CARTOGRAPHY OF THE ENVIRONMENTAL IMPLICATIONS OF ONSHORE OIL PRODUCTION IN THE MUNICIPALITY OF CARMÓPOLIS, STATE OF SERGIPE, BRAZIL[1, 2]

CARTOGRAFIA DAS IMPLICAÇÕES AMBIENTAIS DA PRODUÇÃO DE PETRÓLEO ONSHORE NO MUNICÍPIO DE CARMÓPOLIS, SERGIPE, BRASIL

MAPEAMIENTO DE LAS CONSECUENCIAS AMBIENTALES DE LA PRODUCCIÓN DE PETRÓLEO ONSHORE EN EL MUNICIPIO DE CARMÓPOLIS, ESTADO DE SERGIPE, BRASIL

Ivana Silva Sobral - Universidade Federal de Sergipe - Aracaju - Sergipe - Brasil
ivanasobral@hotmail.com

Gicélia Mendes da Silva - Universidade Federal de Sergipe - Aracaju - Sergipe - Brasil
gicamendes@yahoo.com.br

Abstract

The Carmópolis Field, which is the largest group of onshore oil fields in Brazil, manages the major proportion of onshore oil production in Sergipe State. In spite of its economic importance, it causes significant environmental damage, endangering the health of the population and the quality of the Municipality of Carmópolis landscape. This research aimed to analyze the spatial implications of onshore oil production on the Municipality of Carmópolis, map the use of soil, and calculate the landscape quality index, using landscape ecology as the theoretical and methodological basis. It is hoped that this will support management actions to minimize or compensate for environmental impacts, in compliance with environmental legislation and initiatives to protect the remaining natural ecosystems. Research results show that a) the landscape quality index of the Municipality of Carmópolis is 0.54, classified as regular; b) oil wells, roads, along with gas and oil pipelines fragment the city landscape, jeopardizing the resilience of natural ecosystems.
Keywords: landscape quality, geoprocessing, landscape ecology.

Resumo

O Campo de Carmópolis, maior conjunto de jazidas de petróleo *onshore* do Brasil, é responsável por grande parte da produção terrestre do Estado de Sergipe. Apesar de sua importância econômica, gera impactos ambientais significativos que comprometem a saúde da população e a qualidade da paisagem do município. Visando subsidiar ações de manejo que minimizem ou compensem os impactos ambientais; cumpram com a legislação ambiental e protejam os ecossistemas naturais remanescentes, esta pesquisa objetivou analisar as implicações espaciais da produção de petróleo *onshore* no município de Carmópolis; mapear o uso do solo e calcular o índice de qualidade da paisagem, utilizando a ecologia da paisagem como a base teórico-metodológica. Constatou-se que a) o índice de qualidade da paisagem do município de Carmópolis é 0,54, classificado como regular; b) os poços, as estradas e os dutos de gás e petróleo fragmentam a paisagem do município, comprometendo as resiliências dos ecossistemas naturais.
Palavras-chave: qualidade da paisagem, geoprocessamento, ecologia da paisagem.

1 Translated by Caius Brandão (caiusbrandao@globo.com) and Carla Milani Damião (cmdw16@gmail.com). Revised by Robert Neil Wall (neilwall2005@yahoo.co.uk).

Resumen

El Campo de Carmópolis, más grande conjunto de yacimineto de petróleo *onshore* de Brasil, es responsable por gran parte de la producción terrestre del Estado de Sergipe. A pesar de su importancia económica, genera impactos ambientales significativos que ponen en peligro la salud de la población y la calidad del paisaje de la ciudad. Con el fin de apoyar las acciones de manejo que minimicen o compensen los impactos ambientales; cumplir con la legislación ambiental y la protección de los ecosistemas naturales que quedan, este estudio tuvo como objetivo analizar las implicaciones espaciales de la producción de petróleo *onshore* en el municipio de Carmópolis; la cartografía del uso del suelo y calcular el índice de calidad del paisaje, utilizando la ecología del paisaje como base teórico-metodológica. Se comprobó que a) el índice de calidad del paisaje del municipio de Carmópolis es 0,54, clasificado como regular; b) los pozos, las carreteras y los ductos de gas y petróleo fragmentan el paisaje de la ciudad, lo que afecta la capacidad de recuperación de los ecosistemas naturales.
Palabras clave: calidad del paisaje, geoprocesamiento, ecología del paisaje.

