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## Opinion Article

# Challenges and opportunities for biodiversity conservation in the Atlantic Forest in face of bioethanol expansion

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### Abstract

Brazil is the world largest producer of sugarcane ethanol, an alternative to gasoline. Large players, including international oil companies, are aware of the potential of Brazilian ethanol and are investing in the production and expansion of sugarcane plantations in the country. The growing ethanol market imposes some conservation challenges on Brazil to meet the increasing demand. The market points out to an expansion of sugarcane crops, but this can be extremely harmful to the remaining biodiversity of the Brazilian Atlantic Forest. The impact of such expansion will be more severe in the states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte, the second largest sugar-ethanol production region, and one of the most globally threatened areas of tropical forest (only 12% left, ~ 1% legally protected). There, most forest fragments are smaller than 100 ha and several endemic species are on the verge of extinction. Here we advocate that instead of expanding plantations, increasing crop productivity should be the more logical and environment-friendly solution for that region. Further, we indicate that the current challenge is to increase the number of sugar and ethanol companies following best management practices and to turn these programs into a real opportunity to restore the biodiversity and environmental services of an ecosystems in eminent collapse. We urge that companies should move one step further and, at least, guarantee the protection of the habitats that go beyond the protection area imposed by the current environmental law.

**Keywords:** Best management practices, biodiversity hotspot, conservation dilemmas, forest fragmentation, sugarcane.

### Resumo

O Brasil é o maior produtor mundial de etanol de cana de açúcar, uma alternativa à gasolina. Grandes empresas, incluindo companhias petrolíferas internacionais, estão atentas ao potencial do etanol brasileiro e estão investindo na produção e expansão das plantações de cana no país. O crescimento do mercado de etanol e o atendimento da sua demanda impõem alguns desafios conservacionistas ao Brasil. O mercado aponta para a expansão da área plantada com cana, mas isto poderá ser extremamente prejudicial à conservação do restante da biodiversidade da Floresta Atlântica brasileira. O impacto desta expansão será ainda mais severo nos estados de Alagoas, Pernambuco, Paraíba e Rio Grande do Norte, a segunda maior região produtora de açúcar e etanol do país, e uma das porções mais ameaçadas de florestas tropicais do planeta (apenas 12% restante, ~ 1% legalmente protegido), com a maior parte dos fragmentos florestais menores que 100 ha e várias espécies endêmicas na iminência da extinção. Defendemos aqui que ao invés de expandir a área plantada, o aumento da produtividade deveria ser a solução mais lógica e ambientalmente correta para a região. Mais além, indicamos que o desafio atual é aumentar o número de empresas sucro-alcooleiras que adotem melhores práticas de gerenciamento ambiental e transformar estes programas em oportunidades reais para a restauração da biodiversidade e dos serviços ambientais em um ecossistema em eminente colapso. Recomendamos com veemência que as usinas de cana deveriam dar um passo além e, pelo menos, garantir a proteção dos habitats restantes além do que está estabelecido pela legislação ambiental atual.

**Palavras chave:** Cana de açúcar, dilemas conservacionistas, fragmentação florestal, hotspot de biodiversidade, melhores práticas ambientais.

