The Use of Geotechnologies in the Analysis of Forest Fires in the Floresta Estadual Edmundo Navarro de Andrade, Rio Claro, São Paulo, Brazil

Amanda Lombardo Fruehauf, and Magda Adelaide Lombardo

1. *Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Universidade de São Paulo (USP), SP, Brazil*

2. *Departamento de Ciências Florestais, Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Universidade de São Paulo (USP), SP, Brazil*

Abstract: The management of the Conservation Units can contribute to the mapping and planning in order to ensure the sustainability of these areas. Geotechnologies such as free QGIS software together with Google Earth, assist in the forest management process, allowing constant monitoring of land use and occupation. In this work, the free software QGIS was used to classify the land use and occupation of the "Floresta Estadual Edmundo Navarro de Andrade", located in the city of Rio Claro, São Paulo, Brazil, with the following classes: forest, eucalyptus, palm trees, water body, constructed area and exposed soil. A fieldwork was also done in the study area to identify subclasses of land use and survey of the occurrence of forest fires in the years 2012 up to 2018. In the analysis of forest fires, an environmental impact assessment will be proposed to this cause in the environment. It was verified that there is a need for constant monitoring so that forest fires do not occur, especially during the dry season. With the information acquired through QGIS it is possible for forest managers to better plan the reforestation of the exposed soil areas, improving the various environmental services, thus serving as an environmental tool for the prevention of future fires.

Key words: geotechnology, conservation unit, environmental management, forest fires

1. Introduction

Geotechnologies are increasingly being used to map various areas of interest to environmental study of land use and occupation. The remote sensing products, both aerial photographic and orbital images, assist in the planning process, allowing the identification of the characteristics and origins of the modifying agents of space. Besides allowing to monitor the intensity and extent of changes caused by social human activities. Geoprocesing can be applied in this context because it is a tool that allows the integration of planning with resource management [1].

Among the geotechnologies used for mapping, we use QGIS which has the advantage of being free software and the satellite images are obtained by Google Earth. The Geographic Information System (QGIS), created by the Open Sourc and Geospatial Foundation (OSGeo), has been available in open source and free on the internet since 2009 to support and build geospatial programs.

Geographic Information Systems (GIS) stand out as a mapping tool to get answers to the various questions about physical data collection and environmental planning, mainly by describing the mechanisms of changes in the environment, as well as assisting in the planning and management of existing natural resources [2].

Corresponding author: Amanda Lombardo Fruehauf, Post Graduate in Forest Resource; research areas/interests: forest sciences. E-mail: amandalombardo@usp.br.

It is also noteworthy that the emergence of QGIS together with Google Earth brought people closer to the knowledge of geotechnologies applied in geoprocessing [3].

According to Lombardo (1995) [4], remote sensing products, both aerial photography and orbital images, help in the planning process, allowing to identify the characteristics and origins of space modifying agents, as well as to monitor the intensity and extent of changes caused by land use and occupation.

Among the geotechnologies used for mapping, the QGIS is used. According to Ávila (2013) [5], the joint use of QGIS and Google Earth is a solution for projects related to environmental analysis.

According to Soares and Santos (2003) [6], forest fire is the free or uncontrolled spread of fire in forests and other forms of vegetation.

Vegetation fires can cause damage to the environment, such as damage to fauna and flora, people, including loss of life, as well as considerable economic consequences, such as habitat de-characterization, wood burning and the cost of controlling it [7].

To avoid forest fire in the area as a negative environmental impact, it would be important to implement the Environmental Impact Assessment (EIA), having as one of its objectives to avoid, minimize or compensate for the relevant biophysical and social negative effects.

Therefore, it is important to know the environment in which negative environmental impact is avoided. According to Sánchez (2008) [8], the more we know about an environment, the greater the ability to predict impacts and thus reduce negative impacts.

Fire also causes pollution, which is the introduction into the environment of matter or energy that may negatively affect humans or other organisms [8].

This study aimed to map with the use of QGIS the FEENA located in the city of Rio Claro, state of São Paulo, in the south eastern region of Brazil. Classifying land use and occupation, we also calculated the area of forest and eucalyptus in addition to surveying forest fires in the forest from 2012 to 2018.