Introduction

The development of humankind is related to extraction of mineral resources. In Brazil, mineral exploration, aiming at economic development, started at the beginning of the seventeenth century, with the discovery of gold, diamonds and emeralds. This led to Portuguese immigration, particularly in São Paulo de Piratininga, São Vincente and the northeast coast.

Nowadays, Brazil is one of the major producers of mineral resources in the world. Petroleum, responsible for a large part of Brazilian energy, is used as a raw material in the fabrication of various products, such as gasoline, diesel fuel, benzenes, tar and plastic polymers.

Petroleum constitutes an energy source in the current development model, being an important part of the Brazilian economy, in attracting investment and positive influence in the Gross Domestic Product (GDP), in the balance of trade and the generation of employment and income. On the other hand, its extraction causes negative social and environmental impact[2] on natural ecosystems and in the quality of life of workers and local communities. This being the case, reconciling mining with environmental protection, despite the demands of Brazilian legislation, remains a challenge.

For compliance with Brazilian legislation, the spatial study of the environmental implications of oil production is necessary in order to support the implementation of environmental management strategies. As environmental management tools, land-use mappings and monitoring of landscape quality are fundamental in supporting proposals for mitigation and compensation measures.

The management under the environmental perspective aims to comply with the usage, control and protection of the environment, whilst meeting the social and governmental aspirations for environmental policy, whether expressed or not (Santos, 2004). Taken in this perspective, environmental management reveals harmony with the principles of sustainable development, according to which the welfare of present and future generations and the protection of natural resources are an essential approach.

In the state of Sergipe, the Municipality of Carmópolis is one of the largest producers of onshore oil in the country. Depending on the environmental vulnerability of its landscapes, as a result of the exploitation of mineral resources, affecting the homeostasis of natural ecosystems and the quality of life of local people, a spatial study of environmental quality is necessary in order to subsidize efficient environmental management.

This study starts from the assumption that the landscapes of the Municipality of Carmópolis are being degraded by oil activity and have low levels of environmental quality. Furthermore, it is assumed that environmental impacts from the oil activity are not being compensated or mitigated adequately.

This research aims to analyse the spatial implications of onshore oil production in the Municipality of Carmópolis in order to support the implementation of management actions to offset or mitigate negative environmental impacts, to comply with legislation and protect the remaining natural ecosystems, to map land use and calculate the landscape quality index, using the Landscape Ecology as a theoretical-methodological basis.

Methodology

The Municipality of Carmópolis, located in the Lower Cotinguiba region in Sergipe-Alagoas sedimentary basin, has part of its administrative limits on Carmópolis Field, the largest onshore field in Brazil.

In this research, the use of municipal land was mapped using Rapid Eye satellite's imagery (MMA, 2012), as well as data collected in the field, and further elaboration of the environmental quality map. The photo-interpretation of images was performed in the free software Quantum GIS, which has processing functions of spatial databases. The components of the landscapes were qualitatively and quantitatively valued, in accordance with the evaluation system proposed by this research, based on the methodology adapted from Landovsky et al. (2006) (Table 1).

Table 1- Landscape evaluation system proposed by this research

Landscape Component	Index	Environmental Quality
Native vegetation	1.0	Very high
APP with native vegetation		
River, creek		
Weir, Dam	0.75	High
Flooded area		
Coconut Plantation		
Agricultural Crop	0.50	Average
Grazing land		
APP without native vegetation	0.25	Low
Urban area		
Built-up area		
Road	0.0	Too low
Exposed soil		
Oil and gas mining		

Source: Landovsky et al. (2006).

To assess the environmental quality of landscape components, the following justification was used:

a) Very High Quality

The quality of landscape components “Native vegetation”, “Native vegetation in permanent preservation area” and “River and stream” were classified as “very high” as they constitute the main elements for the sustainability of the landscapes of onshore oil producing cities. Therefore, it is considered that these components are primarily responsible for ensuring the support of the life of natural systems and the local population.

b) High Quality

“Weir” and “Dam” as landscape components were classified as “high” quality, since they are important for the sustainability of the landscape and of the local, - especially the rural -, population.

c) Medium Quality

“Agricultural Crop” and “Grazing land” as landscape units were classified as “average” quality because, even though they are fundamental activities for the local economy, they are detrimental to environmental sustainability.

d) Low Quality

"Urban area "and other units such as "Built-up Areas" and "Permanent Preservation Area without native vegetation" were classified as "low" quality because they fragment the natural ecosystems and seal the soil.

e) Very Low Quality

"Gas and oil mining", "Exposed Soil" and "Road" as landscape units were classified as "very low" quality because they fragment the landscape and cause irreversible damage to the environment.

