Forest fires remote sensing review in a protected state park in Santa Catarina, Brazil

Julia Dutra de Sena [a]

[a] Department of Sanitarian and Environmental Engineering, Federal University of Santa Catarina – Santa Catarina, Florianópolis, Brazil, judutra1708@gmail.com.

Abstract. Burning fires are caused by dry seasons, accidents, agriculture ambitions and real estate speculation, like in the case of a protected state park, called Parque Estadual da Serra do Tabuleiro, in Santa Catarina, Brazil. This preserved area suffers from anthropogenic pressure, especially near the beach, where urbanity takes place. The fires enhanced over the last 3 decades, mainly in 2012 and 2019. This study promotes a reflection about this rising fire and reviews study cases that mapped this state park. The principal objective is to exhibit a historical remote sensing of this area, supporting the park for its management and mitigated actions. Some researchers approached technical ways to map the park and corrected the satellite images with some methodologies. The most common satellite used for these burning areas was the LANDSAT satellite due to its resolution. Other researchers promoted reflections about the fire events describing its facts. Both approaches came with data and important information about the burning areas. In eight years (2001 to 2008) 1,375 hectares burned in the area, and in one year (2019) 1,123.66 hectares have suffered from fire. The rising fire is notable; therefore, this review encourages the remote sensing as a mitigated action for the next years to avoid future burning fires.

Keywords. burning areas, remote sensing, Parque Estadual da Serra do Tabuleiro, Conservation Unit.

1. Introduction

Deforestation and burning areas are related to the principle negative effects in protected areas [1]. Animals, vegetation and even people are prejudiced over a burning area. The fauna and flora live at risk in this situation directly and indirectly. The mortality is the direct action of the fire, and the absence of shelter and food are the indirect action. Both are harmful for the ecosystem and for its recuperation.

The fire initiates with fuel, oxygen, and heat to continue the burning process, what is called a "fire triangle". This event is very sensible, in other words, just with a spark and specific conditions the system can tease catastrophic proportions. Generally, the causes of an uncontrolled forest fire, comes from agricultural ambitions, in the renewal of pasture areas, from dry seasons and real estate speculation [2]. Environmental analphabetism and accidents, such as poorly extinguished bonfires and cigarette ends, are also some of the causes [3]. Burning areas

for devastation were methods utilized since the colonization in Brazil [4].

The Atlantic Forests in Brazil suffered with the entrance of the XVI century [5], only 12.4% of the ancient Atlantic Forests remain in the country [13]. Therefore, protected areas named "Conservation Unit" were created by Brazilian laws, for sustainable uses or for complete conservation.

To conserve these protected areas, there are several mitigation actions to prevent deforestation and forest fires. One of the tools is remote sensing and geoprocessing. The spatial analysis assists not just the Conservation Units management in environmental impact monitoring, caused by human and natural actions, but also allows more knowledge for applied mitigation actions studies [1].

The Chico Mendes Institute for Biodiversity Conservation (ICMBio) manages the Federals Conservations Units and promotes mitigation actions, for example. The institute has a technique

division in the department, called Monitoring and Environmental Information Division (DMIF), which is responsible for monitoring the burning fires, especially mapping the hot spots and the fuel material accumulation constantly [1]. For the States Conservation Units, in Santa Catarina, for example, the Environmental Institute (IMA) or the Conservation Unit team has the responsibility to provide preventive fire monitoring [6].

One of the Atlantic Forest Conservations Units, coordinated by IMA, is Parque Estadual da Serra do Tabuleiro. It was created in 1975 by the studies of two botanicals, Pe Raulino Reitz and Roberto Miguel Klein [5]. The state park reaches 9 municipalities in Santa Catarina (Palhoça, Florianópolis, Santo Amaro da Imperatriz, Águas Mornas, São Bonifácio, São Martinho, Paulo Lopes, Garopaba and Imaruí). It presents five of the six biggest vegetation formations in Atlantic Forests (restinga, mangrove, dense broadleaf forest, mixed rain forest and altitude field). The park biodiversity is very important for the country, which shelters animals in risk of extinction due to burning fires and devastation, such as Bugio (*Alouatta Guariba*), Jacutinga (*Pipile Jacutinga*) and the small spotted feline (*Leopardus Tigrinus*) [5].

