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# Forest fire monitoring in Angolan National Parks between 2008 and 2017

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## A B S T R A C T

The number of forest fires has increased considerably throughout the world. Forest fires are a major cause of damage to terrestrial ecosystems, and National Parks (NP) and Reserves. So it contributed to the increase of research on the theme. The limitations to know the recording of hotspots in Angola using fire detection tower can be met by using techniques and data from GIS and remote sensing. So, this paper aims to monitor the occurrence of forest fires in Angolan National Parks (Iona, Cameia, Quiçama, Cangandala, Mavinga, Bicuar, Luengue-Luiana and Mupa) in the decade 2008-2017 using data from NASA Modis Collection 6 on Protected Areas, that was obtained in Nasa Firms Project and World Database on Protected Areas, relatively. The data was processed in ArcGis version 10.1, Quantum Gis version 2.18 and Google Earth Pro. The main results obtained in this study are described ahead. Most of the forest fires occurred between June and September, which may be associated with the dry season. The Cameia, Luengue-Luiana and Mavinga NP had higher forest fireoccurrences and Iona, Cangandala Quiçama and Mupa NP lower. The average forest fires occurrences between 2008-2017 in study area is 21347, and the average per year is 2135, per month 178 and per day 6 in each Angolan NP. The forest fire in the Angolan NP between 2008-2017 occurred mostly in the day (97 %) in relation to the night (3 %) time.

**Keywords:** Angolan protected areas; hotspots; Modis; geographic information systems (GIS); remote sensing.

## R E S U M O

Monitorização de incêndios florestais nos parques nacionais de angola no período 2008-2017. O número de incêndios florestais aumentou consideravelmente em todo o mundo. Os incêndios florestais são uma das principais causas de danos aos ecossistemas terrestres e aos Parques Nacionais (PN) e Reservas. Isto justifica o aumento do número de pesquisas sobre o tema. As limitações existentes no registo de focos de calor através de torre de detecção de incêndio em Angola, podem ser superadas mediante técnicas e dados de SIG e teledeteção. Assim, este trabalho tem como objetivo monitorar a ocorrência de incêndios florestais nos PN Angolanos (Iona, Cameia, Quiçama, Cangandala, Mavinga, Bicuar, Luengue-Luiana e Mupa) no decénio 2008-2017 utilizando dados da Coleção 6 do sensor Modis e e de Áreas Protegidas, obtidos no Projecto Nasa Firms e no Banco de Dados Mundial sobre Áreas Protegidas. Os dados foram processados nos softwares ArcGis versão 10.1, Quantum Gis versão 2.18 e Google Earth Pro. Os principais resultados obtidos neste estudo são descritos a seguir. Maioritariamente, os incêndios florestais registaram-se entre junho e setembro, o que pode estar associado à estação seca. Os PN da Cameia, Luengue-Luiana e Mavinga registaram maior ocorrência de incêndios florestais e Iona, Cangandala Quiçama e Mupa registaram menor ocorrência. A média de ocorrências de incêndios florestais entre 2008-2017 na área de estudo é 21347, e a média anual é de 2135, mensal 178 e diária 6 em cada PN Angolano. Os incêndios florestais nos PN Angolano entre 2008-2017 ocorreram maioritariamente de dia (97%) em relação á noite (3%).

**Palavras-chave:** Áreas protegidas angolanas; focos de calor; Modis; sistemas de informação geográfico (SIG); teledeteção.

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# 1. Introduction

In intertropical regions, fire is commonly used in agriculture (for clearing agricultural land, opening new agricultural areas and combating/eliminating pests), and in hunting. In Africa, in general, and in Angola fire can be used in cultural rituals. When this activity is carried out in protected or forest areas, it may be the reason for the transformation of forest areas into savannas, due to the considerable reduction of trees. Quissindo (2018) considers that the many forest-savanna transitions are experiencing a change in the fire regime towards a decrease in fire recurrence because of fire extinguishing policies, rural area abandonment and changes in practices cultural and spiritual traditions.

