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PRODUCTION, TECHNOLOGY AND ADAPTATION TO CLIMATE CHANGES: THE CHALLENGES TO THE SUGARCANE SECTOR IN BRAZIL

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ABSTRACT: Due to the economic, environmental and energy importance of the sugarcane to the Brazil, is justified the analysis of its conditions to resist to the climatic variability and to expand the supply of raw material to the production of the products derivatives from the sugarcane. In this way, this paper analyzes the conditions of sugarcane production in Brazil, identifies some vulnerabilities to the global climate changes and the possibilities of adaptation. In this view, the sustainability of sugarcane production has relation to the cultivation of suitable varieties, thus the methodology involved interviews and visits to sugarcane breeding institutions, as well as secondary data from publications, technical events and literature review. The results indicate low yield of the sugarcane production and technological lag of planted and cultivated varieties, a lack of knowledge about climatic scenarios and scarce actions that internalize the sector adaptation. In the last decade, the sector faced difficulties that pointed out the need to change the technological pattern in the sugarcane production and the global climate change reinforced this need. The overcoming of the sectoral challenges will depend on the direct articulation between science and development and changes in management practices, innovation in the regulatory framework, public policies to increase investments and diffusion of technologies. Capacity for adaptation will be directly influenced by farmers, who will implement the main guidelines, and by political and institutional mechanisms that encourage adoption, finance investments, provide training and disseminate new technologies. Increasing sector productivity and adapting to climate effects and risks will only be possible through changes in the production pattern, linking the intensive use of technology and innovation to the natural advantages for sugarcane cultivation that the country has.

KEYWORDS: ethanol, sustainability, innovation, yield, genetic breeding.

PRODUÇÃO, TECNOLOGIA E ADAPTAÇÃO ÀS MUDANÇAS CLIMÁTICAS: OS DESAFIOS DO SETOR SUCROENERGÉTICO NO BRASIL

RESUMO: Dada a importância econômica, ambiental e energética da cana-de-açúcar para o Brasil, justifica-se a análise de suas condições para resistir à variabilidade climática e ampliar a oferta de matéria-prima para a produção dos produtos derivados da cana-de-açúcar. Desta forma, este trabalho analisa as condições da produção de cana-de-açúcar no Brasil, identificando algumas vulnerabilidades às mudanças climáticas globais e as possibilidades de adaptação. Nesse intuito, considera-se que a sustentabilidade da produção de cana-de-açúcar possui relação com o cultivo das variedades adequadas, assim a metodologia envolveu entrevistas e visitas a instituições de melhoramento de cana-de-açúcar, além de dados secundários de publicações, eventos técnicos e revisão de literatura. Os resultados indicam baixo rendimento da produção de cana e atraso tecnológico das variedades plantadas e cultivadas, falta de conhecimento sobre cenários climáticos e ações escassas que internalizam a adaptação do setor. Na última década, o setor enfrentou dificuldades que apontavam para a necessidade de mudar o padrão tecnológico na produção de cana-de-açúcar e a mudança climática global reforçou essa necessidade. A superação dos desafios setoriais dependerá da articulação direta entre ciência e desenvolvimento e mudanças nas práticas de gestão, inovação no marco regulatório, políticas públicas para ampliação dos investimentos e difusão de tecnologias. A capacidade de adaptação será diretamente influenciada pelos agricultores, que implementarão as principais diretrizes, e pelos mecanismos políticos e institucionais que estimulam a adoção, financiam investimentos, proporcionam treinamento e disseminam as novas tecnologias. Aumentar a produtividade setorial e adaptar-se aos efeitos e riscos climáticos só será possível através de mudanças no padrão de produção, unindo o uso intensivo de tecnologia e inovação às vantagens naturais para o cultivo de cana-de-açúcar que o país possui.

PALAVRAS-CHAVE: etanol, sustentabilidade, inovação, rendimento, melhoramento genético.

1 INTRODUCTION

The technological capacitation that Brazil has in the sugarcane production had been built during decades mainly of the 70s onwards. The 1970s stands out due to the implementation of the National Alcohol Program (PROALCOOL) that allowed the structuration of the sugarcane innovation system in Brazil (FURTADO; SCANDIFIO; CORTEZ, 2011). The constants growths of the sugarcane production extended by the 1980s and

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1990s (figure 1). The sector deregulation, in means of 1990, and the adaptation to the free market without incentives, subsidies and the State coordination (MEURER; SHIKIDA, 2014), generated reflexes about the sugarcane production that growth slowed in this decade.