Landscape Ecology was used to identify the three basic elements of landscape structure: Matrix: the element that dominates the dynamics of a landscape; Spots: non-linear fragments of apparent homogeneity that disrupt the matrix; Corridors: linear elements of apparent homogeneity, which are distinguishable in the matrix (Forman; Godrom, 1986).

The quality index of the city's landscape was calculated using the formula proposed by Sobral (2012):

$$IQPA = \frac{(\%\ Ac1 \times Vc1)+(\%\ Ac2 \times Vc2)+(\%\ Ac3 \times Vc3)+(\%\ Ac4 \times Vc4)+(\%\ Ac4 \times Vc4)}{100}$$

Subtitle: QPA = Landscape Quality
% Ac = Percentage of the classes area
Vc = Class value

Source: Sobral (2012).

After the measurement of the Municipality of Carmópolis' landscape quality index, ratings were applied on the following criteria adapted from Martins and Cândido (2008) (Table 2).

Table 2: Classification of Landscape Quality

Landscape Quality Index (0 - 1)	Landscape Quality
0.80 <Index <1.0	Ideal
0.60 <Index <0.80	Good
0.40 <Index <0.60	Regular
0.20 <Index <0.40	Bad
0 <Index <0.20	Terrible

Source: Martin and Cândido (2008).

Results and discussion

Environmental impacts are inherent to oil activity; however, they should be compensated as per the conditions laid down in the environmental licensing process. Licensing is configured in the main environmental management tool to monitor the environmental implications of oil production. The environmental license is a document by which the licensing environmental agency establishes environmental conditions to be fulfilled by Petrobras. After its expiration, the license can only be renewed if the conditions have been agreed upon.

Although most Carmópolis municipal wells were licensed, significant environmental impacts such as gas and oil leakages, deforestation of legally protected areas, fragmentation of ecosystems and contamination of water resources have been observed, indicating a breach of environmental legislation. To comply with environmental legislation it is necessary that Petrobras meets the environmental constraints and performs the monitoring of oil exploration.

The landscape study, in turn, is seen as an important resource in monitoring the impacts of potentially degrading activities as it reveals how the geographic space stands according to its use (Landovsky, 2009). The landscape quality represents the level of excellence of its visual characteristics, the diversity of which makes it difficult to assess in absolute terms; it is therefore necessary to adopt methods based on value judgments (Hardt, 2004).

In spatially analysing the consequences of oil production in the Municipality of Carmópolis, it was found that the "Livestock Grazing" component (48.29%) is the matrix of its landscape, being the element that dominates the city landscape (Figure 1). The matrix is interrupted by stains such as "Coconut Plantation" (12.98%), "Native vegetation" (10.49%); "Agricultural Crop" (7.62%); "Urban area" (3.35%); "Built-up Area" (2.86%); "Oil and Gas Mining" (2.31%); "Flooded Area" (1.91%); "ExposedSoil" (0.215) and "Water Resources" (0.15%) (Figure 2). The corridors Permanent Preservation Areas ("APPs") (8.53%) and "Rivers and Creeks" positively interconnect blots; since the corridor "Road" (1.30%) connects the spots causing negative environmental impacts, as fragmented landscapes.

