONAF AGROINDÚSTRIA (National Family Agriculture Program), through the Cooperative, at the rate of 2% per annum and debt settlement in 10 years, according to requirements of governmental credit program. The rebate on the taxes and duties considered was 15% of the gross revenue. The calculations resulted in a unit cost of raw material equal to R$ 20.68/$t_c$ per hectare each year (5 year cycle of sugar cane), with an average cost of production of R$1,08/L of alcohol.

Under these conditions, therefore, each farmer would have an average annual income of about R$ 2790.00 – equal to 3.88 minimum salaries (Base: R$ 720,00), per sugar cane cultivated hectare. The Pay Back (Fig. 3) shows that the investment pays for itself in almost 5 years. This means that producers would spend the first sugar cane cycle paying off the loan, which may not seem very interesting. However, equipment costs, higher than in previous estimates, include the acquisition of small mechanized self-moving sugar cane harvester – giving a much more speedy harvest and less strain for the manpower involved. Another important inclusion was the equipment for the production of cachaça, sugar and molasses, aiming at a greater resilience of the producers' economic situation in the event of fluctuations in the price of alcohol (pegged to oil), *vis a vis* the sugar price in big productions, noting that the gains in the production of sugar and cachaça may be much higher than alcohol under the present technological and market conditions [114,121]. Furthermore, it should be pointed out that the farmer has other income, especially with food production (milk, corn and soybeans, in general), favored and boosted with the venture [53]. It is worth noting that farming families linked with MPA take part in national innovative programs, such as Food Acquisition Program (PAA) and School Alimentation Program (PNAE), both including 3000 producing families, 58 entities, 8000 beneficiated families and 22,000 children [131]. Subsequent studies should consider the potential gains, with the alcohol and food production integration, specially dairy production [75,123], not addressed in this work. The agricultural productivity expected increase in the future, due to the technological learning (as it ocurred in large scale ethanol production), should also be taken into account in future studies on income improve of smallholders.

**Table 1 – Production data – micro distillery of hydrous ethanol.**

| Raw material | Sugar cane |
|---|---|
| Technology | Orsy Ribeiro |
| Daily capacity (L/d) | 600 |
| Operating days (per year) | 180 |
| No of shifts (12 h per shift) (PCs.) | 2 |
| Industrial yield (L/$t_c$)[a] | 60 |
| Agricultural income ($t_c$/ha)[a] | 70 |
| Volume of ethanol produced per year (L) | 108,000 |
| Qty. required cane per year ($t_c$)[a] | 1800 |
| Production area (ha) | ~26 |
| No of farmers (unit) | 13 |

[a] $t_c$ – metric ton of cane.
Source: Adapted from COOPERBIO [131]

**Table 2 – Costs and revenues – micro distillery hydrous ethanol.**

| | | |
|---|---|---|
| *Costs* | | |
| 1 Initial investment ($) | | |
| -Civil construction | 60,000.00 | |
| -Equipment | 155,115.00 | |
| -Machinery | 39,000.00 | |
| -Documents and other | 34,000.00 | |
| Total | 288,115.00[a] | |
| 2 Depreciation (R$/year) | 6379.00 | |
| 3 Fixed costs (R$/year.ha) | 1st year | Average 11 later years |
| | 18,483.00 | 8482.50 |
| 4 Variable costs (R$/year.ha) | 15,811.00 | |
| 5 Raw material (R$/year.ha) | 37,231.92 | |
| *Revenues* | | |
| Sale of ethanol ($/Ano) | 194,400.00 | |
| Average profit (incl. taxes, per year) | 33,168.00 | |

[a] Financial flows in 12 years at a discount rate of 8% p.a.
Source: adapted from COOPERBIO [131].

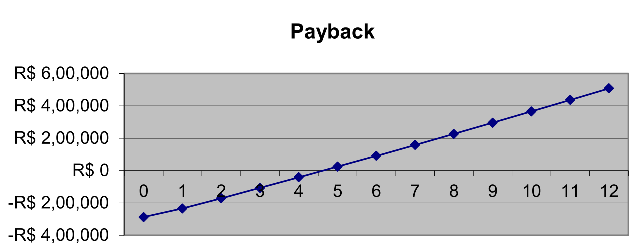


**Fig. 3 – Pay back – micro distillery for hydrated ethanol 600 L/d.**

At last, it is worth noting that, although this analysis confirms the investment return under the present conditions of governmental microcredit, the economic competitivity of this model is limited if compared with scale economies of large production. However the idea is the ethanol production for local market, with its eventual expansion in RS State and not for export. In this case, social and environmental benefits with its adoption should also be considered [27].