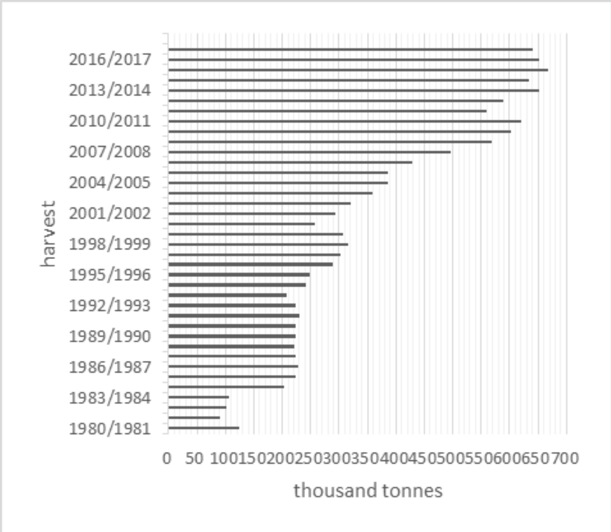

Figure 1 - *Sugarcane production in Brazil*
Source: Prepared by the authors, Unicadata (2018).

From the 2002/03 harvest, there was an increase in ethanol demand due to the beginning of the flex fuel automobile technology in the Brazilian market and the sugarcane production expanded in an accelerated way. Besides that, the sector received impulses of politics instruments and energetic planning actions, the perspective of the ethanol to become a commodity, the economic viability of electrical energy coming from the bagasse burnt and from the sugarcane straw, the strong appeal of environmental and health benefits provided by the ethanol consumption, the good moment of Brazilian economy and the crescent and valorized sugar market (SANTOS et al, 2016). However, between 2007 and 2012, the nominal costs of sugarcane production increased approximately 70%, decreased profit margins and contribute to elevating the indebtedness of the sugarcane sector (UNICA, 2014). With the increase of financial indebtedness of the producers, there were the closing of mills, fusions and acquisitions that increased the sectoral concentration, the investments have been reduced and affected the renewal of sugarcane plantations, the cultural traits and the fertilizing, which are necessary operations to elevate the productivity level (SANTOS et al, 2016). Besides that, the gasoline prices damming by Petrobras, between 2011 and 2014, and the cambial over valorization, from 3.95 BRL/US in 2002 to 1.55 BRL/US in 2011, prejudiced the sugar and ethanol competitively (OLIVA, 2017). The Agro-environmental Protocol of the Sugarcane Sector anticipated to 2014 the deadline for the end of burning sugarcane harvest, which affected the crop yield because the mechanized harvest berried more impurities with the sugarcane and increased the loss in the industrial production. The inadequate of planted varieties to the mechanization harvest also contributed to these losses in the yield. Complementarily, intense climatic variations, with media elevated temperatures and levels of precipitation below the needs, affected the main producers regions (MARTINS; OLIVETTE, 2015).

All these factors leading to the yield decrease in tons per hectares, and in the industrial processing, in concentration of the recoverable total sugar (RTS). The average RTS increased moderately until 2009, followed by the significant fall from 2010. From the 2006/2007 harvest, which overcame 149 kg of RTS/tons in average, consecutive falls marked the followed harvests. The RTS concentration in sugarcane is sensible to the climatic variations, and these reached the Brazilian production in an intense way from 2010.

Braunbeck and Magalhães (2010) affirmed that the increase in the ethanol production, in a way to enable the integral use of sugarcane, should go through the agricultural and industrial process. The production model needs to be reformulated in order to increase the yield in a sustainable way, from economic, social and environmental points of view, and would be necessary to define management strategies to a better resources use. The agricultural production technology would be improved focusing on yield, in reducing the demanded area and in reduction of environmental impacts, besides that, the sugarcane sector would need to recover its investment capacity and were necessary policies that would offer conditions to overcome the sectoral difficulties, guaranteeing the sustainable offer of the raw material to the sugarcane industry. Correa and Belik (2013) reinforced this argument and highlighted that the big growth of sugarcane production in Brazil has been sustained by the expansion of the cultivated area. The contribution of the area to the sugarcane expansion in Brazil, between 1990 and 2009, was 66% and the yield contribution was 34%, greater in the center-west region, where the area contribution was approximately 77% and the yield 23%.

Currently, the sugarcane sector is part of a new perspective of production growth, due to the Brazilian targets dealt in the Paris Agreement (COP-21), which are increase to 18% the biofuels participation in the national energetic matrix and reduce the emissions of carbon dioxide in 37% below the 2005 level until 2025 and in 43% until 2030. The possibilities to enlargement of sugarcane usage in the biofuels production are wide, with a special attention to the biodiesel production. According to Goldemberg (2017), between all the dealt measures, it is practical and realistic to duplicate the ethanol production of the current 30 billion of litters per year, approximately, to 60 billion of litters per year. The generation of clean electrical energy will also have to reach the target of 33% of participation in 2030; the full usage of sugarcane for the energy production involves the sugarcane bagasse, the sugarcane straw and the biogas of the vinasse. In 2016, were generated 21.2TWh of energy in the sugarcane sector, this renewable offer avoided the emission of 9.3 millions of carbon dioxide tons (UNICA, 2017).