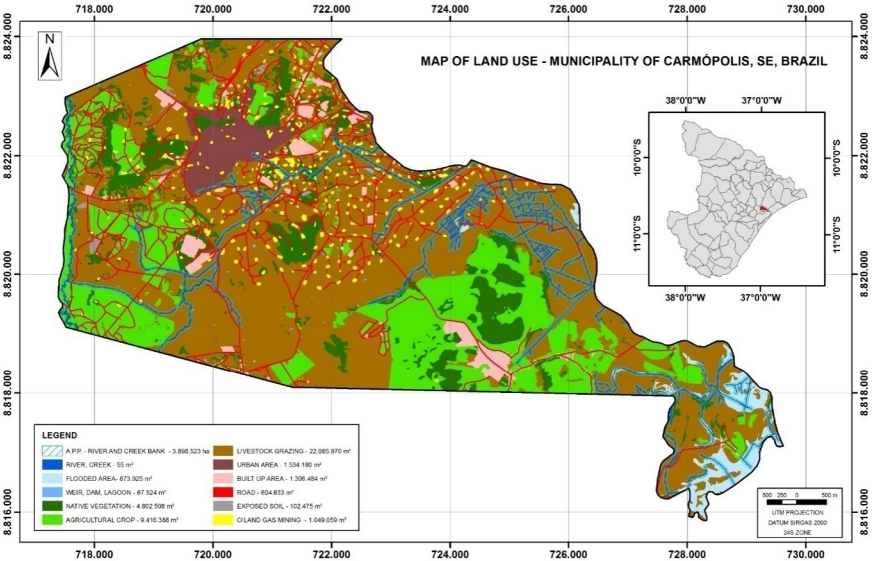

Figure 1- Municipality of Carmópolis (SE) land use location Map

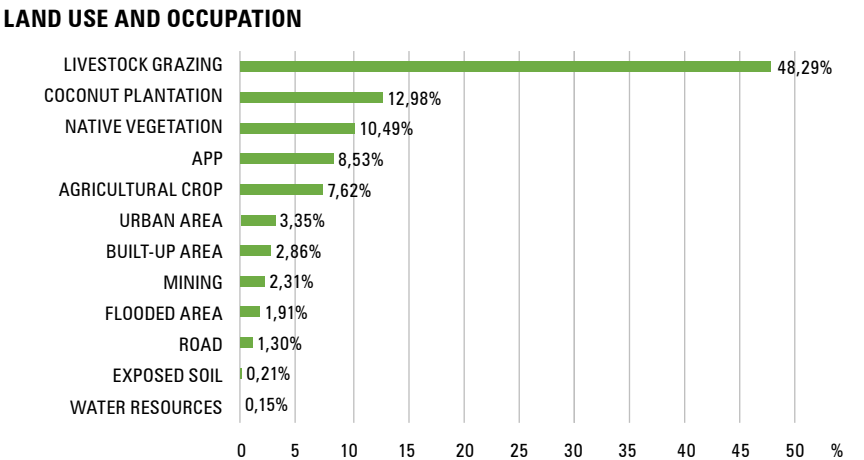

Figure 2 - Usage and occupation of land in the Municipality of Carmópolis, Sergipe

The matrix "pasture" covers the land in both the municipal area of oil production, as well as in the non-producing area. As livestock farming is extensive, the animals are raised in open areas without much supervision, feeding on natural and cultivated pastures, resulting in low productivity. In both natural and cultivated pastures, animals have been observed feeding on the perimeter of exploration wells, in areas contaminated by oil spills and gas leaks, thus casting doubt on the quality of the meat and dairy products produced in the confines of the municipality. According to Netto et al. (2000), polycyclic aromatic hydrocarbons (PAHs), petroleum components, are organic pollutants of environmental significance and toxicological interest, as many have pre-carcinogenic and / or mutagenic properties for humans and animals.

Figure 3 - Oil and gas leakage in the Municipality of Carmópolis, June/2014

Source: Sobral and Mendes (2014).

The Municipality of Carmópolis oilfield contains the highest number of producing wells in the country. The municipal mining area comprises 1,105 oil and gas wells, representing 2.31% of the municipal area and is of very low quality. Such wells manifest themselves as spots that negatively break up the municipal landscape and cause irreversible damage to the environment, such as: soil sterilization, loss of biodiversity, soil erosion, water and soil contamination, as well as air pollution.

Oil and gas leaks were observed in the vicinity of exploration fields (Figure 3), affecting local ecosystems and the quality of life for the region's resident population. According to Magalhães et al. (2006), one liter of oil is sufficient to contaminate the potability of about 1 million liters of water and also create a film covering an area of up to one thousand square meters on the surface of a stream of water, with significant environmental impact as an implication.