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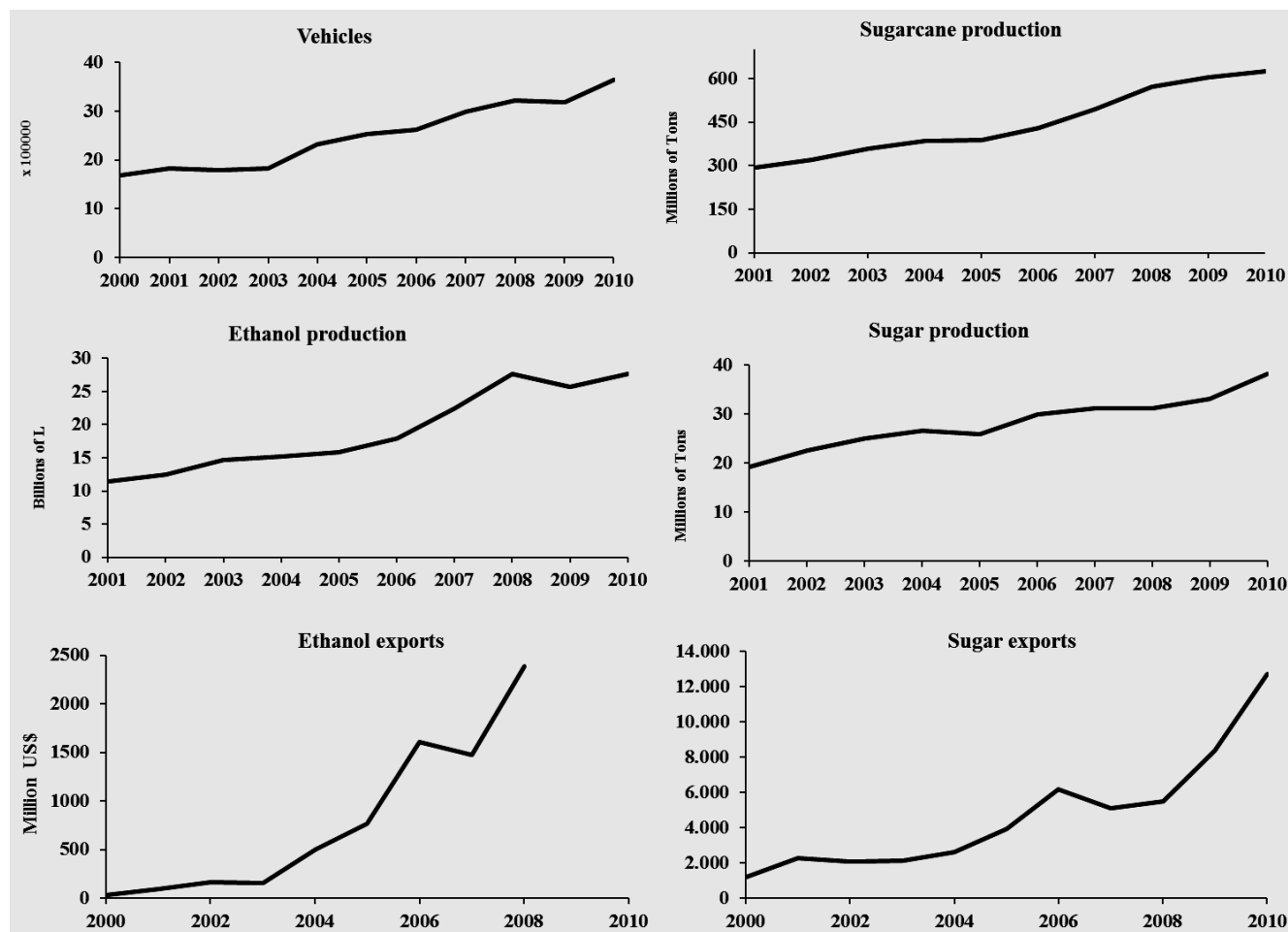
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## Introduction

The use of biofuels as an alternative to fossil fuels has been taken as a fact by governments and the productive sector all over the world [1-5]. The apparently irreversible historical trend of rise in the international oil prices has made biofuels to become competitive in the global market, leading to a strong demand for those products [3-5]. Obviously, every emergent market brings challenges and opportunities that must be conciliated. The opportunities for Brazil in the production of biofuels were acknowledged by several sectors, including the government [3]. Brazil is among the largest producers of soy, corn and sugarcane in the world and all of these cultures can generate biofuel as a by-product. However, none of them is more promising than sugarcane ethanol, an alternative to gasoline known for at least four decades [6].