In this way, this paper analyzes the conditions of sugarcane production in Brazil, identifies some of its vulnerabilities to the global climate changes and the possibilities of its adaptation. Considering the current situation, the sustainable increase of the sugarcane production in Brazil, to meet the ethanol crescent demand and other sugarcane derivatives, will need to overcome the barriers of low yield in the field and in the industry.

2 MATERIAL AND METHODS

This research is the result of the project "Research and Development in Alcohol Production and the Global Climate Changes", developed between November 2012 and December 2014. The methodology involved the collection of primary data, visiting institutions that conduct sugarcane-breeding programs in Brazil, application of questionnaires and interviews with researchers. Secondary data were collected from technical publications, cooperative reports and producers associations and consulting, sectorial information based on data from the Ministry of Agriculture, Supply and Livestock and the Brazilian Institute of Geography and Statistics, complementarily, the sectorial literature review aggregated information that corroborates to the proposal argumentation.

The research considers that the sustainability of the sugarcane production is directly related to the cultivation of adequate varieties of the sectorial conditions. The three main programs of sugarcane breeding in Brazil provided the main information to the study: an Inter-University Network for the Development of the Sugar-Energy Sector (RIDESA), created in 1991, is composed by ten federal universities that are distributed in the national territory. RIDESA varieties have been leading the planting and cultivation of sugarcane for many years; the Sugarcane Center, linked to the Agronomic Institute of Campinas (IAC), is the oldest and most traditional breeding program of Brazilian sugarcane. The Sugarcane Technology Center (CTC), originated from a producer's cooperative, suffered an important restructuration of its activities in 2000 years, and became the second largest program of Brazilian sugarcane breeding. Nowadays, its varieties occupy a little more than a third of planted and cultivated area in Brazil and develop technologies to produce ethanol of the second generation. The respondents for the research were: the IAC coordinators of sugarcane genetic improvement, the commercial manager of varieties and the biotechnology manager both from CTC, RIDESA general coordinator and seven local coordinators of the federal universities that make up RIDESA. They answered qualitative and quantitative questions about the research and innovation activities carried out by each program.

3 ADAPTATION, INNOVATION AND POLITICS: THEORICAL APPROACH

The adaptation to climate change should be based on climate scenarios presented to the society by the specialist's community (IPCC, 2014). The adaptation involves adjustments in order to improve the viability of economic and social activities and reduce their vulnerability related to the climate change, including their current variability and extreme events, and the long-term climate changes. The intensity that the natural systems, the food offer, and the sustainable development will be affected would depend, in parts, on the magnitude, speed, and the climate change nature, moreover, it will be affected by the capacity of adaptation of the systems (SMIT, et al 2000).

The comprehension of the adaptation process involves the vulnerability analysis, defined as the level of susceptibility in a system or the inability to deal with the adverse effects of climate change. The sensibility, which represents the level that the systems is affected, negatively or positively, by the stimuli related to the clime, which involves characteristics such as climate variability, frequency and magnitude of the extremes; and the adaptation capacity, which depends of factors such as wealth, technology, education, information, abilities and access to scarce resources, due to the fact that represents the capacity of a system to be adjusted to the climate changes, decrease potential damages, take advantage of opportunities or face their consequences (IPCC, 2007).

The strategic elements for adaptation would be: to adapt the action for regions specific climate conditions on sectorial, political, social and economic contexts; ensuring the dialogue between the interested ones through cooperative structures and knowledge transference; monitoring the progress to support regular reviews and the inclusion of new scientific information when available. These elements would help to orientate the process of decision making in a systematically way, following a proactive, with precaution and inter-sectorial character approach.

Over time, technological innovations appeared to accommodate the farmers to the spatial variations of climate attributes such as humidity, heat, and sunlight. Technologies as the ones related to irrigation have been facilitating the intensive agriculture and activities that the local climate conditions previously did not allow, technologies focused on no-tillage, associating planting and harvesting technologies and the development of integrated systems of drainage, had capacitated the farmer to deal with the humidity excess in the periods of growing and harvest crop. The technologies from biological sciences have been modify the climatic demands of cultivated plants and promoted the adaptation of the cultivate systems to climatic regions and adequate condition to the period of growth. The innovations in the plants breeding technologies, extending the spatial reach of crops and altering their total climatic exigencies. Another challenge is the development of adapted species that should be tolerant to inter annual variations, once these deviations of normal conditions should define the climate change experience. In addition, innovations in integrated approach of numeric modeling have been used to quantify the climatic changes impacts in the agricultural activities and specifics regions, allowing analyze the sensibility to the impacts of selected adaptive technological innovations, known or anticipated, in different adaptation scenarios (SMITHERS; BLAY-PALMER, 2001).

