THE ENVIRONMENTAL VULNERABILITY AND THE TERRITORIAL PLANNING OF THE SUGARCANE CULTIVATION[1]

CAROLINA DE OLIVEIRA JORDÃO[2]
EVANDRO MATEUS MORETTO[3]

Environmental Vulnerability in the Territorial Planning Processes

Vulnerability of people and of places is a complex phenomenon defined by the longtime history shared between human beings and the environment (LUERS, 2005). The debate on this topic has become of great relevance, considering that many people and places are affected by changes in ecosystems and ecosystemic services, and are highly vulnerable to the ensuing adverse effects that cause significant damage to their well-being (KASPERSON et al., 2005).

The concept of vulnerability may be understood as the probability of a community, a structure, services or a geographical area to be damaged or disrupted by the impact of a certain hazard (TOBIN; MONTZ, 1997). Vulnerability bears a definition composed of multiple elements, but, simply speaking, represents the probability of future conditions to take a negative direction (BRADLEY; SMITH, 2004).

Issues related to vulnerability have become one of the strong interests of science geared to sustainability, in the form a large field of knowledge dealing with human-environmental problems, including the research conducted on global environmental changes and climatic changes. The emergence of this sustainability-focused interdisciplinary field was heralded by the publication of important documents in the late 1980s, such as the Brundtland Report, also known as *Our Common Future* (TURNER, 2010).

Overall, a sustainable socioenvironmental system is one that provides resources and services (in both quality and distribution) to humanity, without compromising the

1. We would like to thank fellow professors, students and staff of the Graduate Program in Environmental Engineering Science of the São Carlos Engineering School of São Paulo University (PPG-SEA/EESC-USP), especially those from the Environmental Policy Center (NEPA), who lent their contribution to author Carolina Jordão's Master's Program, which eventually led to this publication. We also wish to thank the National Scientific and Technological Development Council (CNPq) and the São Paulo Research Foundation (FAPESP) for their support in carrying out this study.

2. M. Sc. in Sciences of Environmental Engineering from Engineering School of São Carlos, University of São Paulo (EESC/USP) and environmental management analyst at Instituto Centro de Vida (ICV). Email: carolina.jordao@icv.org.br

3. Assistant Professor at Universidade de São Paulo (USP), School of Arts, Sciences and Humanities (EACH), Institute of Energy and Environment (IEE) and coordinator of the Research Group in Environmental Planning and Management (PLANGEA/USP). Email: evandromm@usp.br

ability to support the natural environment in a definitive manner. In the scientific field, part of the research involving the topic of sustainability deals with the relationship between environmental services and their effects on humanity, aiming at discovering what characteristics of the system make it more vulnerable and less resilient to different driving forces (TURNER, 2010).

With this in mind, it could be said that a systemic vision of vulnerability has been constructed that, according to Eakin and Luers (2006), focuses on evaluating the processes, conditions and characteristics of the systems that extend out beyond the sensitivity of the environment and that inhibit adaptive responses.

Considering these systems as a cutout of the environment, environmental vulnerability may be construed as the potential of the system to modulate its responses toward stress-inducing factors, over time and space, according to its ecosystemic characteristics (WILLIAMS & KAPUSTKA, 2000). This condition is related to the intrinsic condition of individual territories, insofar as each fraction of a territory has the ability to respond to perturbations that interact with the type and magnitude of the induced event to produce vast adverse effects (SANTOS; CALDEYRO, 2007).

A variety of conceptual structures have been reported in addressing the vulnerability of the ecological-economic system. Among them, those proposed by Kasperson et. al. (2005) and Turner et al. (2003) are particularly worthy of mention. They present three components that determine the vulnerability of the system: exposure, sensitivity and resilience (Figure 1).

Exposure comprises characteristics that define the human actions affecting environmental vulnerability, as an outcome of the perturbations and impacts that were created (TURNER et al., 2003).

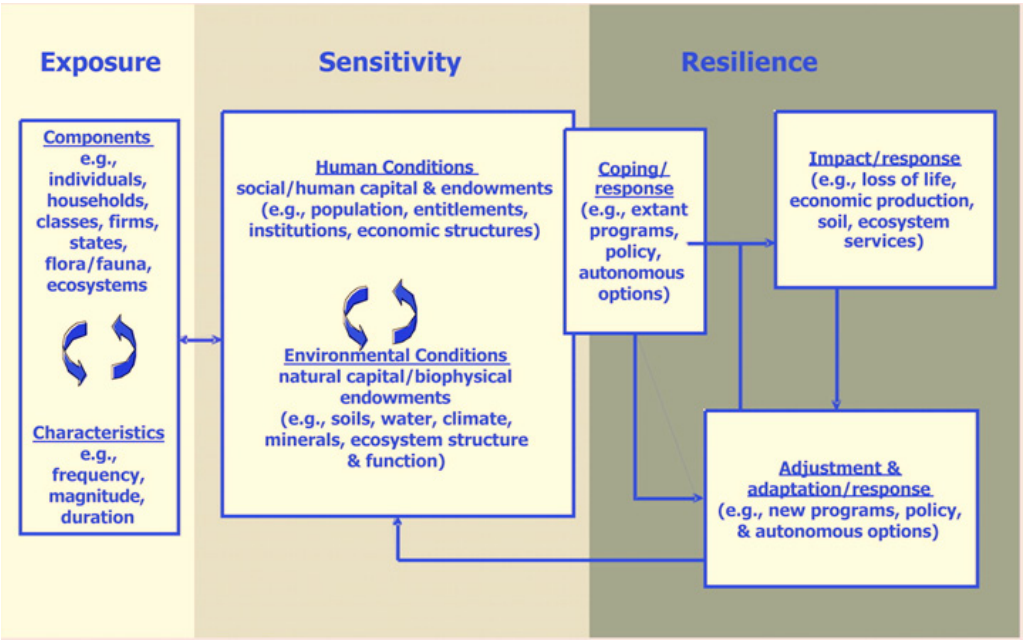
The degree of damage to a system submitted to a certain degree of exposure is determined by its sensitivity (KASPERSON et al., 2005), that is to say, by the environmental conditions of the territory, which can be significantly altered by the driving forces (TURNER et al., 2003).