2. Material and Methods

The study area was mapped using the free software QGIS, land use and occupation were classified into the following classes: eucalyptus stands; native forest; building area; palm trees; water body; exposed soil (degraded). All layers of the work were in shapefile with the polygon vector layer, for the visualization of the images we used Open Layersplugin complement. In the information plans generated in QGIS, the UTM coordinate system with Datum WGS84 22S spindle was used, which presented values in meters and allowed the calculation of the areas of interest.

Several areas of science employ geoprocessing, such as cartography, geography, agriculture and forestry and geology, including studies of urban and rural planning, means of transport, communication and energy [9].

According to Cruciani (2002) [10], more and more mathematical models are being used that have been associated with geographic information systems that allow a detailed and specialized description of the physical characteristics of the area. Remote sensing has been getting better techniques and products, especially in spatial and spectral resolution.

The chosen spatial layout houses an important National Conservation Unit System (SNUC), the Edmundo Navarro de Andrade State Forest (FEENA), standing out for its environmental and historical-cultural aspects [11].

According to Law No. 9,985 of July 18, 2000, which provides for SNUC, the entire Conservation Unit in Brazil must have a document that regulates the management activities to be performed in the corresponding areas.

It was carried out by collecting data from FEENA, a history of arson from 2012 until June 2018. Planning for forest fire prevention and control in a Conservation Unit depends on the survey of the causes, frequency and consequences of the fire. in a certain area, among other knowledge. Thus, one of the main foundations for

protecting Conservation Units is research on the historical patterns of forest fires in and around them [12].

2.1 Study Area Characteristics

FEENA is located in an important Conservation Unit for Sustainable Use of the State of São Paulo, located in southeastern Brazil, in the far east of Rio Claro [13], was founded by agronomist Edmundo Navarro de Andrade (Fig. 1).

According to Moura (2011) [14], the State Forest presents a mixture of forest plantations, highlighting the different eucalyptus species, with different ages and density, which allowed the development of secondary forest vegetation in its interior.

In the early twentieth century, researcher Edmundo Navarro de Andrade directed his research to find a solution to the forests that were being devastated for the use of wood as charcoal fuel in steam locomotives. His research came to fruition when the results of experiments with the use of the eucalyptus species, originating in Australia, proved to be the ideal species to use wood for reforestation and, later in consumption for charcoal (firewood), railway sleepers. and also the manufacture of wooden wagons, so FEENA was initially directly linked to the Paulista Railway Company [15].

Fig. 1 City location of Rio Claro and limits of Floresta Estadual Edmundo Navarro de Andrade (Source adapted: Google Earth).

Known internationally as the "cradle of eucalyptus in Brazil", because in 1916 the "Eucalyptus Museum" was created, which had the objective of exposing the results of experiments on the use of eucalyptus. These experiments were intended to increase their durability and endurance through genetic improvements [11].

The study area of the work was the "Floresta Estadual Edmundo Navarro de Andrade" (FEENA), with an area of 2,222.80 hectares. It is a place for planting exotic trees. The study aimed to map FEENA's land use and occupation in 2017. The areas of planted forest and native forest were calculated, according to the mapping of the area to verify the percentage of each of these vegetation, the respective areas were obtained by field calculator inserted in the attribute table. It is important to highlight that FEENA is a Conservation Unit (UC) that is within the National Forest group.

The FEENA has a public use area that constitutes natural and man-made areas. The forest is composed by the Solar Navarro de Andrade, Eucalyptus Museum, Visitor Center, Chapel, Big House, the gardens and green areas, as well as the trails and the tree.

According to the Brazilian Ministry of the Environment, the UCs are natural areas that can be protected by their special characteristics, they are territorial spaces and their environmental resources, including the jurisdictional waters, with relevant natural characteristics, legally established by the Government, with conservation objectives and defined limits, under special management regime, to which adequate guarantees of protection of the law apply. In addition, they guarantee traditional populations the sustainable use of natural resources in a rational manner and also enable the surrounding communities to develop sustainable economic activities.