Oil companies are aware of the potential of biofuels. Anglo-dutch company Shell and the Brazilian Cosan proclaimed on the second week of February 2011 the closure of joint venture of their ethanol and fuel distribution operations, creating a new company with capacity to produce annually 2.2 billions of liters (Bl) of ethanol [7]. The new company, evaluated in US\$ 12 billions, wants until 2015 to increase in 60% its current volume of crushed cane and reach 100 million tons (Mt) annually. They also want double its current ethanol production capacity, and to increase in 50% the production of refined sugar and in 45% the power generation capacity of its 24 refineries. News published in early May 2011 indicates that the Brazilian state oil company Petrobras might increase its share of the national production of ethanol from the current 5% to 15% in four years [8]. This movement of large players in the Brazilian ethanol market has reinforced expectations of the sugar-ethanol sector on the future role of this biofuel in the world energy matrix, partially replacing gasoline.

In fact, the signals of expansion in the demand for sugarcane in Brazil have become real and evident (Fig. 1). Since 2003 light vehicle sales have increased in the country, on average at 15.8% per year. In 2010 sales were 12% higher than in 2009, and flex-fuel vehicles were responsible for ca. 90% of all sales [9]. Furthermore, the increase in the flex-fuel fleet in the same period led to an increase of 107% in the demand for ethanol in the country [10]. Brazilian ethanol exports jumped from 94 millions of liters in the harvesting season of 2000/01 to 4.7 Bl in 2008/2009, whereas the sugar production went from 6.9 to 20.7 Mt in the same period [11]. Moreover, the price of sugar recently reached the highest value in the past 30 years in the international market [12]. USA, the world's largest oil consumer, has the goal of using at least 45 Bl of renewable fuel per year, and of increasing to 136 Bl until 2022 [13]. In February 2010, the US Environmental Agency declared that the Brazilian ethanol is an 'advanced biofuel', opening the possibility of increasing imports by the American market [13]. The European Union has also classified Brazilian ethanol as 'sustainable' [10].



**Fig. 1. Evolution of the Brazilian production of vehicles, sugarcane, ethanol and sugar (with the respective export incomes) in the last decade. Data sources: ANFAVEA, DCAA/SPA/ MAPA, CACEX.**

### Should Brazil increase the planted area or intensify production?

The expansion of the ethanol market imposes some challenges on Brazil to meet the increase in internal and external demand and to take advantage of the economic opportunity that this market represents. A merely economic-oriented point of view suggests two evident alternatives to meet the increase in the demand: increase the planted area or improve crop productivity. Indeed, the country already is the world's largest sugarcane producer and its crops are, on average, the most productive of the world. However, the national annual growth in productivity (3% a year) [10, 14] is not enough to meet the projected demand. The development of new varieties of sugarcane is feasible and has been occurring, but it takes time for research and dissemination. A significant short-term gain in productivity would be achieved with the arrival of cellulosic ethanol, or second generation ethanol [15]. But that would probably require a decade. Nevertheless, cellulosic ethanol that would be made from sugarcane bagasse and straw would also reduce raw material currently used for power generation by refineries; and this energy is bought by the Brazilian government [4].

In the short-term, the remaining alternative would be, therefore, to increase the planted area. And there seems to be a consensus that this is the short cut that the country will take. Already in 2008, the president of the Brazilian Empresa de Pesquisas Energéticas (EPE), Mauricio Tolmasquim, declared that it would be necessary to double the planted area of sugarcane to meet the ethanol production goal established by the government for 2030 [16]. The sugar-ethanol sector sustained the affirmation [17]. Soon after that, in 2009, the Brazilian Empresa Brasileira de Pesquisa Agropecuária (Embrapa) launched the national sugarcane agroecological zoning (Zoneamento Agroecológico da Cana-de-Açúcar – ZAE) [18]. The study suggests that Brazil has ca. 64.7 Mha of potentially suitable lands for the expansion of this crop, excluding Amazonia, Pantanal and any other forest remnants, and respecting areas of permanent protection (APP). Indeed, the expansion of planted area is already underway: between 2005 and 2009, in center-southern Brazil, the largest producer region, it grew 54.5%, reaching 7.16 Mha [19]. There were significant increase in Goiás (126.2%), Mato Grosso do Sul (99.9%) and Minas Gerais (99.2%). In 2010, the sugarcane area in the country increased 9.2% compared to 2009, reaching 8.1 Mha [20]. In the harvesting season of 2005/06, 703 municipalities of the center-southern region cultivated sugarcane. In 2008/2009, there were 859 [8].