Forest fires are a major cause of damage to terrestrial ecosystems, and National Parks (NP) and Reserves in particular, although protected areas are often affected by uncontrolled fire. According to the Boubeta et al. (2015) & Semeraro et al. (2016), the number of forest fires has increased considerably throughout the world, resulting in further extensions of burned areas and consequent destruction of forest production and environments. In this sense, concerns about the possible impacts of forest fires contributed to the increase of research on the theme in the last decade.

Despite the efforts invested in fire prevention and suppression in the last decades, the general trend in the extent of burnt areas has considerably increased in Mediterranean landscapes, principally due to land use/cover and climate changes, causing severe losses of habitats, biodiversity, landscapes, and historical elements (Pausas & Fernandez Muñoz, 2012; Moreira et al., 2011). This reality can be observed also in tropical areas. Semeraro et al. (2016) considers that these aspects are more relevant in natural protected areas since they represent both hotspots of relevant habitats and cultural landscapes derived from the millennial interaction between human beings and the environment.

The monitoring of areas through fire detection towers not only has limitations in its spatial distribution, but it is also difficult to cover a 100% area with such towers (Eugenio et al., 2016). Thus, the use of Geographic Information Systems (GIS) and Remote Sensing techniques for the detection of hotspots and / or forest fires ensures greater accuracy in the identification of the original source of the fire, aiding decision making by the observation team. Several studies report that GIS automates manually executed tasks and facilitates the performance of complex analyzes integrating geocoded data (Luppi et al., 2015; Santos et al., 2016).

Geographical information system and remote sensing have long been applied to create forest fire vulnerability map (Amalina et al., 2015). Forest fire vulnerability map is a spatial model used to picture field condition that is related to risk of forest fire (Jawad et al., 2015). Through this map, activities of monitoring and prevention of forest fire can be conducted as early as possible (Amalina et al., 2015).

If, on the other hand, there is little information about the occurrence of forest fires in Angolan Protected Areas in, this does not mean that there is no record of such occurrences in these places. Thus, the limitations of fire detection tower installations in these areas and others can be met by using techniques and data from GIS and remote sensing, to know the recording of hotspots and / or forest fires in the Angolan National Parks.

Therefore, this research aims to monitor the occurrence of forest fires in Angolan National Parks (Iona NP, Cameia NP, Quiçama NP, Cangandala NP, Mavinga NP, Bicuar NP, Luengue-Luiana NP and Mupa NP) in the decade 2008-2017 using data from hotspots or heat sources of NASA MODIS Collection 6 (NASA FIRMS MODIS Fire - Hotspot MODIS Collection 6 data).