The process of innovation, as the agriculture itself, is subject to many influences, both intern and extern, and are inserted in legal, institutional and economic circumstances that mediate the research priorities and restrict ways of action. It is essential to comprehend not only the available technological possibilities to climate changes adaptation in agriculture, but also the cultural, economic and institutional circumstances, which broadly determines the farmer's access to innovations. The adaptation reality is on-the-ground, through the rural extension and the adoption of specifics strategies by the farmer. Besides of the challenge to develop effective strategies to the adaptation, there is the challenge of technology transference, which is a critical element of the adaptation planning. It is incorporated as reference to the decision making in the agricultural propriety level, as the adoption process of an innovation, the role of the farmer knowledge to adapt technologies to the local conditions, and the need of own knowledge feedback as input to the planning and higher innovation from the farmers. (SMITHERS; BLAY-PALMER, 2001).

Thus, the technology and innovation are fundamentals elements in the process of agriculture adaptation to the climate changes. Integrate the agents of agricultural innovation system and amplify the incentives to the development and adoption of technologies must be among the mains objectives of the adaptation policies in agricultural sectors, mostly in the sugarcane agriculture in Brazil, as we will discuss following.

4 RESULTS AND DISCUSSION

4.1 THE TECHNOLOGICAL CONDITIONS OF SUGARCANE PRODUCTION

The sustainability of sugarcane production passes through the cultivation of suitable varieties to the sectorial conditions. The variety is the most important and the less cost technology for the farmer and it is the basis that maintains the other sector production technologies. The success in the production of energy, alcohol, sugar and other byproducts necessarily pass through the quality production of the feedstock (BARBOSA; SILVEIRA, 2011). The analytic scenario of cultivated and planted varieties show several obstacles to resumption the increase of sugarcane productivity, in both field and industry.

a. The high concentration of production linked with a few numbers of varieties. In 2012, Brazil had more than 40% of the cultivated area with sugarcane was concentrated in three varieties: RB867515, SP813250 and RB92579 (RIDESA, 2012). The Varietal Census from the harvest 2016/2017 (RIDESA, 2017) shows that RB867515 and RB92579 varieties continue among the three more planted and harvested varieties. The Varietal Concentration Index (VCI) (CTC, 2015) during the harvest 2013/2014 was higher than 50% in a majority of sugarcane producers States, only São Paulo and Minas Gerais were in the interval between 40 and 50%. The variety concentration contributes to keeping the average yield of the production stable.

b. Varieties planted in Brazil are aged and technologically obsolete. Among the ten most planted varieties in 2012, there are varieties that were improved twenty, thirty and forty years ago. In the census of the harvest 2016/2017 (RIDESA, 2017), the time lag of the varieties remained. These varieties were improved considering the sectorial needs differently than the current needs. The lack of renewal regarding these varieties contributes to the low production yield. The Varietal Update Index (VUI) (CTC, 2015), which is used to measure the adoption speed, by a farmer, of the commercially released varieties, represents the average age of the varietal population and means that the higher the average age, older varieties are used. The great part of the sugarcane producer's States showed the VUI higher than seven years during the harvest 2013/2014, São Paulo and Mato Grosso States were between five and seven years, and just Alagoas State showed a satisfactory level, which was less than five years (CTC, 2015). It means that the farmers do not learn about the new technologies and varieties available in the market.

c. Sugarcane varieties cultivated in traditional regions of São Paulo State, with productive soil and suitable clime were planted in States of Mid-West, with less productive soil and with a dry and hot weather, thus the same varieties were planted in significantly different soil and weather conditions. According to the sugarcane specialist, during the higher period of sugarcane production, between 2004/05, there was a lack of seedlings and the growers had to replicate in large-scale varieties that they used to cultivate in their farms, however, in two years, this situation was back to normal and the farmers kept the same behavior. The need to minimize the production costs linked with the fear of the risk to change the varieties, lead producers not to perform the expansion and renewal of the sugarcane plantation with new varieties, which affected agriculture fields and increased the average age of the Brazilian plantation. The increase of the average cutting stage of the culture came out to a decrease of yield in the

Mid-West region, mainly during 2011 and 2012 (CTC, 2015).