### 3.3. *Environmental analysis*

In principle, the vast majority of environmental impacts observed in large-scale production of ethanol are avoided in small-scale units, providing they are planned out according to a study of the soil and climate characteristics. The problem of the change in land use and its impact on biodiversity (see Refs. [1,49,109]) will be avoided with the allocation of about 2 ha for the production of sugar cane at the family properties. The local impact on air quality is minimized both by increase in the use of ethanol for transportation in municipalities (which also reduces emissions of $CO_2$ to replace fossil fuels), and prohibition of pre-harvest burning, as set down in RS State Forest Code legislation [132]. It should be noted that, in global terms, reduction of $CO_2$ would also be helped along by the reduction in the use of long-distance transport [76], prevalent due to the importation of alcohol by Rio Grande do Sul from other regions of the country. Another key factor in the large-scale ethanol industry is the intensive use of water in production processes [21,124], also avoided in this case of small-scale agro-industries. The possible contamination of waters by fertilizer, particularly nitrogen-based, pesticides and herbicides (the latter used a lot in the extensive production of cane and soybean[4]), as well as erosion and loss of the carbon content of soil, are also problems avoidable by agro-ecological practices (multiple cropping and crop rotations [16,123,124], nitrogen fixation by plants [25], organic fertilizers, vinasse as bio-fertilizer, vegetation cover, fodder for livestock and other [75,116] spread by COOPERBIO, which has also the potential to reduce GHG emissions [16,53,133]. Intercropping, besides favoring food security and avoiding deforestation [31], also reduces the principal risks involved in the activity: influence of climate on peasant crops and fluctuation of resale prices [27,109]. Soil compaction is avoided by the use of light machinery in properties. The COOPERBIO also works with agroforestry systems in communities that combine trees, livestock and agricultural plantations and provide firewood for boilers [125], also contributing for GHG mitigation [16,49,124]. In conclusion, it can be affirmed that the ethanol production from small farming has the advantage of preserving ecosystem services [123] essential to maintaining production and well-being of families [44], unlike simplistic biological monocultures, which make the crops dependent on chemical controls and may unbalance ecosystems [92]. With respect to the use of transgenic crops, a source of controversies (food contamination and impact on biodiversity), investigation will be needed on the sugar cane situation in RS, since transgenic soybeans are widely used in the State [134]. Another risk is the eventual promotion of new medium scale projects in other regions, without watershed planning considerations including biodiversity protection. Finally, one must consider the risks of accidents (in micro distilleries and on access routes), since ethanol is highly flammable, requiring special training for farmers involved in those operations [135].

[4] It should be noted that, due to the expansion of agribusiness, Brazil has become the world's largest agrochemical market, with 84% of the total sales in Latin America [92].

### 3.4. *Social analysis*

At the current stage of the enterprise, 70 families are directly involved. When the COOPERBIO system initial target is reached, there will be 150 families. In addition to the limitations imposed by the difficulties already addressed, it is believed that the technical team's biggest challenge, as development agents, has been deploying and optimizing new technologies *on site*, rather than in the planning office. This may well have provoked some insecurity among rural communities, known to be resistant to change and used to pragmatic choices. In parallel, decentralization of production and consumption of energy and food, in accordance with local realities, tends to decentralize jobs and strengthen local economies, expanding the benefits to a greater number of people [27,120,123,134]. Access to improved quality food and at lower prices favors local and regional food security and, consequently, population health. Another important gain is the prospect of gradual replacement of tobacco cultivation by that of food and energy crops [114,120]. Tobacco cultivation is traditional in Rio Grande do Sul. It is labor intensive, consumes fertilizers and agrochemicals and is governed by partnerships between small producers and large tobacco companies. The situation puts rural families at a disadvantage and in a position of risk due to the danger of proximity to agrochemicals. Despite bringing financial benefits to proprietors, tobacco growing does not create beneficial synergies – unlike sugar cane [116]. Recent field research conducted by Silva [114] confirms the interest of region smallholders to adhere to COOPERBIO system in order to quit the tobacco production. The increase in technological knowhow [102] and the increase in autonomy for farmers [123], in the joint role of economic partners in the micro distilleries management, is a measurable benefit particularly in qualitative terms. The need for community organization for perfecting operational aspects of micro distilleries, thereby encouraging cooperatives, facilitates: i) collective access to lines of credit; ii) purchase of inputs; iii) processing and marketing of products; iv) access to technical assistance; v) extension of rural activities; and vi) improved articulation of producers in formulating public policies geared to the needs of the segment. It should be noted that these sector structural problems (agricultural, market and management bottlenecks) [52] also prevent the expansion of family smallholders inclusion in PNPB [3,97]. Following up of this concrete initiative would help in knowledge advance of social impacts of small scale biofuels production [14,17,19,102]. The consolidation of the COOPERBIO experiment will be able to widen the horizon of young people [14], giving them practical perspectives for improvement in the quality of life, both subjectively and objectively. It should be noted that, unlike technology advances, one cannot speed up processes of social involvement, due to risk of not being enduring. It should be noted, finally, that, however promising and appropriate an initiative may be, economically and environmentally speaking, it is believed that the ones who determine the internalization, rooting and flourishing rhythms are the farmers themselves.