In geographic terms, the Baixada do Maciambu in Parque Estadual da Serra do Tabuleiro is considered a geological monument due to the result of the sea level fluctuations over the years, which now has formed sandy ridges in semicircles [5]. This plain comprises one of the most expressive landscapes of the Brazilian restinga.

This paper focuses on reviewing literature about forest fires remote sensing and mapping, registered on the Parque Estadual da Serra do Tabuleiro, in Santa Catarina, Brazil. Thus, this study promotes historical information for the park and resumes the methodological ways for mapping this area. This research also promotes reflections above the importance of mitigated actions and exhibits the park's rising fire in the last years. The literature researched describes events in 2001 to 2019.

2. Methodology

2.1 Literature review

The research involved some principal words in the database, such as "Parque Estadual da Serra do Tabuleiro", "burning areas", "remote sensing", "Conservation Unit", "mapping". The database use was researched in the CAPES periodicals. Additionally, Google Scholar searches were performed. Some information sources were studied in E-books and management plans, which was elaborated for the park safety over the years.

2.2 Localization and importance of the state park

The Parque Estadual da Serra do Tabuleiro is in the east of Santa Catarina and occupies 1% of its area.

The territory occupies 84,130 hectares and protects the biodiversity of Brazil [6].

Besides biodiversity, the park is important in hydrological terms as well. In fact, the sources of the rivers are protected by the vegetation. Especially because these rivers provide the water to nearby cities and regulate the hydrological and meteorological cycles [6]. This park is essential for human beings and for their safety, that is why the mitigation actions above burning fires must be implemented.

2.3 Fire mapping in 2001 to 2008

The principal objective of [7] research mapping was to delimitate the burning area of the park in 2001 to 2008 and calculate the emissions of greenhouse gases liberated by these burning fires. Besides that, the albedo, reflectance on spectral visible range and solar infrared (proximal and medial) were analyzed as well.

To map the area were utilized satellite images of LANDSAT 5 with a sensor *Thematic Mapper* (TM) which possesses spatial nominal resolution of 30 meters and captures spectral information in 7 bands. Furthermore, with a radiometric resolution of 8 bits and a temporal resolution of 16 days.

Another satellite was used, Chinese Brazilian CBERS 2 e 2B (*China-Brazil Earth Resources Satellite*) sensor CCD (High resolution CCD Camera) with nominal spatial resolution of 20 meters, radiometric resolution of 8 bits, temporal resolution of 26 days and with 5 spectral bands.

For processing the images were utilized SPRING 4.3.1 (Georeferenced Information Processing System). In this app, 22 satellite images were enplaned and corrected geometrically from the first degree of the polynomial model and from the interpolar nearby.

2.4 Fire mapping in 2004 and 2005

The objective of [8] research was to evaluate and map the burning areas through three different multispectral indexes, extracted by orbital images. For the analysis, the sensor LANDSAT 5/TM was used.

The selected area, Parque Estadual da Serra do Tabuleiro, was mapped on 30th August 2004 and 21st November 2005. This procedure analyzed the index variations of Normalized Difference Vegetation Index (NDVI) and Normalized Burnt Ratio (NDBR and NDBR2.5) for a scene before and after the burning occurrence.

In the burning studies, the satellite information has several interferences in the image acquisition. Therefore, the NDVI indexes minimize these interferences for a better remote sensing.

For NDVI variation, the equation is:

$$\Delta NDVI = \left(\frac{\rho b_4 - \rho b_3}{\rho b_4 + \rho b_3}\right)_{pre} - \left(\frac{\rho b_4 - \rho b_3}{\rho b_4 + \rho b_3}\right)_{pos} \quad (1)$$

Where:

ρb_4 = band 4 (nearby infrared);

ρb_3 = band 3 (red);

pre = images from before the fire episode;

pos = images after que fire episode.

For NDBR variation, the equation is:

$$\Delta NDBR = \left(\frac{\rho b_4 - \rho b_7}{\rho b_4 + \rho b_7}\right)_{pre} - \left(\frac{\rho b_4 - \rho b_7}{\rho b_4 + \rho b_7}\right)_{pos} \quad (2)$$

Where:

ρb_7 = band 7.