The market points out to a need for expanding sugarcane crops. But where should they be planted? Tolmasquim, from the EPE, suggests that, as a way to minimize environmental impacts and risks of competition with food crops, sugarcane should occupy areas that are currently used as pastures [5]. Indeed, the sugarcane ZAE points out that ca. 57% (or 37.2 Mha) of the potentially expansible area for sugarcane is currently used as pasture for livestock, mainly beef cattle. This is where problems start, since beef cattle represents the largest share of Brazilian agribusiness and gives international prominence to the country. In addition to that, the successive increase in price, consumption and exports of Brazilian meat [21-23] would make a conversion without resistance from pastures to sugarcane even more difficult. Therefore, even if the resistance by the meat sector is overcome and sugarcane occupies former pastures or replaces other crops, pasture and crops that eventually lose their planted area would press the advance of agribusiness over natural areas [24-26]. Moreover, that would have implications on the carbon savings from biofuels [27].

## Threats and opportunities for biodiversity conservation in the Atlantic Forest

The expansion of the agricultural frontier is a historical phenomenon in a large country such as Brazil. The sugarcane itself underwent intensive expansion cycles; the largest of them was during the 1970s. At that time, the Brazilian military government stimulated the conversion of forests into sugarcane plantations to supply the internal market with ethanol, in response to the oil crisis. This expansion was a cruel blow to the Atlantic Forest and explains, in part, the reduction to less than 12% of its original area [28]. Therefore, like watching the same movie again, a new expansion of sugarcane crops can be extremely harmful to the conservation of the remaining biodiversity of this Brazilian environment.

The possible environmental effects of sugarcane expansion over the Atlantic Forest will not be homogeneous and can be more severe in a specific region: the remaining forest to the north of São Francisco River. Composed of forest remnants located in the states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte, this region, also known as Biodiversity Corridor of the Northeast (Corredor de Biodiversidade do Nordeste - CBNE), is located in the second largest sugar-ethanol region of the country. CBNE is considered one of the most globally threatened areas of tropical forest. From its original distribution there is only 12.1% left [29], but only 1% of this area is legally protected through parks and reserves. Most remaining forest fragments are on average smaller than 100 ha (Fig. 2). As a consequence, several endemic species of the region are on the verge of going globally extinct [30], making conservation efforts in this region urgent.

Here lies the paradox of sugarcane expansion in CBNE. According to the sugarcane ZAE, there are still ca. 865,000 ha of areas that are moderately suitable for sugarcane expansion in the states of CBNE [13]. However,



almost all forest remnants in this Atlantic Forest section belong to private landowners, mainly sugar and ethanol refineries. These remnants have been already mapped and classified as irreplaceable sites for biodiversity conservation [31]. Some forest remnants in refinery areas harbor more extinction-threatened birds and mammals than the reserves of the region [30]. Hence, it is absolutely necessary to find solutions to conciliate the socioeconomic development potential resulting from the expansion of sugarcane and the conservation of the biodiversity of those areas.