d. The sugarcane sector shows management conditions of the fields very heterogenic, with farmers that do not spend with cultural treats and farmers that have high technology and use precision farming equipment and advanced crop management software. The sugarcane sector presents important technical differences between North-Northeast and Mid-South regions, on the other hand, inside these regions also exists differences regarding yield and production scale, showing a high productive heterogeneity, with distinct levels of use of by-products and competitiveness. It is possible to find fields where the sugarcane cultivated is in the 8th or 9th cutting stage, which means that they are higher than the five cutting recommendation. According to specialists, these fields become more susceptible to weather variation, insects and disease, because the sanity conditions become low and increase the crop budding failures, which consequently decrease the sugarcane yield on the field. A regression of this process was attempt with the Program of Support to Renewal and Implementation of new sugarcane plantations (PRORENOVA), settled by federal government by the Brazilian Development Bank (BNDES). Launched in 2012, stimulate farmers for the renewal of sugarcane plantations by offering special financing to the sector. The canebrake renewal has a positive impact related to the yield, bringing more vigor to the cultivated fields, furthermore, represents an opportunity to change the older varieties by the modern ones, which have genetic advantages from breeding programs (CTC, 2015). The increase of the renewal sugarcane fields should reflect in an increase of yield for the next harvest, however, the harvested area decreased in the years following ProRenova, possibly indicating the farmers didn´t perform the substitution of the varieties. It should be noted PRORENOVA discriminates as eligible items for investment projects directed to the planting of protected varieties or potential clones of sugarcane, but does not condition the release of resources to the use of new cultivars, and therefore it did not represent a technology diffusion policy.

The breeding programs, the consulting companies of sugarcane sector and some producers association have been alerting the farmers regarding the need of production deconcentrating and for an adequate management of the sugarcane production in all regions however any increment in the production cost configures a great barrier to these changes. There are some exceptions like big entrepreneur groups that have been doing the gradual and planned substitution of varieties, including the collaboration in experiments of the breeding programs. Landell and Bressiani (2010) define the varietal management in sugarcane as a strategy to explore the gains generated by the genotype and environment interaction, which means, to allocate different commercial cultivars in an environment that provides the better production expression. Some studies indicate that the production biological potential of sugarcane is approximately 350 ton/ha, while the yield average in São Paulo State, the more productive, were maintained in 75 ton/ha, approximately 22% of the crop biological potential.

Oliveira and Gianoni (2015) also verified technological bottlenecks in agricultural bond coincident with the ones found in this research. The need of varieties development focused on physical yield increment and adapted to non-traditional regions of production; the lack of seedlings with good quality and sanity to supply the commercial crops; the need of machines, implements and chemical inputs adequate to the mechanization; and the need of enlarge the development and the use of transgenic varieties. The overcoming challenges of agricultural bond in the sugarcane sector depend on the strict relation among research, development, the changes in the practices of management and organization work, as well as innovations in the regulatory framework and public policies to stimulate gains in productivity, quality and sustainability and to reduce the indebtedness of companies in the sector. Besides that, mechanisms to amplify the innovation diffusion are fundamental, minimizing the inter-sectoral heterogeneity and enabling the technological pattern change in the sugarcane production in Brazil, consequently, reducing its vulnerability in climate and biological events and in the probability of financial, social and environmental debts, considering the prospective scenarios about the climate variability (IPCC, 2014).

4.2 CONDITIONS FOR ADAPTATION OF SUGARCANE PRODUCTION TO CLIMATE CHANGE

Instability in the sugarcane supply, both in quantity as in quality, would affect the national production of ethanol, sugar, energy and others derivatives, consequently, it would affect the economy, with intense regionals effects, and would threat achieve the assumed targets by the Brazil in the COP-21. Considering those, some factors identified can support and other can difficult the sugarcane adaptation to the global climate changes.

4.2.1 Favorable factors to the adaptation

a. The crop expansion to more dry, hotter and with less fertile soils regions instigated the sugarcane breeding programs (RIDESA, CTC and IAC) to start researches to develop adequate varieties to those conditions, having a great responsibility with the sector to cease the lack of cultivars to these regions. The sugarcane expansion also has promoted the learning and capacitated the producers in the field management under restricts hydrological conditions and high temperatures;

b. The weather differences between South-Southeast and Mid-West intensified the process of regionalization in the sugarcane breeding. The breeding programs are adjusting precisely the selection of varieties to specific conditions at each location where it will be planted, since the breeding first stage (seedling separation). This fact represents an important breakthrough because should weaken the concept of eclectic variety, which could be planted all over the country and gain a satisfactory yield per hectare;