For NDBR2.5 variation, the equation is:

$$\Delta NDBR2.5 = \left(\frac{2,5 + \rho b_4 - \rho b_3 - (\rho b_7 * 2)}{\rho b_4 - \rho b_3 - (\rho b_7 * 2)}\right)_{pre} -$$
$$\left(\frac{2,5 + \rho b_4 - \rho b_3 - (\rho b_7 * 2)}{\rho b_4 - \rho b_3 - (\rho b_7 * 2)}\right)_{pos} \quad (3)$$

2.5 Fire mapping in 2001 to 2015

The principal objective of [9] research mapping was to use the Geographic Information System (QGIS) for the inventory of geodiversity, geoheritage and geosites in Nature Conservation Units, especially for the Parque Estadual da Serra do Tabuleiro planning. This work registered hot spots from 2001 to 2015 in a burning area map. Moreover, a register of 2012 also occurred. To map this area, the method utilized was the LANDSAT 7 and CBERS satellite to analyze the vegetation.

Another researcher registered the burning fire in April 2012 [2]. The objective was to analyze the burning fire that occurred in April 2012 in the Parque Estadual da Serra do Tabuleiro, discuss the cause, and point out a bibliographical survey about the environmental impacts due to the fire. This study didn't map any burning areas, but it described the whole burning fire event.

2.6 Fire mapping in 2019

The Action Plan for Ecological Restoration, [10], in the Baixada do Maciambu, described and estimated the fire damage in 10th and 11th September 2019. This burning fire area was mapped utilizing SENTINEL-2 with compositions 8, 4 and 3.

For October 2019 burning fires mapping was utilized by the same satellite, SENTINEL-2 with compositions 8 (nearby infrared), 4 and 3. Besides that, after the Action Plan for Ecological Restoration was executed, a Forest Fire Fighting Contingency Plan was necessary to avoid new burning fires and to control if the event occurs again.

3. Results and discussion

3.1 Fire mapping in 2001 to 2008

[7] detected scars in the Palhoça's beach region at Parque Estadual da Serra do Tabuleiro. The images LANDSAT 5/TM display these scars on 9th September 2002, 8th April 2004, and 11th November 2005. As mentioned before, the most common cause is anthropogenic and serves to renew the pastures for cattle, according to the fire department report.
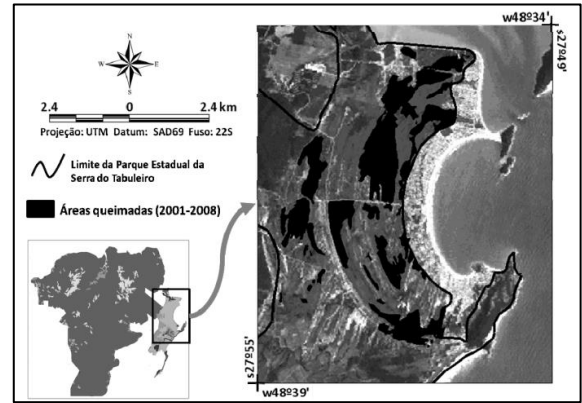

Fig. 1 – Burning areas in 2001 to 2008 [7].

The estimated burning area in 2001 to 2008 was approximately 1,375 hectares [Fig. 1], which is 15% of the territory park, equivalent to 1,273 soccer camps. This study focuses on the technical way to pass a message of the remote sensing importance in the burning areas monitoring. It showed alarming results and different methods of analysis.

3.2 Fire mapping in 2004 and 2005

[8] focused on the NDVI variation index application. The best scenario was the NDBR2.5 variation, with burning area medium values between -0.27 and -0.14 and the non-burned area was between -0.01 and 0.02. The classified result area as a terrestrial truth was estimated approximately by 200 hectares. This study applied another method of burning fires classification in the Parque Estadual da Serra do Tabuleiro, which is another way to map these areas.

3.3 Fire mapping in 2001 to 2015

The objective of the burning fire is the vegetation mischaracterization to promote public invasion lands, according to [9]. The result of this mentioned work was the map indicating 1,840 hectares of burning area between 2001 to 2015 [Fig. 2]. The biggest recorded event was in 2012, with 922
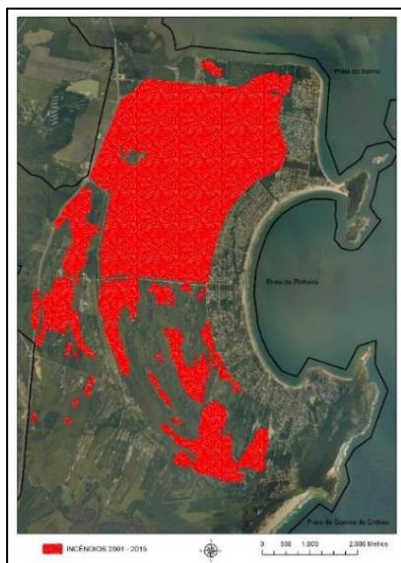
hectares of burning fire.