**Fig. 2. A typical scenario in the Atlantic Forest at the Northeastern Biodiversity Corridor, where forest remnants are surrounded by sugarcane plantations. Most of the remaining forest fragments are, on average, smaller than 100 ha. Photo credit: Adriano Gambarini.**

The Brazilian sugar-ethanol sector itself can and should play a key-role if it wants to be even more competitive. Indeed, the great opportunity to increase competitiveness in a more and more monitored global market will come through environmental suitability, by using environment-friendly modes of production and by recovering environmental liabilities. Considering that many rural properties in Brazil are not in accordance with current environmental laws, bringing those properties within the law would be a good first step to increase competitiveness. However, the recent vote from the Brazilian Congress to roll back environmental regulations in the current law (Código Florestal) poses as an incentive to deforestation [32-33].

Many large companies are adopting ways to minimize their ecological footprint, ruling the production of their commodities according to Better Management Practices (BMP) [34]. These practices aim at protecting biodiversity and ecosystem services through a commitment assumed by landowners and companies to conservation policies and direct investments in the environmental agenda. The BMP debate gained power within the productive sector with the increasing concern by the market on product and origin certification. Companies are interested to be more competitive in the international scenario, with concerns on their image and strengthening of brands associated with environmental protection.

According to the initiative *The Economics of Ecosystems & Biodiversity* [35] of the United Nations Environment Programme (UNEP), the BMP strategy is already consolidated in the international scenario and in companies that want to be more competitive and aggregate value to their products. This can also be observed by the *Global Initiative Reporting* [34], which aims at creating conditions for clear and reliable information interchange on sustainability through the development and continuous improvement of organizational reports. This initiative created a demand among large companies for reporting their environmental initiatives and projecting their brands on several markets that have environmental restrictions for products from regions with high biological richness.

### **Advices for a future with ethanol and biodiversity in the Atlantic Forest**

Increasing sugar and ethanol production by expanding the planted area in one of the most threatened ecosystems of the planet is an outdated and unsustainable vision, both environmentally and economically. Thus, increasing crop productivity should be the more logical and environment-friendly solution, mainly in states of northeastern Brazil, where sugar and ethanol productivity per ha is 21% (in Alagoas) to 40% (in Paraíba) below the average production of center-southern Brazil [36]. In fact, such movement is underway in Alagoas and Rio Grande do Norte (18% and 13% productivity increase per year from 1990 to 2009, respectively), but there is still room for significant improvements in the other states: productivity in Pernambuco increased only 0.1% per year, while in Paraíba it decreased 15% from 1990 to 2009 [37].

But even with an increase in productivity, the scenario for biodiversity conservation in the region remains very sensitive. Since Alagoas and Rio Grande do Norte are getting closer to reach the optimum economical and technical efficiency of center-southern Brazil, one can expect that a short-term increase in sugarcane production there will inevitably occur through horizontal expansion (more land). Furthermore, in Northwestern Brazil the price of sugarcane lands increased about 280% in the last 5 years, while forested areas had their values increased in 100% [38]. Alagoas presented the highest index, ca. 370%, what could reinforce the horizontal expansion phenomenon. In all States, the value of forested areas is significant, but not enough to change the “sugarcane-forest ratio” that favorably tends to deforestation. In face to such pessimistic scenario, the current challenge in the CBNE is to pursue an increase in the productivity maintaining the current crop area, changing the perception and valuation of the remaining forest.

Local sugar and ethanol companies must assimilate and internalize the need to preserve their remaining forest. They must convert them into important assets to get access to certified markets, an alternative to maintain the conventional efficiency conquered. Moreover, in some situations they will have to replant critical lost areas, turning these programs into a real opportunity to restore the biodiversity and environmental services of an ecosystem in eminent collapse. Eliminating environmental liabilities from those companies, restoring ecosystem services (mainly the maintenance of water supply), and increasing biodiversity persistence in those altered landscapes mean increasing gain with the biofuel wave. To reach this result and increase the scale of BMP, it is advisable that these programs exceed the simple mitigation of impacts associated with the production chain of companies [39-40]. It is necessary that these programs incorporate conservation-oriented technologies developed by universities and research institutes and, mainly, adopt really effective long-term biodiversity conservation measures. In other words, companies should move one step further and, at least, guarantee the protection of the habitats that go beyond the protection area imposed by the environmental law.