c. In the Mid-West, the irrigation had been intensifying during the development stage of the crop (rescue irrigation) and the farmers are learning how to use it, including its adequacy to the mechanized harvest. The expertise generated by the use of irrigation will help its expansion when the climatic events will intensify. The farmers located on the Southeast traditional regions are also accepting the need to use the irrigation and they are making analysis of economic and environmental viability for this, because several fields have been affected by extended drought in last harvests. Precision farming equipment has also been increasingly used by farmers with greater investment capacity;

d. There is consensus among the breeding programs about the need of intensifying basic research in areas such as biotechnology regarding the search to a new level of sugarcane productivity, mainly for the development of transgenic varieties. In 2017, the CTC received the approval of the first transgenic variety of sugarcane, which is resistant to one of the main pests that affect the crop (NovaCana, 2017). FAPESP has financed researches in this field by the Bioenergy Program (BIOEN), which is offering scientific subsides for the progress of the sugarcane breeding programs, and also the FAPESP Global Climate Changes Program is supporting the elaboration of specific climate scenarios for Brazil, providing useful information for the adequacy of sugarcane varieties to specific regions;

e. The development of the technology for second generation ethanol production lead the breeding programs (RIDESA, IAC and CTC) to intensify researches with sugarcane varieties with a higher biomass content, which are called as ‘sugarcane energy’. These cultivars, besides a higher content of fibers, also are more suitable to restrictive environments; they are more resistant to water stress and the temperature increase. They should represent important options in restrict environments where the crop area is increasing and, according to the projections, where the climate change will be more intense. Hence, besides these cultivars have a higher yield potential on the field and in the industry, they will also help the sugarcane industry adaptation to the global climate changes.

4.2.2 Factors that opposite the adaptation

a. RIDESA, IAC and CTC did not know about the prospective scenarios of the climate change, reinforcing the deficit of information and consequently have not researches for varieties breeding or to the development of management techniques directed to climate change. The unfamiliarity of the prospective scenarios also extends to the farmers, which are focused on the current climatic forecasts, and respond as a reactive way to the climate change, because there are not sufficient time to preventive actions;

b. The high level of the production concentration in some sugarcane varieties increase the sugarcane fields susceptibility of the climate events, pests and diseases, affect the crop yield and consequently increase the economic and social impacts of these events;

c. Regarding the group of sugarcane cultivars that are available commercially, a small amount of them is recommended to locals where the weather and soil conditions are restricted. However, these locals represent the main areas of current expansion of the crop and where the climate change will be more intense. The sectorial pressure for the increase of this number is huge, due to the fact that the process for variety selection is slow and could take until 15 years to release a new variety to commercialization;

d. The financial resources for the experiments and the researches of sugarcane breeding programs, mainly RIDESA and IAC, come from the private companies associated or collaborating of the programs. This fact puts pressure on these institutions to invest in research that primarily addresses the needs of these funders, usually related to the current problems of crop management, specific solutions to improve crop yield;

e. According to the scientists and experts interviewed, the conventional breeding is at a level where the new varieties present few improvements of yield in metric tons per hectare and in RTS (recoverable total sugar). The genetic complexity of the crop has been postponed the advance of biotechnology, which could provide a significant leap in crop breeding, for example, by selecting traits of interest in the DNA varieties ;

f. The main aspect regarding technological development, the slow diffusion of new commercial varieties, reflected by the varietal update index, decrease the return regarding the investment done in research and development of the new technologies, furthermore, the institutions presented administrative difficulties to charge the royalties of the cultivars, including due to the limited human resources available for this function;

g. There is a lack of public support for the development of sectorial researches that involve higher risks and uncertainty, which the private sector currently has not shown interest to invest, such as researches to adapt the sugarcane crop to climate change;

h. The low investment in crop management has led to actions such as the increase in the number of cuts, carrying out minimal cultural care, replanting the same variety in the same field during followed harvests, providing fewer yields on the field. The low investment in renewal sugarcane plantations, with the reform of smaller areas than recommended and the use of technologically depleted varieties, accentuated the vulnerability of production to climatic events;

i. The risk aversion of the farmer increased due to the absence of specific sectorial policies and the strategic planning in the medium and long term. The greater the farmer uncertainty, the smaller the investments in the harvest, especially in a situation of financial indebtedness and increase of the costs of production, as the current one.

The set of factors highlighted reinforces the need for reflection on the possibilities of adaptation of the Brazilian production of sugarcane. The favorable factors do not involve direct and preventive action, based on prospective climate scenarios, but rather specific strategic decisions, derived from diverse and dispersed objectives that could even contribute to an adaptation process, but would certainly be insufficient to guarantee an increasing and sustainable supply of the raw material for the sugarcane industry in the long term. There are climatic scenarios constructed for Brazil in mid-term, to 2030 year (ZULLO JR.; KOGA-VICENTE, 2016), which indicate the increase of the areas with weather risk and with irrigation recommendation in sugarcane producers regions.