The component "Coconut plantation" appears as minute specks in the oil producing area. In non-producing areas, however, it dominates both landscape and pasture. It was found that 5,930,491 hectares of the municipality are covered by Coco-of-Bahia plantation (*Cocosnucifera L.*). According to the Brazilian Institute of Geography and Statistics (IBGE) (2013), 3,000 fruits per hectare are produced in the region.

The landscape component "native vegetation" occupies only 10.49% of the municipal area. For the municipality to be in compliance with the forest legislation, however, this figure should be approximately 18.03%. Consequently, the municipality has a deficit of about 3,446,968 hectares, mainly caused by the suppression of natural vegetation to allow the installation of wells, roads, as well as oil and gas pipelines.

The Atlantic Forest, the typical vegetation of the region, although highly degraded, has great economic and environmental value. In this sense, it was observed that the largest natural vegetation blots are not in the oil producing areas. In these areas of production, the stains are at an advanced process of fragmentation. Among the consequences of forest fragmentation process, attention is called to the decline of biological diversity, the disturbance of the hydrological regime of river basins, the degradation of natural resources and the deterioration of the quality of life of its populations, especially the traditional ones (Martins et al., 2002).

Confronted by the environmental implications caused by oil exploration, it is necessary to restore degraded areas so that the principles

of "polluter pays" and of cooperation enshrined in the Brazilian Federal Constitution are achieved. The principle of "polluter pays", through its economic character, must be used to demand that Petrobras faces its negative impacts, shouldering the costs essential to the reduction, elimination or neutralization of environmental damage caused.

The principle of cooperation, in social nature, holds that environmental preservation is a diffuse and collective right, thus requiring popular participation in decision-making, in tandem with the government and Petrobras, concerning impacts and restoration of degraded areas.

The areas of "Permanent Preservation (APPs): river border" cover approximately 8.53% of the municipal area, although most are deforested and occupied by oil wells and administrative buildings. The APPs are protected territorial spaces in accordance with the provisions of section III, § 1 of art. 225 of the Federal Constitution.

Forest legislation, through the medium of Federal Law No. 12,651 (Brazil, 2012), details the PPAs, whose objectives relate to the conservation of water resources, landscape, geological stability, biodiversity and gene flow of fauna and flora. In addition, this ensures the well-being of human populations. In other words, if APPs are preserved, they will be fundamental to the quality of the landscapes, since they form important ecological corridors for environmental balance.

Agricultural crops form themselves into blots on the landscape and occupy about 7.62% of the municipal area. *Coco-da-Bahia*, banana, sugar cane, beans, corn and manioc are the main products, which may be contaminated as a result of the pollution of aquatic resources and of the land by hydrocarbons.

The urban area occupies 3.35% of the total area. Therein are Petrobras installations, a natural gas processing plant and 216 companies with 3,936 employees (IBGE, 2013).

"Roads" (1.30% of the area), from an economic perspective, form important corridors for the flow of goods, supplies and maintenance of oil and gas wells; however, in its environmental aspect, it is responsible for fragmenting natural ecosystems fundamental to the environmental quality of the landscape.

In addition to urban space and roads, the municipality comprises 2.86% of the built-up area. These areas primarily contain oil installations,

such as a natural gas processing plant, a steam injection station, substations, as well as water treatment and pumping stations.

Wetlands, occupying 1.91% of the municipal area, commonly present aquatic macrophytes with denitrification capacity, serving as a reduction of nitrogen index systems. In areas contaminated by oil spillage and gas leakage, as observed in the Municipality of Carmópolis, the resilience capacity of these environmental systems is reduced.

Water resources components (0.15%), represented by rivers, streams, weirs and dams, are fundamental to the sustainability of the landscape, being essential for the survival of biodiversity and population. Nevertheless, some of the spots observed are contaminated by oil. The Japaratuba and Riachão rivers, and Mariquita and Diogo streams form drainage corridors with constant water flows, biodiversity and sediments.

When analyzing the landscape quality map of the Municipality of Carmópolis, it was observed that 11.51% of the area is of very high quality, 11.26% high, 55.90% average, 13.71% low, and 3.93% very low (Figure 4). Therefore, the Municipality of Carmópolis landscape quality index is 0.54, classified as regular performance (Table 3).