We came to a time when actions in the social, political and economic domains will decide the fate of Earth's species. Therefore, it is essential that decisions that affect the future of nature have a scientifically solid basis. Hence, expanding the sugarcane planted area in the CBNE without the respective counterpart in the commitment of conserving the biodiversity means to accelerate the end of the last forest remnants that are

already in a critical state [29-31]. Northeastern Brazil is currently facing a singular moment of economic and social development, with large investments in industry and infrastructure [41-42]. The local sugarcane industry, which for centuries moved the economy of the region, needs more than ever to understand that it is necessary to adapt to the new environmental practices and to become a partner of the society in the conservation of the natural capital: biodiversity. The increase in biofuel competitiveness comes not from a more intensive extraction of natural resources, but from an efficient, environmentally sustainable and socially fair optimization.

**Box: Key policy recommendations for a future with ethanol and biodiversity in the Atlantic Forest.**

- **Freeze the expansion of the sugarcane planting over forest remnants, and update the analysis of the most critical areas for biodiversity conservation under crop pressure.**
- **Provide a detailed mapping indicating irreplaceable sites and the potential areas for lower-impact crop expansion.**
- **Increase crop productivity through the adoption of better sugarcane varieties, improved machinery and harvesting techniques, with emphasis on the states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte.**
- **Speed up the dissemination of second generation ethanol (cellulosic ethanol).**
- **Convince sugarcane company owners to value their natural capital by restoring the ecological services in their areas and guarantee the protection of habitats beyond the current environmental law.**
- **Disseminate the adoption of BMPs as a business opportunity for sugarcane companies and their segments to increase gain scale with biofuels.**
- **Increase the number of sugar and ethanol companies following BMPs as a public commitment.**
- **Create a common agenda between sugarcane companies, universities, NGOs and research institutes to identify the main challenges of BMPs adoption in the companies' supply chain.**

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## References

- [1] The economist. [www.economist.com/node/17358802](http://www.economist.com/node/17358802)
- [2] O Estado de São Paulo. <http://economia.estadao.com.br/noticias/economia+geral,fao-defende-biocombustiveis-para-impulsionar-economia,67351,0.htm>
- [3] Universo On Line. <http://economia.uol.com.br/ultimas-noticias/efe/2011/06/06/governo-autoriza-r-35-bilhoes-para-projetos-de-biocombustiveis.jhtm>