There are others scenarios considering that sugarcane should depend only on the water regime (JAISWAL et al, 2017) given that climate changes will set limitations of water resources for irrigation, in this case, the consolidation of the ethanol second-generation production, with the total utilization of the sugarcane biomass, would be essential for the assistance of potential demand. In any case, however, achieving increases in ethanol production will require more efficient use of pasture, effective production of cellulosic ethanol, and the continuation of national policies that lead to steady improvements in sugarcane production and sustainability, in addition to more efficient processing. In addition, the ability of sugarcane production to adapt to global climate change will be directly influenced by producers. At the end of the process of adaptation are these agents, in a top-down configuration, who will implement the main guidelines and, in this regard, political-institutional mechanisms that stimulate adoption, finance investments, train for the use and dissemination of new sectoral technologies will be fundamental.

5 CONCLUSIONS

The production of sugarcane has presented decreasing agricultural and industrial yields. Macroeconomic and environmental factors affected production costs and increased producer indebtedness. The reduction in investment limited the absorption of new technologies in sugarcane varieties, cultural practices and the renewal of sugarcane plantations as severe weather fluctuations also affected production in recent harvests. In the medium and long term, the picture tends to be aggravated by the lack of information on climate issues, portrayed in the lack of knowledge of climatic scenarios by both breeding programs and by producers, to this reality is added the institutional incapacity that public policies have demonstrated in recognizing, assessing and anticipating climate risks.

Despite some actions of breeding programs and farmers favor adaptation in the short term, they should not be sufficient to ensure the sustainability of production in the long term. The different climatic scenarios for the country reinforce the need for a significant change in the technological pattern of the sugarcane production in Brazil. The intensification of the use of agricultural technologies for crop management, varietal deconcentrating, the need for new cultivars, more suited to the sectoral needs and the edaphoclimatic conditions of each region, investments to overcome the technological bottlenecks of second-generation production represent urgently need to foster the diffusion and access to these technologies with appropriate sectoral policies.

The development of a strategic adaptation plan should include the breeding and farmers programs, and also other public and private agents who coordinate the sector and the innovation sectorial system of sugarcane in Brazil (Federal government and governments of sugarcane producing States). The formulation and implementation of sectoral adaptation actions should be strategically inserted into an economically, socially and environmentally sustainable development plan. New horizons are being envisioned for the 2018 implementation of the RENOVABIO Program, which, in order to achieve the targets agreed by Brazil at COP-21, should strengthen investments in research and development in the sugar-energy sector as well as establish and regulate a credit market of carbon for ethanol.

In this way, the structural difficulties faced by the Brazilian sugarcane sector emphasize the need to change the technological pattern of sugarcane production and the climate scenarios reinforced this need. The challenges to increase the sector productivity, to adapt to the climate effects and risks, and to compete in renewable and clean technologies, will only be possible though the intensive use of technology and innovation, joining the natural advantages that Brazil has in the sugarcane production with advances in the technological frontier.

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6 REFERENCES

BARBOSA, M. H. P.; SILVIEIRA, L. C. I. Melhoramento genético e recomendação de cultivares. In: SANTOS, F.; BORÉM, A.; CALDAS, C. **Cana-de-açúcar:** bioenergia, açúcar e etanol: tecnologias e perspectivas. 2. ed. rev. e ampl. Viçosa: Os Editores, 2011. p. 637.

BRAUNBECK, O. A.; MAGALHÃES, P. S. G. Avaliação tecnológica da mecanização da cana-de-açúcar. In: CORTEZ, L. A. B. (Coord.). **Bioetanol de cana-de-açúcar**: P&D para produtividade e sustentabilidade. São Paulo: Blucher, 2010. p. 451-464.

CORREA, V. H. C.; BELIK, W. A expansão recente e a ocupação de novas áreas pelas produções de soja, cana-de-açúcar e pecuária bovina no centro-oeste. Anais do 51o. **Congresso da Sober**. Belém: SOBER. 2013, julho. Disponível em: <http://www.sober.org.br/congresso2013/>. Acesso em: 7 jul. 2014.

CENTRO DE TECNOLOGIA CANAVIEIRA - CTC. **Censo CTC safra 2013/14**. Piracicaba: CTC. 2015. Disponível em <http://www.ctcanavieira.com.br/downloads/Censo2015.pdf>. Acesso em: 15 jun. 2015.

FURTADO, A. T.; SCANDIFFIO, M. I. G.; CORTEZ, L. A. B. The Brazilian sugarcane innovation system. **Energy Policy**, London, v. 39, n. 1, p. 156–166, 2011.