The climate in the study area, according to the Koeppen classification, is Cwa type, with the coldest month average ranging between 3 and 18°C and during the warmer months average temperature above 22°C and annual rainfall is 1,400 mm/year [16].

The ortophoto illustrates in greater detail the differences in FEENA forest and eucalyptus, considering texture and roughness. In the west portion stand out the urban area of Rio Claro, characterized by little vegetation area, this image was available by CEAPLA, UNESP, Rio Claro, São Paulo (Fig. 2).

FEENA is inserted in the relief called Paulista Peripheral Depression, Middle Tietê Zone, consisting mainly of sandstones. This geomorphological unit has its morphogenetic evolution associated with the erosion work of rainwater and rivers, forming a compressed relief unit between the Atlantic Plateau and the Cuestas relief [17].

According to Bartsch (2015) [18], FEENA is located in the Corumbataí river basin region, more precisely in the Ribeirão Claro sub-basin and there are forests plus two sub-basins represented by the Santo Antônio and Ibitinga streams.

The satellite images were taken from Google Earth which showed the visualization of the desktop and the delimitation of the state, city of Rio Claro and FEENA, were obtained from the database available on the IBGE website.

We highlight the importance of conducting the mapping of FEENA, as this is an important Conservation Unit of the city of Rio Claro, SP. In addition to sheltering eucalyptus, in the forest there is an understory rich in native species that attracts a great diversity of fauna that must be preserved. Also, its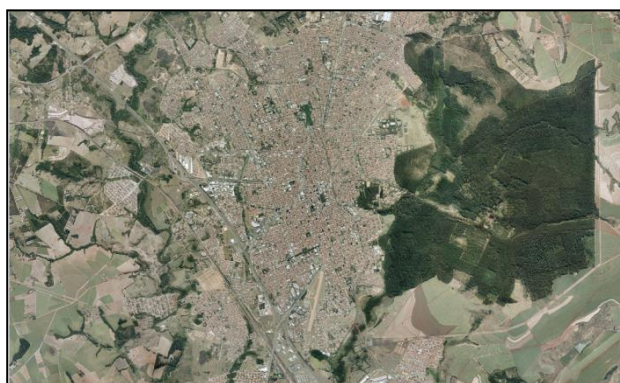 presence provides a better quality of life for the inhabitants, creating an atmosphere favorable to the temperature decrease.

According to Maciel (2010) [19], trees are extremely important for maintaining the quality of life, as they provide numerous benefits to the existing community. They improve air quality, provide shade and soften high temperatures.

3. Results and Discussion

FEENA, mapped in QGIS, was classified as land use and occupation: eucalyptus, forest, palm trees, body of water, built-up area and exposed soil. During the mapping the biggest challenge was to define the difference between the forest and the eucalyptus vegetation. The roughness analysis was thus adopted to differentiate the native forest from eucalyptus (Fig. 3).

Calculations of area of native forest and planted forest (eucalyptus) showed that in FEENA 47.50% corresponds to native forest and 40.26% to eucalyptus and 12.24% related to built-up areas and exposed forest soil.

Thus, the park's green area occupies almost half of the entire area, with the eucalyptus area also very significant. However the map shows that there are places where the soil is exposed and this was mainly due to arson forest fires in the area.

A survey of historical data of forest fires in the forest from 2012 to June 2018 was made and through them, a table was made to quantify these fires (Table 1).
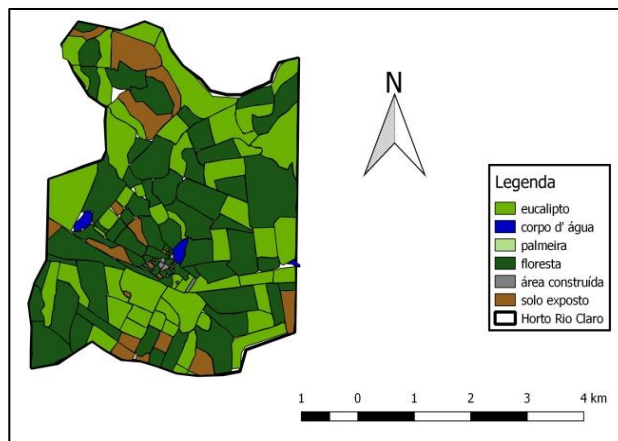

Fig. 2   Orthophoto image of "Floresta Estadual Edmundo Navarro de Andrade", EMPLASA 2010/2011.