### 3.5. *System expansion in Rio Grande do Sul*

#### 3.5.1. *Ethanol production and prospects*

Rio Grande do Sul (RS), the country's largest producer of biodiesel [100], has an insignificant production of 7.5 $dam^3$ of ethanol [65], representing 2% of the internal demand, most of it produced by Coopercana (Porto Xavier/RS), a cooperative formed by farming families [129]. Hydrated ethanol fuel, imported largely from São Paulo, reaches high prices at consumer level. There is, however, a very appropriate framework for the promotion of ethanol market in the State. In 2007, the State legislature created the Subcommittee on Sugarcane and Ethanol [136], to analyze the technical and economic feasibility of deployment of sugar cane culture, advocating a production system centered on small and medium-sized properties, respecting the agronomical characteristics of the State, where 84% of agricultural establishments are family smallholding type [88]. In 2008, EMBRAPA studies [137], reinforced by IPEA [138], concerning the agricultural changes in the country until 2020 for climate change, pointed to an increase in the cultivable area of sugar cane and manioc in the country (but a reduction of soy), favoring in particular RS State. In 2009, "Risk Climate Zoning" for sugar cane was established for the first time, identifying 182 municipalities in RS apt to produce large-scale sugar cane and more 34 localities that could produce cachaça and other derivatives [73]. Therefore, everything indicates that there is a political and institutional environment of great promise for the ethanol-sugar industry in the State, in different model from the hegemonic one in Brazil.

#### 3.5.2. *Panorama of micro distilleries expansion*

According to agricultural census of 2006, the total agricultural area in RS State is about 20,199 thousand ha [88]. On the other hand, the available areas for sugar cane production, indicated by ZAE cane [73] total 1287 thousand ha, considering only those classified as high and medium ability to conservative ends, which corresponds to 6.37% of the total agricultural area in the State. But how many were family farms establishments within that area? According to the agricultural census of 2006 [88], 378,546 rural establishments belong to family farmers, occupying around 6172 thousand ha. For estimation purposes, and based on experience and guidance of EMATER/RS [129], it was assumed that these establishments have an average area of 12 ha and the same percentage of 6.37% has been applied for the family-owned area within the area conducive to the production of sugar cane and associated crops, thus, coming up to the approximate number of 32,700 family establishments in this area. Considering that each property can devote 2 ha of land for sugar cane, with average productivity of 70 $t_c$/ha and industrial alcohol yield of 60 L/$t_c$, one arrives at a production of 274.6 $dam^3$ of alcohol. In 2011, the hydrated ethanol fuel consumption of the state was 137 $dam^3$ [82] and, therefore, would be covered by the eventual expansion of the micro distilleries envisaged. Of course, with lower prices, obtained with State production, consumption would increase and the break-even point would be something else. It would also be important to estimate the amount of food production that expansion would favor. Other interactions of trends and uncertainties must also be taken into account in future scenarios, such as: increasing the productivity of sugar cane; prices of ethanol as commodity; increased utilization of electrically-driven cars; price fluctuations of sugar, alcohol and gasoline; 2nd generation ethanol production subsidies – among others.

## 4. Conclusions

In spite of all limitations of ethanol large scale production in Brazil, one can say that the benefits of its use in substitution of fossil fuels, as well by the sugar cane bagasse use (for electric energy and 2nd generation ethanol production) would justify the Brazilian Government support to the sugar and ethanol sector, conditioned to the permanent search of sustainability increase of its production (and distribution) chain, in the regions where the sugar cane industry is already consolidated.

On the other hand, considering the specific situation of RS State, which presents a great deficit of its ethanol internal offer, this research approached the possibility of integration of food and hydrated ethanol production by smallholders as an opportunity for the rural sustainable development in the state. The many and diverse aspects of the COOPERBIO initiative seem to be promising and justify close and continuous monitoring plus the possibility of financial subsidies in order to achieve expansion targets. Experiment is aligned to social questions opened up in the biofuels debate and in FAO's IFES prospective. With appropriate technological adjustments plus training and qualification of farmers, the experiment opens the door to development of a pioneer model for the decentralized production of hydrated ethanol fuel and food in RS, favored by its cultural and agronomic heritage (high incidence of organized smallholders). In spite of technological and economic limitations of small scale production, *vis-a-vis* agrobusiness, social and environmental benefits resulting from its adoption are also structural compounds of a sustainable and climate-smart rural development. It is to be noted that this perspective would be only possible with long term planning (local and regional) and public policies, restricted to smallholding farmers organized in cooperatives (e.g., permanent services of rural extension, special credit conditions, fiscal incentives, minimum price guarantee, ethanol distribution). It is suggested that, in case of governmental support, it should be conditioned to food and sugar cane integrated cultivation (reserving up to 2 ha of the properties for this type of production), respect of present environmental legislation (water use, biodiversity protection) and adoption of agroecological techniques to guarantee environmental services preservation.

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