# 2. Material and Methods

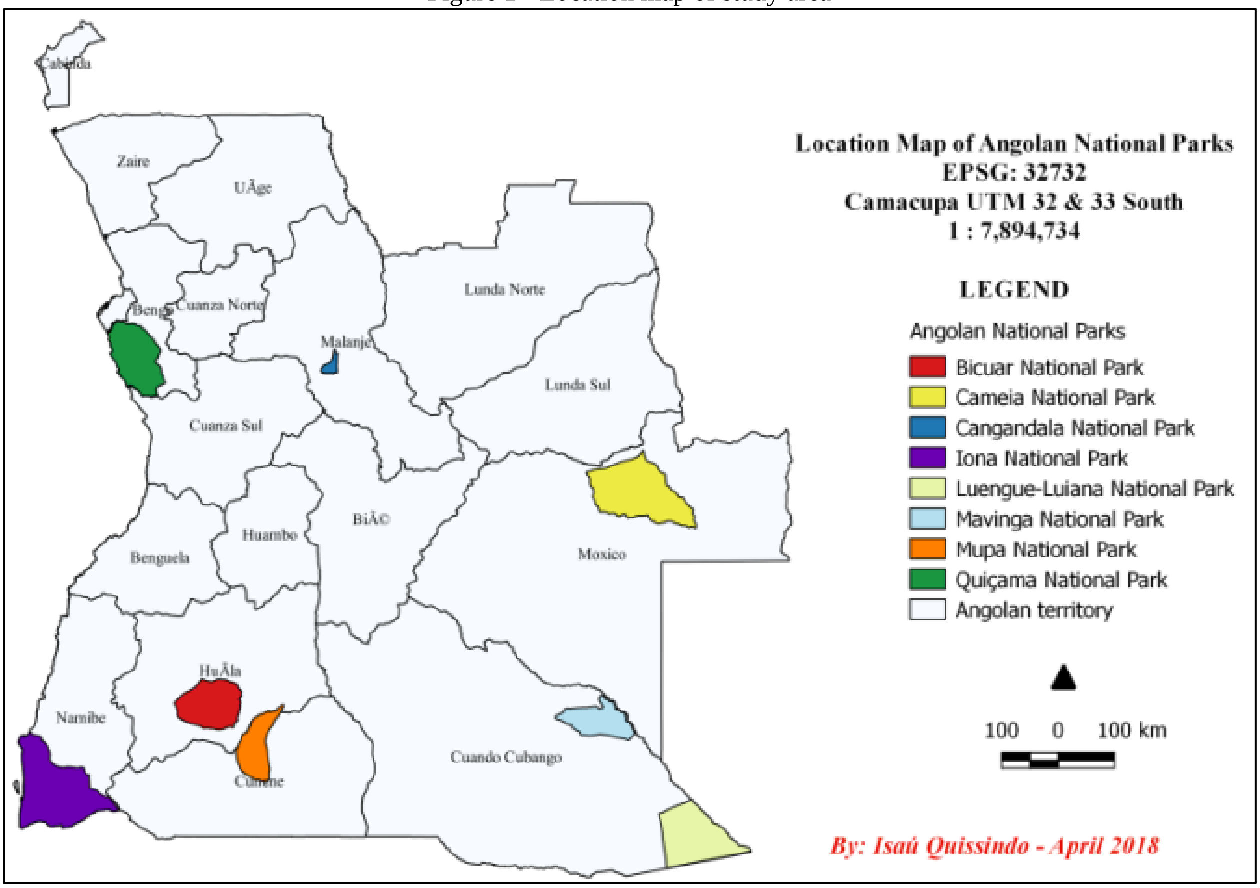
## *2.1. Study area*

The study area, Angolan National Parks, has an extension of 70.340 km², its location map can be seen in the following figure (Fig. 1).

More other detailed information, according to analisys done by this paper author and some studies, are described in the table 1 in chapter of results.

Methodological steps for the mapping and monitoring of hotspots in Angolan National Parks In general, the databases used for obtaining information are World Database on Protected Areas and Nasa Firms Modis; already the processing of this data was done with the aid of the software ArcGis version 10.1, Quantum Gis version 2.18 and Google Earth Pro.