Fig. 3   FEENA map of land use and occupation in 2017.

Table 1   History of forest fire.

Ano	Quantidade de incêndios	Área total atingida (ha)
2012	13	80.3
2013	5	26.08
2014	10	286.09
2015	3	6.12
2016	19	66.2
2017	8	120
2018 (janeiro até junho)	4	12.2

The causes of these fires are predominant criminals, but there are also other causes. In 2017 the fire occurred due to 2 pasture renovations, 5 of criminal origin and 1 due to religious manifestation. In the current year, 2018 from January to June all fires in FEENA were of criminal origin.

With the information acquired through QGIS it will be possible for forest managers to plan the reforestation of exposed soil areas, improving the various environmental services that FEENA brings, and to serve as an environmental education tool for the prevention of future fires.

4. Conclusion

It was possible to map the land use and occupation of the Edmundo Navarro de Andrade State Forest (FEENA) with the aid of the QGIS georeferencing program, proving to be an easily accessible software at no cost. Thus, it should be noted that the QGIS software can assist in the planning of Conservation Units, in the pursuit of sustainability.

Obtaining the history of forest fires was possible by collecting data in the area, so that they could be quantified. From geoprocessing, the work demonstrated how much FEENA has a large green area inside and also eucalyptus due to its history, but also found that there is still in the place the occurrence of forest fires that must be fought, besides the maintenance of the area should be done more often. This is how the sustainability of this important Conservation Unit occurs.

Based on the fieldwork, it is possible to observe the difficulty of the responsible public agencies in the aspects related to the infrastructure and improvement in the attendance to the population. Thus, the work can contribute to strengthen the discussions about the importance of FEENA in the context of the city of Rio Claro, helping its preservation and contributing to the improvement of the population's quality of life.

The methodology used, with application of geotechnologies and field work, can be performed in other Conservation Units and can serve as a basis for the implementation of improvements to encourage the proper management of environmental resources.

References

[1] B. S. Oliveira, E. Hamada and J. T. de O. Lana, Tendência das projeções de precipitação dos modelos climáticos globais para o Brasil utilizando SIG, in: *Simpósio Brasileiro De Sensoriamento Remoto*, 15, 2011, Curitiba, Anais, São José dos Campos: INPE, 2011, acesso em: 19 set. 2019, Available online at: http://www.alice.cnptia.embrapa.br/alice/handle/doc/915447.

[2] F. J. C. Magalhães Filho et al., Integrando SIG e USLE para mapeamento da perda de solo em área de proteção ambiental, in: Encontro Nacional De Engenharia De Sedimentos, *Integrando SIG e USLE para mapeamento da perda de solo em área de proteção ambiental*, Foz do Iguaçu, ABRH, 2012.

[3] R. C. Bossle, *QGIS e geoprocessamento na prática. São José dos Pinhais*, PA: Edição do autor, Editora Íthala, 2015, p. 232.

[4] M. A. Lombardo, Qualidade Ambiental e planejamento urbano: considerações de método. Tese (Livre – docência em Geografia) – Departamento de Geografia da Faculdade de Filosofia, Letras e Ciências Humanas, Universidade de São Paulo, 1995.

[5] W. R. de Ávila and L. C. N. de. Oliveira, Usodo Quantum GIS e Google Earth para delimitação e análise de áreas de preservação permanentes da sub-bacia do córrego Água Branca em Goiânia, in: *Anais XVI Simpósio Brasileiro de Sensoriamento Remoto-SBSR*, Foz do Iguaçu, Brasil, Vol. 13, 2013.

[6] R. V. Soares and J. F. Santos, Perfil dos incêndios florestais no Brasil de 1994 a 1997, *Curitiba: Floresta* 32 (2003) (2) 219-232.