Lastly, the resilience of the system is the set of natural and human responses to the damages, elicited to reestablish the earlier standard (or close to it) of dynamic balance of the environment (TURNER et al., 2003). If the perturbations persist over the course of time, the type and quality of the resilience may be altered, leading the system to revolve around a new dynamic point of equilibrium (KASPERSON et al., 2005).

The efforts currently being made to identify the environmental vulnerabilities of a certain territory have represented a potential tool to guide management efforts toward the conservation of natural resources and to provide resilience to ecosystems, in addition to driving actions that seek to diminish the environmental vulnerability of territories already offering low resilience (SOPAC, 2005).

What is indispensable for managing vulnerability, in a dynamic and unpredictable world, is a concrete change in the way decision-makers on several levels address issues of socioeconomic development and use of natural recourses. Both institutional and legal reforms are needed so that planning and management processes can look to the future and consider vulnerability-related issues, such as sensitivities and the ability of the ecosystem to adapt (LUERS, 2005).

Figure 1 – Components of environmental vulnerability (taken from TURNER et al., 2003)



In this respect, planning is an essential component for constructing an approach to deal with the connections between the components of the natural environment and man, which interact within the same territory. The aim of this scheme would be to aid decision-makers, since planning is a logical process that aids rational human behavior in performing forward-looking activities, but that is guided by an analysis conducted of past and present conditions and having a systemic and realistic design (MIRANDA NETO, 1981).

It is essential that the planning efforts be constantly reviewed and suitably address any possible changes or information not fully interpreted at the start, so that sounder alternatives for the real situation can be constructed. The set of planning alternatives results from the construction of different scenarios that can identify the potentials, fragilities, successes and conflicts existing in the territory. The alternatives must be varied in order to respond to the problems. They must also present the respective consequences, limitations, risks and costs (financial, social, environmental and political) (SANTOS, 2004).

According to Ross (2006), the situation of Brazil's environmental degradation, owing to predatory economic practices that diminish the quality of the environment and of life, shows how vital it is for politicians, planners and society as a whole to leave behind the narrow view of development determined only by economic and technological aspects. It is important to envision a form of development that considers the potentials

of natural resources, but also the fragilities of the environment in view of human interventions against nature.

With this in mind, it is indispensible that public policies be put into place on different levels (federal, state, municipal, river basin, etc.), and address territorial ordering to place greater value on the conservation and preservation of nature, within a sustainable development approach (ROSS, 2006).

The many different dimensions of the environmental vulnerability concept – such as the sensitivity of an environmental system that is target to a certain intervention – are typologies of crucial information to steer the diagnosis and development of alternatives for planning and management processes.

As a consequence, the ability of a certain product of planning to induce a lowering in the vulnerability of an environmental system is proportional to the ability (albeit not alone) of introducing the components of this product as typologies of information to underpin the decisions during the territorial planning process.

Public policies incentivizing sugarcane and its socioenvironmental impacts

The production of sugar cane was the main economic activity from colonial days up until the second half of the 18th century, when exports to the European market tumbled, mostly as an upshot of sugar production in the Antilles (SANTOS, 2010). Following the changes in the production cycles of the 19th century, sugarcane production diminished and the country stepped down from largest sugar producer in the world to occupy a fifth ranking position (UNICA, 2009).

For many years, Brazil's Sugar and Alcohol Institute (IAA) controlled sugar and alcohol production and marketing, and made it possible to continue these activities even through the many crises that affected the industry, mainly influenced by the international state-of-affairs (SZMRECSÁNYI & MOREIRA, 1991).

The industry was saved from going under by the discovery of a new way of exploring sugarcane by producing alcohol fuel, ethanol, viewed as the solution to the oil crises of the 1970s (UNICA, 2009). At the time, government policies were in place to incentivize expansion of the industry by funding the establishment of sugar and alcohol mills, and conducting technical and scientific research in the area (SANTOS, 2010).

A development worthy of note that emerged during this period was the creation of the National Alcohol Program (PROÁLCOOL), in 1975, by which the Brazilian government incentivized the production of ethanol with the official justification of substituting gasoline with ethanol and relieving the pressure of oil on the trade balance, exerted by the increase in the international price of oil. Nevertheless, it should be said that this program was established as an alternative to solve the idle capacity of the country's sugarcane agro-industry (SZMRECSÁNYI; MOREIRA, 1991). However, less than a decade later, ethanol became less attractive, prompted by an easing of the impact caused by the oil crisis, and by a shortage in ethanol (UNICA, 2009).