Table 3: Landscape Quality Index for the Municipality of Carmópolis, Sergipe

Quality of Landscapes Classes	Percentage of classes areas	Landscape Quality Index
Very high	11.51%	11.51 x 1.00 = 11.51
High	15.02%	15.02 x 0.75 = 11.26
Average	55.90%	55.90 x 0.50 = 27.95
Low	13.71%	13.71 x 0.25 = 3.43
Very low	3.83%	3.83 x 0.00 = 0.00
Municipality of Carmópolis Landscape Quality Index		54.14/ 100
		0.54 (Regular)

Source: Sobral and Mendes, 2015.

The loss of landscape quality is chiefly caused by oil wells and mining industry installations, which, in fragmenting natural vegetation,

provoke discontinuity in the spatial distribution of resources, affecting the carrying capacity of natural systems, species survival and quality of life of the population. The implementation of mitigating measures such as: environmental monitoring of wells to arrest the impacts of oil and gas leakages, the implementation of ecological corridors to facilitate gene flow, the landscape management to ensure that the environmental protection areas are jointly managed, as well as reforestation to mitigate the areas deforested by mining activity, is fundamental in minimizing the environmental implications of onshore production.

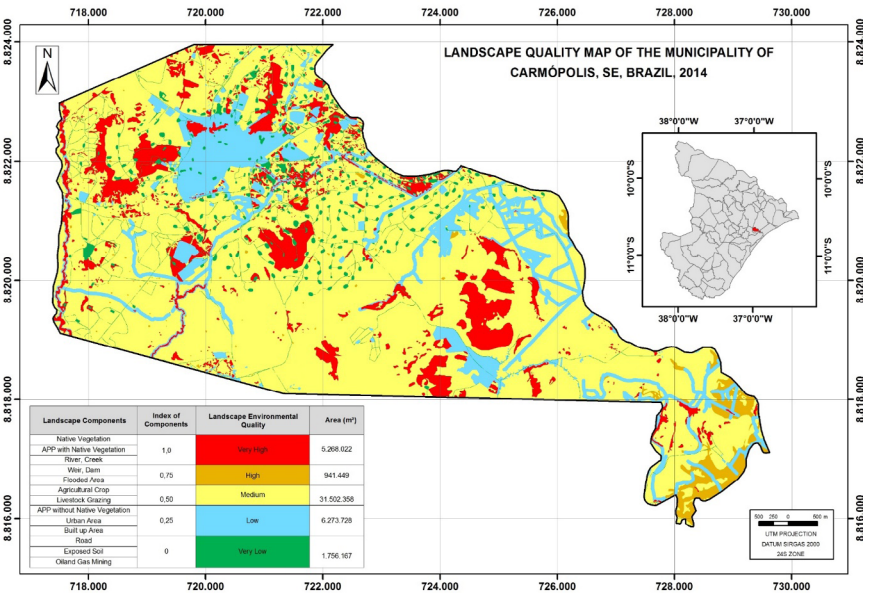

Figure 4 - Municipality of Carmópolis landscape quality map

Source: Sobral and Mendes, 2015.

Final Considerations

Hypotheses concerning degradation of the Municipality of Carmópolis landscapes through oil activity, and that environmental impacts are not being adequately mitigated, have been confirmed.

Therefore, it is necessary to face urgently the environmental constraints contained in the environmental licensing process of oil wells in the Municipality of Carmópolis, otherwise the licenses will not be renewed.

The implementation of priority management actions to stop, minimize and offset the environmental impacts arising from onshore oil production has become crucial, in order to ensure the protection of natural ecosystems and the quality of life of the local population. In this context, important tools for environmental management of oil production activities are: the monitoring of the environmental licensing process, the recovery of the landscape quality of the mined areas, the implementation of ecological corridors through reforestation with native species.

Acknowledgements

We would like to thank the Higher Education Personnel Training Coordination (CAPES/PNPD) for its granting of the post-doctoral fellowship. We would also like to thank the Post-Graduation Program in Development and Environment of the Federal University of Sergipe (UFS) for its institutional support.

Endnote

[2] CONAMA 001 Resolution defines environmental impact as "any change in the physical, chemical and biological properties in the environment, resulting from human activities that directly or indirectly affect the biota; the environment; the population's quality of life as well as social and economic activities" (BRAZIL, 1986).