- [4] Valor Online. <http://economia.ig.com.br/empresas/industria/petrobras+biocombustiveis+pretende+ampliar+producao+de+etanol/n1597007681519.html>
- [5] Exame. <http://exame.abril.com.br/economia/meio-ambiente-e-energia/noticias/por-que-as-petroliferas-estao-investindo-em-biocombustiveis>
- [6] Moraes, M. 2011. Lessons from Brazil. Nature 474:s25. Biofuel Outlook Special Edition.
- [7] Universo On Line. <http://economia.uol.com.br/ultimas-noticias/efe/2011/02/14/cosan-e-shell-criam-empresa-de-us-12-bilhoes-no-brasil.jhtm>
- [8] Folha de São Paulo. <http://www1.folha.uol.com.br/poder/912308-petrobras-tera-participacao-maior-na-producao-de-etanol.shtml>
- [9] ANFAVEA. [www.anfavea.com.br/tabelas/autoveiculos/tabela11\\_vendas.pdf](http://www.anfavea.com.br/tabelas/autoveiculos/tabela11_vendas.pdf)
- [10] Empresa de Pesquisas Energéticas - Análise de Conjuntura dos Biocombustíveis. [www.epe.gov.br/Petroleo/Paginas/PainelDeBiocombust%C3%ADveis%E2%80%93Boletinsdean%C3%A1liseDeconjuntura.aspx](http://www.epe.gov.br/Petroleo/Paginas/PainelDeBiocombust%C3%ADveis%E2%80%93Boletinsdean%C3%A1liseDeconjuntura.aspx)
- [11] UNICA. Estatísticas. [www.unica.com.br/dadosCotacao/estatistica/](http://www.unica.com.br/dadosCotacao/estatistica/)
- [12] Federação da Agricultura do Estado de São Paulo. [www.faespenar.com.br/geral/noticias/detalhe/demanda-por-acucar-favorece-ano-de-novos-records-de-precos/2749](http://www.faespenar.com.br/geral/noticias/detalhe/demanda-por-acucar-favorece-ano-de-novos-records-de-precos/2749)
- [13] Ecodebate. [www.ecodebate.com.br/2010/02/08/agencia-ambiental-do-governo-dos-estados-unidos-reconhece-eficiencia-do-etanol-brasileiro/](http://www.ecodebate.com.br/2010/02/08/agencia-ambiental-do-governo-dos-estados-unidos-reconhece-eficiencia-do-etanol-brasileiro/)
- [14] EMBRAPA. [www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONTAG01\\_66\\_711200516719.html](http://www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONTAG01_66_711200516719.html)
- [15] Revista Pesquisa FAPESP. <http://revistapesquisa.fapesp.br/?art=3934&bd=1&pg=1>
- [16] Empresa Brasil de Comunicação. <http://agenciabrasil.ebc.com.br/noticia/2008-04-10/plantio-de-cana-de-acucar-tem-que-dobrar-para-cumprir-meta-de-producao-de-alcool>
- [17] UNICA. [www.unica.com.br/FAQ/](http://www.unica.com.br/FAQ/)
- [18] Manzatto, C.V., Assad, E.D., Bacca, J.F.M., Zaroni, M.J. and Pereira, S.E.M. (orgs.). 2009. Zoneamento Agroecológico da Cana-de-Açúcar. Expandir a produção, preservar a vida, garantir o futuro. [www.cnps.embrapa.br/zoneamento\\_cana\\_de\\_acucar/ZonCana.pdf](http://www.cnps.embrapa.br/zoneamento_cana_de_acucar/ZonCana.pdf)
- [19] Silva W.F., Aguiar, D.A., Rudorff, B.F.T., Sugawara, L.M., and Aulicino T.L.I.N. 2009. Análise da expansão da área cultivada com cana-de-açúcar na região Centro-Sul do Brasil: safras 2005/2006 a 2008/2009. Anais XIV Simpósio Brasileiro de Sensoriamento Remoto, Natal, Brasil, 25-30 abril, INPE, p. 467-474.
- [20] Canal Rural. [www.canalrural.com.br/canalrural/jsp/default.jsp?uf=1&local=1&id=2888234&action=noticias](http://www.canalrural.com.br/canalrural/jsp/default.jsp?uf=1&local=1&id=2888234&action=noticias)
- [21] Correio do Estado. [www.correiodoestado.com.br/noticias/preco-da-carne-nao-vai-diminuir-para-consumidor-final\\_99037/](http://www.correiodoestado.com.br/noticias/preco-da-carne-nao-vai-diminuir-para-consumidor-final_99037/)
- [22] Jornal Zero Hora. <http://zerohora.clicrbs.com.br/zerohora/jsp/default.jsp?uf=1&local=1&section=Economia&newsID=a3200717.xml>