In the early 21st century, the sugarcane industry began a new cycle of sugarcane cultivation for ethanol production, no longer based on the goal of substituting gasoline

consumption (CAMARGO et al., 2008), but rather, based on the concern that ethanol could be related to global warming, the effects of greenhouse gas emissions (GGE) and the atmospheric pollution of large cities (GOLDEMBERG et al., 2008).

In the last decades, there has been a sizable expansion in the sugar industry, together with strong mechanization of all production stages (soil preparation, planting, crop maintenance and harvesting). Governmental funding and research policies, along with the economic attractiveness of the activity, paved the way for using pesticides and new genetically modified sugarcane varieties (SANTOS, 2010).

In recent years, Brazil has become the top world sugarcane and sugar producer, and now ranks second only to the United States in ethanol production (INPE, 2010). However, the growth in sugarcane activities has placed these activities on the agenda, owing to the historical social and environmental issues that they pose in the localities where they are now conducted, and in regard to the consequences of their expansion to new localities. In this respect, some socioenvironmental issues that must still be discussed should ultimately aid the sugarcane industry in reflecting about how to solve the problems that persist and tend to increase with the expansion of these activities.

These problems derive from the several different phases of the activity, pointing out especially the practice of burning the sugarcane before it is harvested. Some of the adverse effects include soil degradation, water pollution, pressure on other crops and native forestland, and application of pesticides and fertilizers, as well as the destruction of legal reserves and permanent preservation areas (COELHO et al., 2007; NOEL, 2007; GOLDEMBERG et al., 2008; MARTINELLI e FILOSO, 2008; WWF, 2008).

Agro-environmental zoning as a planning tool for the sugarcane industry

Zoning is a tool for environmental policymaking. Its goal is to aid in the spatial planning of production activities, based on studies related to the soil and other natural characteristic, such as geology, geomorphology and climate (MILLIKAN; DEL PRETTE, 2000).

In 2009, the Agro-ecological Zoning Plan (ZEA) for sugarcane was launched by a presidential decree (6.961/2009), seeking to meet a demand to consider environmental sustainability criteria in expanding ethanol production and also to earn the approval of the international market. However, for this to be put into motion, environmental sustainability criteria must be added (REPÓRTER BRASIL, 2009).

The overall objective of the sugarcane agro-ecological zoning (ZAE) plan was to lend technical assistance in making public policies, thus contributing to the orderly expansion of this crop and to the sustainable production of ethanol and sugar in the Brazilian territory. It should be noted that the agro-ecological zoning plan considers the areas of the Amazon, Pantanal and Upper Paraguay River Basin biomes not suitable for producing sugarcane. Another important issue is that the zoning plan aims at diminishing the competition between sugarcane cultivation and food production areas (MANZATTO et al., 2009).

In 2007, the Department of the Environment for the state of São Paulo – the largest sugarcane producing state – created 21 Strategic Projects for the environment,

among which Ethanol Verde (Green Ethanol) stands out in particular. Its foremost aim is to "encourage sustainable ethanol production, respecting natural resources, controlling pollution, and practicing socioenvironmental responsibility, in a partnership with the sugarcane-energy industry" (SÃO PAULO, 2011).

This project led to the creation of the Agro-environmental Protocol and the Agro--environmental Zoning Plan, undertaken between the government and the Brazilian Sugarcane Industry Association (UNICA), and offering sugarcane industries certification for good practices, granted to producers for conforming to certain criteria; it is renewed periodically.

The protocol is an instrument designed to reduce the impacts caused by sugarcane farming, and covers issues like advancing the deadlines for eliminating the burning of sugarcane straw, the protection of riverheads and remaining forest land, erosion control and disposal of pesticide packaging (SÃO PAULO, 2011).

Enacted as an outcome of this agro-environmental zoning of São Paulo's sugarcane industry was Resolution SMA 88/2008. It provides the technical guidelines for licensing the industry's projects in the state, and grew out of the need to define due procedures according to the specific characteristics of the territory where the projects are to be established. Accordingly, the type of environmental study to be presented to demonstrate project feasibility is defined according to where the facility is located on the agro-environmental zoning map (SÃO PAULO, 2008).

The creation of the agro-environmental zoning of São Paulo's sugarcane industry was warranted by the expected expansion of the crop area, because of the great international demand for ethanol and the need to protect natural resources (fauna, vegetation, soil, surface and ground water resources) by the planning and management of protected areas (Units of Conservation), and by helping to define distinct actions to be taken toward areas of environmental sensitivity (SÃO PAULO, 2009a).

The agro-environmental zoning of São Paulo's sugarcane industry is considered an instrument of environmental planning, designed mainly to order the expansion and occupation of the land by the sugarcane industry, and also to help make public policies and aid entrepreneurs in preparing their business plans and expansion projects (SÃO PAULO, 2009a).