[7] J. F. Santos et al., Evolução do perfil dos incêndios florestais em áreas protegidas no Brasil, de 1993 a 2002,

Curitiba: Floresta 36 (2006) (1) 93-100.

[8] L. E. Sanchez, Avaliação de Impacto Ambiental. Conceito e Métodos, Editora Oficina de Textos, 2008. Bay. StMWi, Energie-Atlas, p. 495, acesso: 15 set. 2019, available online at: http://www.energieatlas.bayern.de/index.html.

[9] M. A. Moreira, *Fundamentos do Sensoriamento Remoto e Metodologias de Aplicação* (2nd ed.), Viçosa, UFV, 2003, p. 307.

[10] D. E. Cruciani, R. E. Machado and P. C. Sentelhas, Modelos da distribuição temporal de chuvas intensas em Piracicaba, SP, *Revista Brasileira de Engenharia Agrícola e Ambiental* 6 (2002) (1) 76-82, acesso em: 19 set. 2019, available online at: http://www.scielo.br/pdf/%0D/rbeaa/v6n1/v6n1a14.pdf.

[11] I. Panagassi, Proposta de trilha interpretativa para a Floresta Estadual Edmundo Navarro de Andrade (FEENA), Rio Claro, 2015.

[12] E. F. Matos, Prevenção e combate aos incêndios florestais em unidades de conservação, in: *Fórum De Prevenção E Combate Aos Incêndios Florestais Do DF*, Brasília. Anais, Brasília: SEMARH, 2004, pp. 19-30.

[13] C. Cigagna, D. M. Bonotto and J. R. Sturaro, Batimetria e Estudo de Parâmetros Morfométricos do Reservatório da Floresta Estadual "Edmundo Navarro de Andrade" (FEENA) Rio Claro/SP, UNESP, Rio Claro, São Paulo, *Revista Geociências* 33 (2014) (4) 720-732.

[14] L. C. Moura, D. Zanchetta and F. E. Luca, Gestão, sustentabilidade e enriquecimento da flora nativa em floresta plantada de eucalipto, in: *VII Congresso Nacional de excelência em gestão*, Niterói, Rio de Janeiro, 2011, acesso em: 28 set. 2019, available online at: http://www.inovarse.org/sites/default/files/T11_0359_1961.pdf.

[15] I. C. Zampin and S. L. Ribeiro, Análise da conservação das matas ciliares da FEENA (floresta estadual "Edmundo Navarro de Andrade"), às margens do ribeirão claro e sua influência no clima urbano, definida por SIG'S – uma abordagem preliminar, UNESP, Rio Claro, São Paulo, Revista Gestão em Foco, Edição nº: 06, mês/ano: 05/2013, pp. 30-3, acesso em: 10 nov. 2017, available online at: http://www.unifia.edu.br/revista_eletronica/revistas/gestao_foco/artigos/ano2013/analise_conservacao.pdf.

[16] CEPAGRI (São Paulo) Centro de Pesquisa Meteorológicas e Climáticas Aplicados a Agricultura, 2017.

[17] L. Castanheira, P. M. Landim and R. W. Lourenço, Variabilidade do Índice de Vegetação por Diferença Normalizada (NDVI) em áreas de reflorestamento: Floresta Estadual Edmundo Navarro Andrade (FEENA), Geociências, *Rio Claro* 33 (2013) (3) 449-456.

[18] L. P. L. Bartsch, Elaboração de um roteiro interpretativo para trilha de ciclista da Floresta Estadual Edmundo Navarro de Andrade, Rio Claro/SP. 2015. 36 f. Trabalho de conclusão de curso (bacharelado – Ciências Biológicas) – Universidade Estadual Paulista, Instituto de Biociências de Rio Claro, 2015, acesso em: 20 set. 2019, available online at: http://hdl.handle.net/11449/139008.

[19] J. L. Maciel et al., Trilhas ecológicas como ferramentas para educação ambiental nos parques de Porto Alegre, Revista EGP, *Porto Alegre* 1 (2010) 1.