GOLDEMBERG, J. O etanol e os compromissos do Brasil em Paris. In: UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR. **Ethanol Summit 2017**: um salto para 2030**.** Campos do Jordão, SP: UNICA, 2017.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE - IPCC. **Fifth Assessment Report:** Climate Change – Synthesis Report. 2014. Geneva: Core Writing Team, R. K. Pachauri and L. A. Meyer, 2014. Disponível em <http://www.ipcc.ch/report/ar5/syr/>. Acesso em: 08 set. 2014.

JAISWAL, D.; DE SOUZA, A. P.; LARSEN, S.; LEBAUER, D. S.; MIGUEZ, F. E., SPAROVEK, G.; LONG, S. P. Brazilian sugarcane ethanol as an expandable green alternative to crude oil use. **Nature Climate Change,** London, v. 7, n. 11, p. 788-792, 2017. doi: https://doi.org/10.1038/nclimate3410

LANDELL, M. G. A.; BRESSIANI, J. A. Melhoramento genético, caracterização e manejo varietal. In: DINARDO-MIRANDA, L.; MACHADO DE VASCONCELOS, A. C.; LANDELL, M. G. A. (Ed.). **Cana-de-Açúcar.** 1. ed. Campinas: Instituto Agronômico, 2010. p. 882.

MARTINS, V. A.; OLIVETTE, M. P. A. Cana-de-açúcar - safra 2013/14 – e Fatores Climáticos: panorama dos impactos na produtividade nos Escritórios de Desenvolvimento Rural (EDRs) no Estado de São Paulo. **Análise e Indicadores do Agronegócio,** São Paulo, v. 10, n. 3, p.1-10 , 2015. Disponível em <http://www.iea.sp.gov.br/ftpiea/aia/aia-14-2015.pdf>. Acesso em: 15 jan. 2018.

OLIVA, F. C. Avaliação financeira do setor sucroenergético depois do boom. **Revista de Política Agrícola**, Brasília, ano 26, n. 1, p. 49-64, 2017.

OLIVEIRA, A. L. R.; GIANONI, C. B. Desafios de inovação segundo empresas do setor. In: SALLES FILHO, S. (Coord.). **Futuros do bioetanol**: o Brasil na liderança. 1. ed. Rio de Janeiro: Elsevier, 2015.

REDE INTERUNIVERSITÁRIA PARA O DESENVOLVIMENTO DO SETOR SUCROENERGÉTICO - RIDESA. **Censo Varietal 2012.** Araras, 2012. Disponível em: <https://ridesa.agro.ufg.br/n/44741-confira-o-censo-varietal-brasil-2012>. Acesso em: 15 jun. 2015.

REDE INTERUNIVERSITÁRIA PARA O DESENVOLVIMENTO DO SETOR SUCROENERGÉTICO - RIDESA. **Censo Varietal 2016/2017.** Araras, 2017. Disponível em: <https://www.ridesa.com.br/censo-varietal>. Acesso em: 10 jan. 2018.

SANTOS, G. R.; GARCIA, E. A.; SHIKIDA, P. F. A.; RISSARDI JÚNIOR, D. J. A agroindústria canavieira e a produção de etanol no Brasil: características, potenciais e perfil da crise atual. In: SANTOS, G. R. (Org.). **Quarenta anos de etanol em larga escala no Brasil**: desafios, crises e perspectivas. Brasília: IPEA. 2016.

SMIT, B.; BURTON, I.A.; KLEIN, T. J. T.; WANDEL, J. An anatomy of adaptation to climate change and variability. **Climate Change**, Dordrecht, v. 45, p. 223-251, 2000.

SMITHERS, J.; BLAY-PALMER, A. Technology innovation as a strategy for climate adaptation in agriculture. **Applied Geography**, Kidlington, v. 21, p. 175-197, 2001.

UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR - UNICA. **UNICADATA**, **2018**. São Paulo: UNICA, 2018. Disponível em: <http://www.unicadata.com.br/index.php?idioma=1.> Acessos em 23 jun. 2014 e 10 jan. 2018.

UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR - UNICA. **Ethanol Summit 2017**: um salto para 2030. Campos do Jordão: ÚNICA, 2017.

ZULLO JR, J.; KOGA-VICENTE, A. Riscos Climáticos e a importância do planejamento no setor sucroenergético em um contexto de mudanças climáticas. In: ZULLO JR, J.; FURTADO, A. T.; PFEIFFER, C. C. (Org.). **Planejamento da Produção de Cana-de-açúcar no contexto das mudanças climáticas globais**. Campinas: Unicamp, 2016.