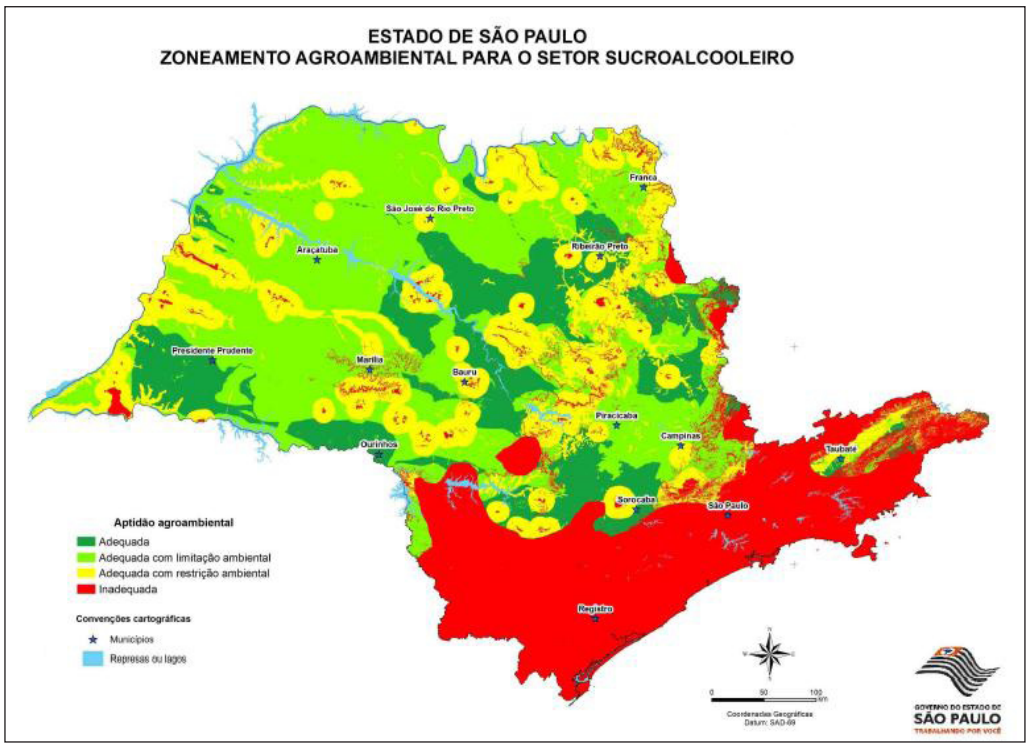
It is an indicative instrument that does not have the power to ban the existence of an activity in certain places or allow it in others. It is designed to lend assistance, so that new projects may preferentially be located in places with favorable agricultural features and without restrictions from the point of view of certain environmental components.

Bearing this in mind, the expected consequences are that sugarcane projects, such as mills, will preferentially be located in areas indicated as adequate, but adequate in the sense of being limited and restricted, subject to the application of due technical measures to minimize the impacts determined by environmental licensing.

Agro-environmental Zoning (ZAA) divides the territory of São Paulo into four categories, according to how suitable the land is for sugarcane cultivation and the territory is for establishing agro-industrial facilities (Figure 2).

1) '**Suitable**' corresponds to a territory with favorable edaphoclimatic features for developing sugarcane farming and without any specific environmental restrictions.
2) '**Suitable with Environmental Limitations**' corresponds to a territory with favorable edaphoclimatic features for sugarcane farming and with some Environmental Protection Areas (EPAs), with areas of average priority for enlarging connectivity, and with river basins considered as critical.
3) '**Suitable with Environmental Restrictions**' corresponds to a territory with favorable edaphoclimatic features for sugarcane farming and with some buffer zones of Integral Protection Conservation Units, with areas of high priority for enlarging connectivity, and areas of high vulnerability of groundwater in the state of São Paulo.
4) '**Unsuitable**' corresponds to Integral Protection Conservation Units (state and federal), fragments classified as being of extreme biological importance for conservation, Wildlife Zones of Environmental Protection Areas (EPAs), areas with restrictively favorable edaphoclimatic features for sugarcane farming, and areas with a declivity greater than 20%.

Figure 2 – Agro-environmental Zoning of the Sugarcane Industry in São Paulo (taken from SÃO PAULO, 2009a)



Lastly, if we consider the agro-environmental zoning of São Paulo's sugarcane industry as an instrument of the spatial planning of sugarcane farmed as a monoculture in the state, its analysis in the present study aims at determining if it is an instrument that adequately considers socioenvironmental sensitivities in spatial terms, so that its use in public policy will not induce an expansion in the environmental vulnerabilities of the São Paulo state territory.

Consideration of environmental vulnerability in the agro-environmental zoning of São Paulo's sugarcane industry

The components of environmental vulnerability for sugarcane cultivation as a monoculture were identified to gain a better understanding of the relationship between environmental vulnerability and the sugarcane industry. These components are shown in Table 1, divided into factors of exposure, sensitivity and resilience. Compilation of the data was based on studies related to the environmental issues involved in this cultivation, including: Coelho et al. (2007), Noel (2007), Goldemberg et al. (2008), Martinelli and Filoso (2008), WWF (2008), São Paulo (2009b), IEA (2010) and São Paulo (2010).

In Table 1, the exposure factors are the anthropic pressures resulting from cultivating sugarcane as a monoculture, the sensitivity factors are the main conditions altered by sugarcane monoculture farming in the territory, and the resilience factors are the human and natural actions that seek to diminish territorial vulnerability. Viewed as such, the model represents the chief variables that should be addressed when dealing with the issue of environmental vulnerability of sugarcane-farmed territories. Based on this overall picture, an analytical model was established to ascertain how Agro-environmental Zoning determines the dimensions of sensitivity of environmental vulnerability.

The model analyzes all the documents pertaining to the zoning plan, according to a list of environmental indicators sensitive to the spatial expansion of sugarcane, particularly those that point to negative or positive changes in environmental vulnerability, based on the existence of exposure factors – in this case, of sugarcane farming per se.