Fig. 2 – Burning areas in 2001 to 2015 [9].

The 2012 fire started in the beginning of the beach road in Palhoça and it lasted for 3 days. The flames reached 5 meters of height and there were indications that the fire was criminal. The firemen, the volunteers and the police succeeded, including the native population, which was extremely important to be the guardians of this place. There wasn't an oversight necessary in this situation by the state government when the fire spread [2], therefore it is necessary to correct this gap in the park's history.

3.4 Fire mapping in 2019

The total burning area was 1,123.66 hectares in 10th and 11th September, and additionally 5 days in October 2019. It was the biggest event that happened in Baixada do Maciambu [10].

After the incident, lots of actions were initiated to remediate the damage. IMA created the work group in October to elaborate the Forest Fire Fighting Contingency Plan, and after 10 days of the incident, an event was created to plant seedlings. The Action Plan for Ecological Restoration was also elaborated, coordinated by ecology and restoration specialists, demonstrating the burning areas in maps and data.

Besides the remote sensing, another important mitigation was the creation of a Forest Fire Fighting Contingency Plan. After the incident in 2019, IMA reunited a technical team to elaborate this important program. The plan separated three levels of burning fire and organized the initial drive, communication settings and the necessary resources to prevent bigger danger for the area [11].

3.5 Reviewed fire mapping

The area burned in the park enhanced over the years. According to Tab 1., in eight years (2001 to 2008), 1,375 hectares burned in the area and in one year (2019) 1,123.66 hectares of fire devastated the place.

It is a drastic situation, according to these data and especially the events in 2012 and 2019, as observed in Tab. 1.

The area was studied with remote sensing data in 2001 to 2015, and yet the oversight in the park was still precarious, resulting in hectares of burning in 2019. The state institutions must utilize these remote sensing tools to avoid these events from happening. Such as hot spots areas, which support decisions regarding inspection processes, regarding firefighting and for management [1].

Tab. 1 - Remote sensing and mapping in a protected area [author].

Year	Type	Area burned (hectares)	Reference
2001 to 2008	LANDSAT 5 CBERS 2 CBERS 2B	1,375	[7]
30th August 2004 and 21st November 2005	LANDSAT 5	200	[8]
2001 to 2015	LANDSAT 7 CBERS	1,840	[9]
2012	LANDSAT 7 CBERS	922	
2019	SENTINEL-2	1,123.66	[10]

The most utilized satellite was LANDSAT [Tab. 1]. LANDSAT's 30-meter resolution is ideal for measuring human impacts on the land, such as evaluating forest health and wildlife habitat, conducting global assessments for forest inventory and carbon accounting, and assessing the effects of tropical deforestation [12].

4. Conclusions

The Atlantic Forests in Brazil must be protected due to its biodiversity and its ecosystem equilibrium promotion, including for human beings. There are several national and state institutions in Brazil which are responsible for mapping the Conservation Units for its protection. Although some areas that never suffered with constant fire over the years don't have

an official and specific monitoring, such as the Parque Estadual da Serra do Tabuleiro. This study showed that the fire events are increasing at certain proportions, bringing attention to mapping these areas.

Some studies approached more technical methods to map the park, such as describing the corrections methods and some indexes that correct the interferences by utilizing the satellites. The maps production was based in LANDSAT, CBERS or SENTINEL-2, with or without describing image corrections. The LANDSAT's 30-meter resolution is ideal for burning fires mapping; therefore, it was the most utilizable tool. Other studies approached a social critical side to these events or even proposed plans and management for the Conservation Unit.

The park must be monitored with remote sensing and promote mitigated actions, especially because of the fire rise. The burning areas always happened in the park, although the Forest Fire Fighting Contingency Plan was initiated only in 2019 when 1,123.66 hectares was already burnt, for example.

This event in 2019 was the biggest one, and there isn't a specific study in remote sensing about this event, just some registers for the plans and management. It would be interesting to analyze this event and amplify the academic research on remote sensing, helping understand the type of landing and the meteorological changes over the past years in the state park.