Bibliography

BRASIL. Resolução Conama 001, de 23 de janeiro de 1986. *Diário Oficial da União*, Brasília, 23 Jan. 1986. Retrievied from: <http://www.mma.gov.br/port/conama/res/res86/res0186.html>. Accessed on: 15 feb. 2015.

_____. Lei n. 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis n. 6.938, de 31 de agosto de 1981; 9.393, de 19 de dezembro de 1996; e n. 11.428, de 22 de dezembro de 2006; revoga a Lei n. 4.771, de 15 de setembro de 1965; e n. 7.754, de 14 de abril de 1989, e a Medida Provisória n. 2.166-67, de 24 de agosto de 2001; e dá outras providências. *Portal da Legislação:* Leis Ordinárias. 2013. Retrievied from: <http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.html>. Accessed on: 15 feb. 2015.

FORMAN, R. T. T.; GODROM, M. *Landscape Ecology.* New York: John Wiley & Sons, 1986.

HARDT, L. P. A. Ecologia da paisagem: fundamentos à gestão do espaço urbano. *OLAM: Ciência & Tecnologia*, Rio Claro, v. 4, p. 597-612, 2004.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. *Censo*, 2013. Retrievied from: <http://cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=280150>. Accessed on: 12 aug. 2015.

LANDOVSKY, G. S.; ARAKI, H.; BATISTA, D. B. Análise da qualidade visual da paisagem da região de Tibagi, PR, aplicando o sensoriamento remoto. *Revista Brasileira de Engenharia Agrícola e Ambiental,* Campina Grande, v. 10, p. 188–195, 2006.

LANDOVSKY, G. S. Utilização de imagens CBERS para a avaliação da qualidade visual da paisagem. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 14., Natal, 2009. *Anais*... Natal, 2009.

MAGALHÃES, J. M; DONOSO, F. F.; MELO, P. L. R. *Re-refino no Brasil: A reciclagem de óleos usados.* Universidade do Vale do Rio dos Sinos, 2006. 14 p. Retrievied from: <http://www.ead.fea.usp.br/semead/10semead/sistema/resultado/trabalhosPDF/584.pdf>. Accessed on: 17 july 2015.

MARTINS. I. C. M.; SOARES, P. S.; SILVA, E.; BRITES, R. S. Diagnóstico ambiental no contexto da paisagem de fragmentos florestais naturais "IPUCAS" no município de Lagoa da Confusão, Tocantins. *Revista Árvore*. Viçosa, v. 26, p. 299-309. 2002. Retrievied from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-67622002000300005>, Viçosa, v. 26, p. 299-309, maio/jun. 2002. Accessed on: 14 aug. 2015.

MARTINS, M. F.; CÂNDIDO, G.A. *Índice de Desenvolvimento Sustentável para Municípios (IDSM):* Metodologia para análise e cálculo do IDSM e classificação dos níveis de sustentabilidade – uma aplicação no Estado da Paraíba. João Pessoa: Sebrae, 2008.

MINISTÉRIO DO MEIO AMBIENTE. *Imagens de satélites RapidEye. Brasília, 2012.*

NETTO, P. A. D.; MOREIRA, J. C.; ARBILLA, G.; FERREIRA L. F. V.; OLIVEIRA S. A.; BAREK, J. Avaliação da contaminação humana por hidrocarbonetos policíclicos aromáticos (HPA's) e seus derivados nitratos (NHPAS): Uma revisão metodológica. *Química Nova*, São Paulo, v. 23, p. 265- 273, 2000.

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

SOBRAL, I. S. *Instrumentos de gestão ambiental como subsídio para o desenvolvimento sustentável dos projetos de assentamentos de reforma agrária de Sergipe***.** Tese (Doutorado) – NPGEO, Universidade Federal de Sergipe, São Cristóvão, 2012.

Ivana Silva Sobralhas a degree in Biological Sciences and Geography, a Master's degree in Agroecosystems and a PhD in Geography from the Federal University of Sergipe (UFS). She is currently collaborating lecturer in the Graduation Program in Development at that University.

Gicelia Mendes da Silva has a bachelor's degree, a Master's degree and PhD in Geography from the Federal University of Sergipe (UFS). She is currently a lecturer in the Department of Geography at that University.

Received for publication on August 6, 2015
Accepted for publication September 26, 2015