As a result of this analysis, synthetic information was obtained, presented in Table 2. You can observe that only one of the ten environmental indicators sensitive to the spatial expansion of sugarcane cultivation was fully considered in the agro-environmental zoning plan; seven indicators were partially considered, and two indicators were not considered.

Among the factors analyzed, air quality was the only environmental indicator that was duly addressed in the zoning plan, probably because there are specific air quality standards in federal and state legislations, which are applicable to different human activities, including sugarcane farming.

The sensitivity of air quality is of great relevance to the analysis of environmental vulnerability, especially because of the impacts caused by the practice of burning the sugarcane an easier alternative to hand-cutting it, and to repel animals. These impacts are always associated with the health problems of the population from the plantation region, because of the emission of pollutants like Co_x and CH_4 and particulate matter, as well as the increase in tropospheric ozone formation (GOLDEMBERG et al., 2008).

Table 1 – Components of environmental vulnerability related to sugarcane cultivation as a monoculture

	Theme	Variables to be observed in ZAA
Factors of Exposure	Changes in the landscape	Homogenizing of the Landscape Fragmentation of Natural Vegetation Coverage Compliance with the Legal Reserve and Permanent Preservation Areas
	Pollution	Emission of air pollutants Pesticide application Residue production
	Use of natural resources	Use of water Change in soil characteristics
	Expansion-related pressure	Pressure on non-sugarcane crops Suppression of native vegetation
Factors of Sensitivity	Natural resources	Soil quality Water quality Air quality Streamflow
	Landscape	Natural Vegetation Coverage Occupation by non-sugarcane crops
	Biodiversity	Legal Reserve Permanent Preservation Area Diversity of Species Closeness of monoculture to Conservation Units
Factors of Resilience	Landscape control	Zoning Licensing Inspection Monitoring
	Specific legislation	Eliminating burns Regulations
	Controlled expansion	In already degraded areas In pastureland where expansion has become more efficient
	Direct action by owners	Agricultural management Recomposing of forest reserve Mechanization Burn control
	Conservation of Biodiversity	Conservation Units Compliance with the Legal Reserve and Permanent Preservation Areas

Table 2 – Consideration of environmental sensitivity factors in the Agro-environmental Zoning of the São Paulo State Sugarcane Industry

Factors of environmental sensitivity	How the factor was considered in the Agro-environmental Zoning
Air quality	Fully considered
Soil quality	Partially considered
Water quality	Partially considered
Streamflow	Partially considered
Coverage of natural vegetation	Partially considered
Legal reserve	Partially considered
Diversity of species	Partially considered
Units of conservation	Partially considered
Permanent preservation areas	Not considered
Other agricultural uses	Not considered

The soil quality indicator was dealt with as a criterion of favorable farming features, according to a study made available by the Integrated Center of Agro-meteorological Information of the São Paulo Government (CIIAGRO, 2008). In this study, edaphoclimatic analyses were performed on the different soil types and their characteristics, in respect to natural fertility, depth and rock content, as conditions for sugarcane production.

However, soil quality was not included as an environmental attribute affected by sugarcane cultivation; that is to say, the soil was not considered the main focus of negative environmental impacts of sugarcane farming, even though soil degradation from compaction and erosion is an important problem related to sugarcane cultivation. Erosion is caused by large areas of exposed soil susceptible to intense rain and wind in the initial process of soil use conversion, and in the intermediary process between harvest time and the new planting period. Compaction occurs because of the constant traffic of heavy agricultural machinery, which changes the physical properties of the soil substantially, like porosity and density, culminating in decreased water infiltration, leading to a greater risk of erosion (MARTINELLI & FILOSO, 2008).

Much of the information gathered on water quality and streamflow was mapped by governmental agencies and institutions, such as the Geological Institute (IG), the Environmental Sanitation Technology Company (CETESB) and the Department of Water and Electricity (DAEE), and considers data on both ground and surface water.

Data on ground and surface water were also collected, but no attributable relationship was drawn between the quality of these water resources and sugarcane farming. It should be pointed out that the residual water and vinasse from sugarcane processing contain a great proportion of organic material that effects changes in water quality, as

well as inorganic pollutants from the agro-chemicals used in the plantations, which contaminate the water resources (GOLDEMBERG et al., 2008).

In determining the environmental indicator of amount of natural vegetation coverage, the zoning plan considered the publication of the BIOTA/FAPESP Program on priority areas for biodiversity in the state of São Paulo as a reference (FAPESP, 2008). The plan even considered the connectivity between fragments of vegetation and the creation of ecological corridors between these fragments – a very positive point. However, what was not considered was precisely the amount of existing vegetation coverage and its geography in the São Paulo State territory, a factor of great importance in a space that no longer holds large areas of primary vegetation.

The indicators of diversity of species and of conservations units specifically related to biodiversity were included, based also on the work developed for the BIOTA/FAPESP Program (FAPESP, 2008), and on the delimiting of both the integral protection conservation units and the environmental protection areas (EPAs). Further included were the respective buffer zones, where the sugarcane activity is not considered adequate and where it was not clear whether the zoning represents restrictions to sugarcane farming. It should be noted that, other types of conservation units of sustainable use were not included, nor any types of protected areas on a municipal level.

The legal reserves and permanent preservation areas were not duly considered in the Agro-Environmental Zoning; this led to ensuring compliance to the Forest Code. The legal reserves were regarded as priority areas for connectivity, but the low percentage of these registered areas in relation to the rural areas of the municipalities was not addressed.