Deforestation and burning areas are unsuitable cases for human and environmental health. Not only does it harm flora and fauna, but also raises greenhouse gases, contributing to climate change. The world is running across its time to maintain an ecological equilibrium. Therefore, the society must defend their land instead of devastating its biodiversity.

5. References

[1] K. M. Resende Borges, J. C. Orozco Filho, G. P. de O. Coan, and T. M. M. Vasconcelos, "Sensoriamento Remoto e Geoprocessamento como Subsídio ao Manejo do Fogo e ao Combate aos Incêndios Florestais em Unidades de Conservação Federais," *Biodiversidade Brasileira - BioBrasil*, no. 2, pp. 168–178, May 2021, doi: 10.37002/biobrasil.v11i2.1685.

[2] D. Prim, I. L. Walter, J. N. Vieira, W. L. Schutz, M. Benedita Da, and S. Prim, "INCÊNDIOS EM UNIDADE DE CONSERVAÇÃO: crime ou casualidade?" - Revista Maiêutica, Indaial, v. 4, n. 1, p. 43-50, 2016. Available: www.uniasselvi.com.br.

[3] M. M. A. Genebaldo, F. Dias, G. Freire, and D. Genebaldo, "Queimadas e Incêndios Florestais: Cenários e Desafios I B A M A.",

2006. [E-book]. Available: www.ibama.gov.br/prevfogo.

[4] S. De Aragão, "Aspectos da Transformação da Paisagem Brasileira.", Anais do XXI Encontro Estadual de História-ANPUH-SP-Campinas, Sept. 2012.

[5] S.T. Ishiy, A. Nunes, A. de Souza, B.T. Pauli Marterer, D. M. Brasil, E. Mussatto. "Parque Estadual da Serra do Tabuleiro: Retratos da Fauna e da Flora." [E-book]. Available: https://www.ima.sc.gov.br/index.php/downloads/ecossistemas/unidades-de-conservacao/parque-estadual-da-serra-do-tabuleiro.

[6] SDS, IMA, SC. "Plano de Manejo do Parque Estadual da Serra do Tabuleiro". [E-book]. Available: https://www.ima.sc.gov.br/index.php/downloads/ecossistemas/unidades-de-conservacao/parque-estadual-da-serra-do-tabuleiro.

[7] G. Pereira, N. J. Ferreira, C. Moraes, F. Da, S. Cardozo, and S. Ribeiro De Freitas, "Análise das áreas queimadas e das emissões dos gases do efeito estufa no Parque Estadual da Serra do Tabuleiro - Santa Catarina." - Geosul, Florianópolis, v. 24, n. 47, p 113-130, jan./jun. 2009.

[8] G. Pereira, F. da Silva CARDOZO, E. Arai, E. Caria MORAES, N. Jesus FERREIRA, and S. Ribeiro de FREITAS, "Avaliação de áreas queimadas a partir de índices espectrais derivados de dados orbitais." - Rio Claro, v. 33, n. 3, p. 513-525, set./dez. 2008.

[9] L. H. F. Pimenta, "Estudo da geodiversidade e do geopatrimônio da Mata Atlântica do Parque Estadual da Serra do Tabuleiro e do mosaico das Terras do Maciambu com base em Sistema de Informação Geográfica (SIG)," thesis, CFH-PPGG, UFSC, Florianópolis, 2016.

[10] Z. Paiva, "Plano de ação para a restauração ecológica da Baixada do Maciambu". Available: https://www.ima.sc.gov.br/index.php/biodiversidade/unidades-de-conservacao/parque-estadual-da-serra-do-tabuleiro.

[11] PLANCON Maciambu, CIGERD, Governo do Estado de Santa Catarina. "Pano de Contingência de Combate a Incêndios Florestais no Parque Estadual da Serrra do Tabuleiro – Àrea da Baixada do Maciambu, Palhoça." [E-book]. Available: https://www.defesacivil.sc.gov.br/noticias/plano-de-contingencia-para-a-reserva-do-tabuleiro-comeca-a-ser-criado/.

[12]   NASA, "Landsat and Forests Landsat's Critical Role in Forest Management A B O U T L A N D S AT Landsat Data for Local and Global Decision-making." [Online]. Available: www.fs.fed.us/foresthealth/applied-sciences/mapping-.

[13]   SOS Mata Atlântica e INPE lançam novos dados do Atlas do bioma, [Online]. Available: http://www.inpe.br/noticias/noticia.php?Cod_Noticia=5115. [Visited on 30/03/2023].