- [23] O Estado de São Paulo. <http://economia.estadao.com.br/noticias/economia+geral,demanda-mundial-vai-ampliar-vendas-de-carne-e-graos,53900,0.htm>
- [24] Sparovek, G., Berndes, G., Egeskog, A., Freitas, F.L.M., Gustafsson, S., and Hansson, J. 2007. Sugarcane ethanol production in Brazil: an expansion model sensitive to socioeconomic and environmental concerns. *Biofuels, Bioproducts and Biorefining* 1:270–282.
- [25] Sparovek, G., Baretto, A., Berndes, G., Martins, S., and Maule, R. 2009. Environmental, land-use and economic implications of Brazilian sugarcane expansion 1996–2006. *Mitig Adapt Strateg Glob Change* 14:285–298.
- [26] Nassar, A.M., Rudorff, B.F.T., Antoniazzi, L.B., Aguiar, D.A., Bacchi, M.R.P. and Adami, M. 2008. Prospects of the sugarcane expansion in Brazil: impacts on direct and indirect land use changes. In: *Sugarcane ethanol: contributions to climate change mitigation and the environment*. Zuurbier, P. and van der Vooren, J. (Eds.), pp. 63-93. Wageningen Academic Press, Wageningen.
- [27] Lapola, D.M., Schaldach, R., Alcamo, J., Bondeau, A., Koch, J., Koelking, C., and Priess, J.A. 2010. Indirect land-use changes can overcome carbon savings from biofuels in Brazil. *PNAS* 107(8):3388-93.
- [28] Ribeiro, M.C., Metzger, J.P., Martensen, A.C., Ponzoni, F.J., and Hirota, M.M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation* 142(6):1141-1153.
- [29] Roda, M., and Tabarelli, M. 2007. An opportunity to Pernambuco Endemism Center. *Natureza e Conservação* 3:128-134.
- [30] Goerck, J.M. 1997. Patterns of rarity in the birds of the Atlantic forest of Brazil. *Conservation Biology* 11:112-118.
- [31] CI-Brasil, Fundação SOS Mata Atlântica, Fundação Biodiversitas, Instituto de Pesquisas Ecológicas, Secretaria do Meio Ambiente do Estado de São Paulo, and SEMAD/Instituto Estadual de Florestas-MG. 2000. [www.conservation.org.br/publicacoes/files/Sumario.pdf](http://www.conservation.org.br/publicacoes/files/Sumario.pdf)
- [32] Mongabay. [http://news.mongabay.com/2011/0614-moukaddem\\_brazil\\_forest\\_code.html](http://news.mongabay.com/2011/0614-moukaddem_brazil_forest_code.html)
- [33] Environmental Defense Fund. <http://blogs.edf.org/climatetalks/2011/06/02/brazil-at-the-crossroads/>
- [34] Global Reporting Initiative. [www.globalreporting.org](http://www.globalreporting.org)
- [35] The Economics of Ecosystem and Biodiversity. [www.teebweb.org/](http://www.teebweb.org/)
- [36] Companhia Nacional de Abastecimento. Conab 2008 – Perfil do Setor do Açúcar e do Álcool no Brasil. [www.conab.gov.br/conabweb/download/safra/perfil.pdf](http://www.conab.gov.br/conabweb/download/safra/perfil.pdf)
- [37] [www.sidra.ibge.gov.br](http://www.sidra.ibge.gov.br)
- [38] AGRANP (2011). *Agrianual 2011: anuário da agricultura brasileira*. Instituto FNP, São Paulo.
- [39] Sachs, I. 2007. A revolução energética do século XXI. *Estudos Avançados* 21(59): 21-38.
- [40] Abramovay, R. (Org.). *Biocombustíveis: a energia da controvérsia*. Editora Senac, São Paulo.
- [41] *Jornal Diário de Pernambuco*. [www.diariodepernambuco.com.br/2011/01/27/economia5\\_0.asp](http://www.diariodepernambuco.com.br/2011/01/27/economia5_0.asp)
- [42] PE 360 Graus. <http://pe360graus.globo.com/noticias/economia/emprego/2011/02/15/NWS,529212,10,180,NOTICIAS,766-COM-EMPREGOS-AGORA-SERTAO-SEDUZ-FORASTEIROS.aspx>