For example, a better quantitative handling of this indicator, by considering the deficits of the legal reserve by river basin, could indicate where the priority for land use would be the recovery of the legal reserve, and consequent regulation of this space, instead of the spatial advance of the sugarcane crop.

The areas of permanent preservation were not considered in the zoning plan, nor was there a quantitative handling of the data that could reveal important information to delimit the advance in sugarcane farming space. This is a major problem for São Paulo's seven large river basins, affected by agricultural encroachment, seeing that only 25% of what should be the permanent preservation area designated for river margins has some sort of natural vegetation. The remaining 75% are covered with agricultural cultivation and pastureland (SILVA et al., 2007).

The Agro-environmental Zoning plan could have innovated by indicating the percentage calculation for permanent preservation area by river basin, showing where the priorities lie for recovering these areas, and, consequently, the unavailability of space for sugarcane cultivation. The several other agricultural products that compete or could compete spatially with sugarcane, like soybeans, corn and oranges, were also not considered, even though the existence of diversified crops in the territory could be strategic to render the regional economies more dynamic and the landscape, more heterogeneous.

The pressure being put on the other crops has created a situation of concern. Even if most of the new sugarcane crops are being farmed on degraded pastureland, thus making this land more efficient (GOLDEMBERG et al., 2008), it could be that other crops are

being replaced by sugarcane as a monoculture. This would cause a spatial displacement that could lead to the clearing of native areas and a decrease in food production. In this respect, it is necessary to enforce controls to restrict sugarcane from encroaching on soybean and corn farmland, and even on cattle-raising land in the savanna and the Amazon (COELHO et al., 2007).

It should be pointed out that, on the maps of favorable agricultural features and on the final zoning map (Figure 2), most of the area considered inadequate for sugarcane expansion, located to the south of São Paulo, is marked by unfavorable edaphoclimatic features. The rest of the area is composed of integral protection conservation units, where agricultural activity is banned.

It can be concluded that, even if the components of sensitivity of the territory's environmental vulnerability were somehow to be considered, the predominant criterion is in fact the favorability of the edaphoclimatic features; in other words, the potentials for producing sugarcane are given greater consideration than the vulnerabilities.

Final Considerations

In the case of sugarcane monocultures, it is indispensable that the several different socioenvironmental issues related to these cultures be considered effectively by all the interested players, namely, property owners, public policy makers and enforcers, researchers and civil society.

The state of São Paulo offers a set of policies and instruments related to sugarcane farming, considered of major importance to the state and the national economy. The São Paulo State Agro-environmental Zoning for the Sugarcane Industry should be pointed out as being an instrument of territorial planning that considers environmental variables to some extent, seeing that the zoning covers topical mappings related to groundwater, surface water, conservation units, biodiversity and air quality.

However, many of these mappings do not address environmental vulnerability factors satisfactorily. They do not consider the information related to soil quality, water quality, streamflow, natural vegetation coverage, diversity of species, conservation units and legal reserve in a suitable manner, nor do they consider any information about permanent preservation areas or other farm crops. Therefore, by not considering these environmental vulnerabilities of the territory fully, application of the Agro-environmental Zoning of the Sugarcane Industry has a substantial potential for inducing even greater environmental vulnerability in the territories of São Paulo State, and ultimately constitutes a mapping of the farming potentials and of the legal restrictions for territorial expansion of sugarcane cultivation in the state of São Paulo.

Bibliographic references

BRADLEY, M. P.; SMITH E. R. Using science to assess environmental vulnerabilities. **Environmental Monitoring and Assessement**. v. 94, p. 1-7, 2004.

CAMARGO, A. M. P.; CASER, D. V.; CAMARGO, F. P.; OLIVETTE, M. P. A.; SACHS, R. C. C.; TORQUATO, S. A. Dinâmica e tendência de expansão da cana-de-açúcar sobre as demais atividades agropecuárias, estado de São Paulo, 2001-2006. **Informações Econômicas**. Vol. 38, n° 3, 2008.

CIIAGRO, CENTRO INTEGRADO DE INFORMAÇÕES AGROMETEOROLÓGICAS. **Aptidão edafoclimática da cultura de cana de açúcar.** Agência Paulista de Tecnologia e Agronegócios, Instituto Agronômico, 2008

COELHO, S. T.; GUARDABASSI, P. M.; LORA, B. A.; MONTEIRO, M. B. C. A.; GORREN, R. A sustentabilidade de expansão da cultura canavieira. **Cadernos Técnicos da Associação Nacional de Transportes Públicos**. São Paulo, v. 6, 2007.

EAKIN, H.; LUERS, A. L. Assessing the vulnerability of social-environmental systems. **Annual Review of Environmental Resources**. v. 31, p. 364-394, 2006.

FAPESP, FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO. **Diretrizes para a conservação e restauração da biodiversidade no Estado de São Paulo.** São Paulo: Secretaria de Meio Ambiente do Estado de São Paulo, Instituto de Botânica, FAPESP, 2008

GOLDEMBERG, J.; COELHO, S. T.; GUARDABASSI, P. The sustainability of ethanol production from sugarcane. **Energy policy**. v. 36, 2008.

IEA – INSTITUTO DE ECONOMIA AGRÍCOLA. **Banco de dados.** São Paulo: IEA, 2010. Disponível em: <http://ciagri.iea.sp.gov.br/bancoiea/indices_new.aspx>. Acesso em: 05 Abr. 2011.

INPE – INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS. **Uso de imagens de satélite de sensoriamento remoto para mapear a área cultivada com cana-de-açúcar no Estado de São Paulo – Safra 2009/10**. 2010. Disponível em: <http://urlib.net/sid.inpe.br/mtc-m19@80/2010/02.09.18.47>. Acesso em: 05 Abr. 2011.

KASPERSON, R. E.; DOW, K.; ARCHER, E. R. M.; CÁCERES, D.; DOWNING, T. E.; ELMQVIST, T.; ERIKSEN, S.; FOLKE, C.; HAN, G.; IYENGAR, K. VOGEL, C.; WILSON, K. A.; ZIERVOGEL, G. Vulnerable Peoples and Places. In: HASSAN, R,; SCHOLES, R.; ASH, N. 9 (ed.). Ecosystems and human well-being: current state and trends. **Millennium Ecosystem Assessment.** Washington, DC: Island Press, 2005.

LUERS, A. L. The surface of vulnerability: An analytical framework for examining environmental change. **Global Environmental Change**. N° 15, p. 214–223, 2005.

MANZATTO, C. V. ASSAD, E. D.; BACCA, J. F. M.; ZARONI, M. J.; PEREIRA, S. E. M. (org.). **Zoneamento agroecológico da cana de açúcar**. Rio de Janeiro: Embrapa Solos, 2009.

MARTINELLI, L. A.; FILOSO, S. Expansion of sugarcane ethanol production in Brazil: Environmental and social challenges. **Ecological Applications**. v. 18, p. 885–898, 2008.

MILLIKAN, B. H. & DEL PRETTE, M. E. **Documento base para discussão sobre metodologia de zoneamento ecológico-econômico na Amazônia**. In: Seminário de Avaliação da metodologia de Zoneamento Ecológico-Econômico para a Amazônia Legal. Programa Piloto de Proteção das Florestas Tropicais Brasileiras. Manaus, AM. 2000. CD-ROM.

MIRANDA NETO, M. J. **A crise do planejamento**. Rio de Janeiro: Nórdica, 1981.

NOEL, F. L. Etanol: o desafio do combustível verde. **Problemas Brasileiros**. São Paulo, n. 382, jul./ago. 2007.

REPÓRTE BRASIL. **O zoneamento agroecológico da cana de açúcar: análise dos avanços e das lacunas do projeto oficial**. 2009. Disponível em: <http://www.reporterbrasil.org.br/documentos/zoneamento_cana_reporterbrasil_out09.pdf>. Acesso em 8 Fev. 2011.

ROSS, J. L. S. **Ecogeografia do Brasil: subsídios para o planejamento ambiental**. São Paulo: Oficina de Textos, 2006.

SANTOS, L. Doce e amargo açúcar: Concentração de renda e relações de trabalho na produção agroindustrial canavieira do Brasil. **Revista Crase.edu**. n. 1, v. 1, 2010.

SANTOS, R. F. (org). **Vulnerabilidade ambiental**. Brasília: MMA, 2007.

SANTOS, R. F.; CALDEYRO, V. S. Paisagem, condicionantes e mudanças. In: SANTOS, R. F. (org). **Vulnerabilidade ambiental**. Brasília: MMA, 2007

SANTOS, R. F. **Planejamento Ambiental: teoria e prática**. São Paulo: Oficina de Textos, 2004.

SÃO PAULO, SECRETARIA DE MEIO AMBIENTE. **Resolução SMA 88 – Define as diretrizes técnicas para o licenciamento de empreendimentos do setor sucroalcooleiro no Estado de São Paulo**. 2008. Disponível em: <http://www.cetesb.sp.gov.br/licenciamentoo/legislacao/ estadual/resolucoes/2008_Res_SMA_88.pdf >. Acesso em 19 Mai. 2011.

SÃO PAULO, SECRETARIA DE MEIO AMBIENTE. **Relatório Etanol Verde**. 2009a. Disponível em: <http://homologa.ambiente.sp.gov.br/etanolverde/relatorio_etanol_verde_2009A.pdf>. Acesso em 19 Mai. 2011.

SÃO PAULO, SECRETARIA DE MEIO AMBIENTE. COORDENADORIA DE RECURSOS HÍDRICOS. **Relatório de Situação dos Recursos Hídricos do Estado de São Paulo**. São Paulo: SMA/CRH, 2009b.

SÃO PAULO, SECRETARIA DO MEIO AMBIENTE. COORDENADORIA DE PLANEJAMENTO AMBIENTAL. **Meio Ambiente Paulista: Relatório de Qualidade Ambiental 2010**. São Paulo: SMA/CPLA, 2010

SÃO PAULO, SECRETARIA DE MEIO AMBIENTE. **Etanol Verde**. 2011. Disponível em: <http://homologa.ambiente.sp.gov.br/etanolverde /portugues.asp>. Acesso em 19 Mai. 2011.

SILVA, A. M.; NALON, M. A.; KRONKA F. J. N.; ALVARES C. A.; CAMARGO, P. B.; MARTINELLI, L. A. Historical land-cover/use in different slope and riparian buffer zones in watersheds of the state of São Paulo, Brazil. **Scientia Agricola**. Vol. 64, 325–335, 2007.

SOPAC. COMISSÃO DE GEOCIÊNCIA APLICADA DO PACÍFICO SUL. **Building Resilience in SIDS. The Environmental Vulnerability Index**. 2005. Disponível em <www.sopac.org>. Acesso em: 15 Abr. 2009.

SZMRECSÁNYI, T. & MOREIRA, E. P. O desenvolvimento da agroindústria canavieira do Brasil desde a Segunda Guerra Mundial. **Estudos Avançados,** n. 5, v. 11, 1991.

TOBIN, G.A.; MONTZ, B.E. **Natural Hazards, Explanation and Integration**. New York, London: The Guildford Press, 1997.

TURNER, B. L. Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science?. **Global Environmental Change**. 2010.

TURNER, B. L.; KASPERSON, R. E.; MATSONE, P. A.; MCCARTHYF, J. J.; CORELLG, R. W.; CHRISTENSENE, L., ECKLEYG, N. KASPERSONB, J. X.; LUERSE, A.; MARTELLOG, M. L.; POLSKYA C.; PULSIPHERA, A.; SCHILLERB, A. A framework for vulnerability analysis in sustainability science. **Proceedings of the National Academy of Sciences**. n. 14, v. 100, p. 8074–8079, 2003.

UNICA – UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR. **Setor Sucroenergético – Histórico.** 2009. Disponível em: < http://www.unica.com.br/content/default.asp?cchCode={C2B 8C535-736F-406B-BEB2-5D12B834EF59}>. Acesso em: 16 Mai. 2009.

WILLIAMS, L. R. R., e KAPUTSKA, L. A. Ecosystem vulnerability: a complex interface with technical components. **Environmental Toxicology and Chemistry**. v. 19, p.1055–1058. 2000.

WWF – WORLD WILDLIFE FOUNDATION BRASIL. **Análise da expansão do complexo agroindustrial canavieiro no Brasil**. Brasília: WWF, 2008.

Submitted on: 09/05/2013
Accepted on: 03/09/2014
http://dx.doi.org/10.1590/1809-4422ASOC675V1812015en

THE ENVIRONMENTAL VULNERABILITY AND THE TERRITORIAL PLANNING OF THE SUGARCANE CULTIVATION

CAROLINA DE OLIVEIRA JORDÃO
EVANDRO MATEUS MORETTO

***Abstract*:** Environmental vulnerability is crucial to understanding the sustainability and feasibility of human activities. In light of this, a problem is now emerging in Brazil, specifically in the state of São Paulo. It relates to the expansion of sugarcane cultivation as a monoculture, with consequential negative impacts that decrease the systemic resilience of the affected territories. Bearing this in mind, the present study analyzes to what extent environmental vulnerability was taken into account in the spatial planning of the expansion of this farming activity, focusing on the agro-environmental zoning of São Paulo's sugarcane industry as the main public policy currently guiding the state's industry. The analysis shows that this zoning, overall, considers only the edaphoclimatic potentials in planning the expansion of sugarcane farming, and disregards the restrictions related to the existing environmental vulnerability. Thus, agro-environmental zoning could ultimately increase the territorial environmental vulnerability of the state of São Paulo.

***Key words*:** environmental vulnerability, environmental planning, environmental management, agro-environmental zoning, sugarcane crop.

***Resumo*:** A vulnerabilidade ambiental de um território é fundamental para a compreensão da sustentabilidade e da viabilidade de atividades humanas. Nesse contexto, um problema emergente no Brasil, e especificamente no estado de São Paulo, refere-se à expansão da atividade agrícola da monocultura de cana de açúcar devido aos impactos negativos e à diminuição da resiliência sistêmica dos territórios afetados. Neste sentido, o presente trabalho analisa como a vulnerabilidade ambiental foi considerada no planejamento territorial da expansão desta atividade baseado no zoneamento agroambiental do setor sucroalcooleiro de São Paulo. Com as análises realizadas foi possível concluir que o referido zoneamento preconiza, de forma geral, as potencialidades agrícolas para o planejamento da expansão do cultivo da cana de açúcar, desconsiderando as restrições relacionadas à vulnerabilidade ambiental existentes, podendo o seu uso induzir o aumento da vulnerabilidade ambiental no território do Estado de São Paulo.

***Palavras-chave*:** vulnerabilidade ambiental, planejamento territorial, zoneamento agroambiental, cultivo de cana-de-açúcar.

***Resumen*:** La vulnerabilidad ambiental de un territorio es fundamental para entender la sostenibilidad y viabilidad de la existencia de las actividades humanas. En este contexto, un problema que está emergiendo actualmente en Brasil, se refiere a la expansión del monocultivo agrícola de la caña de azúcar debido a la impactos negativos y la disminución en la resistencia sistémica. Así, este estudio tuvo como objetivo examinar cómo se inserta la vulnerabilidad ambiental en la planificación territorial de la expansión de esta actividad, se centrando en la zonificación agro-ambiental de este sector de São Paulo. Para nuestro análisis concluimos que esta zonificación, en general, sólo considera el potencial agrícola para la planificación de la expansión del cultivo de caña de azúcar, sin tener en cuenta las restricciones relacionadas con la vulnerabilidad ambiental existe, ya que su uso aislado aumentan la vulnerabilidad del medio ambiente en el Estado de São Paulo.

***Palabras-clave*:** vulnerabilidad ambiental, planificación ambiental, zonificación agro--ambientale, cultivo de la caña de azúcar.