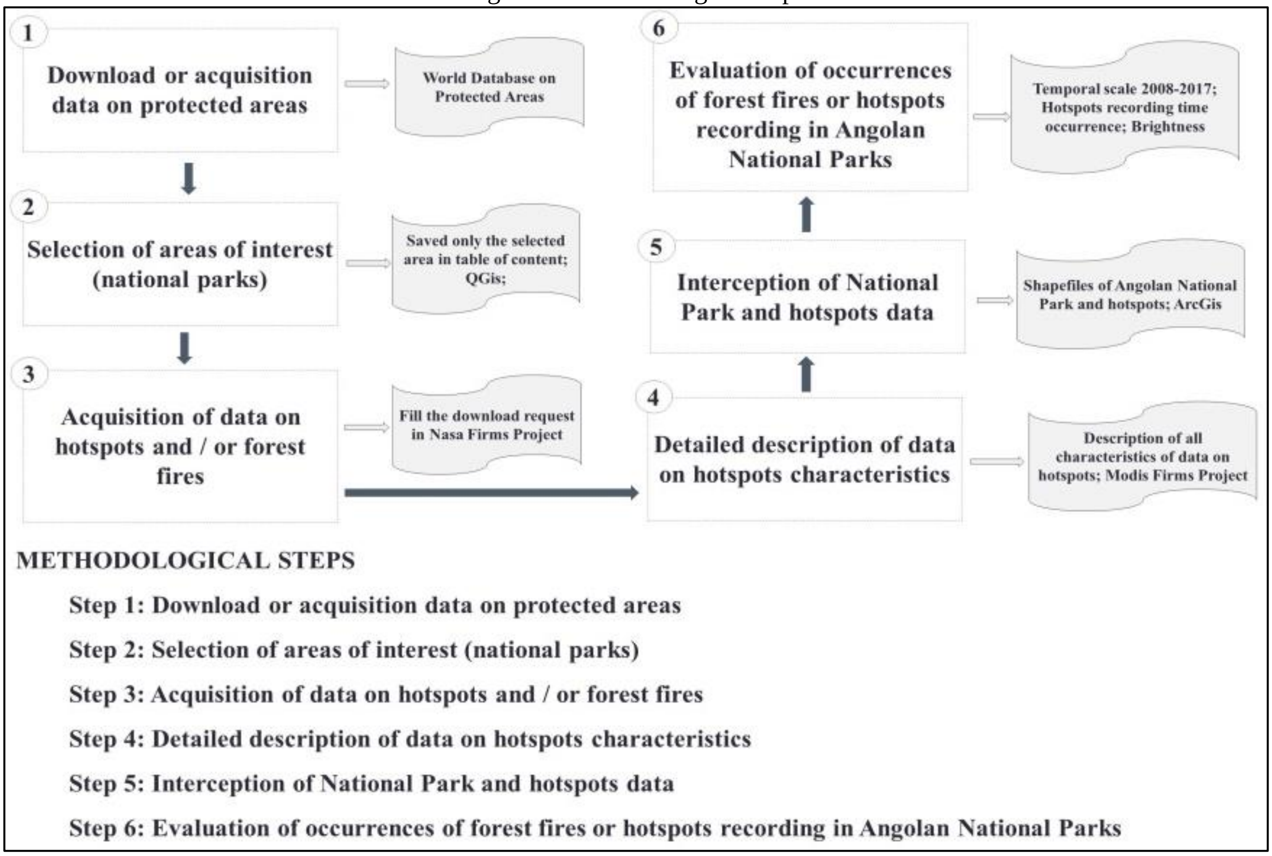
Figure 1 - Location map of study area




**Source:** Authors (2018)

Briefly, the methodological steps of this investigation can be seen in figure 2 and the detailed description of these steps in the following paragraphs.

Figure 2 - Methodological steps




**Source:** Authors (2021)

Step 1: Download or acquisition data on protected areas

The geospatial data (shapefile) of the Angolan NP were downloaded on March 8, 2018, in the World Database on Protected Areas - WDPA (https://www.protectedplanet.net), that is the most comprehensive global database on terrestrial and marine protected areas (IUCN and UNEP-WCMC, 2018; UNEP-WCMC, 2016).

Step 2: Selection of areas of interest (national parks)

Since the data downloaded in the previous step contained information on all protected areas (natural reserves and regional and national parks), the second step from these data was the creation of a vector file on Angolan NP in Quantum Gis software.

Step 3: Acquisition of data on hotspots and / or forest fires

Then, on March 29, 2018, the files with information on record hotspots in Angola were obtained. The selected time scale was the decade 2008-2017.

Data collection was done by filling out a NASA data request form on the official website (https://earthdata.nasa.gov/active-fire-data). After requesting the NASA FIRMS project website at https://earthdata.nasa.gov/firms, the download link (https://firms.modaps.eosdis.nasa.gov/data/download/DL_FIRE_M6_6256.zip) was automatically received. zip).

Step 4: Detailed description of data on hotspots characteristics

After downloading the data, they presented the following summary (NASA Firms Project, 2018; Giglio et al., 2006; Roy et al., 2008):
- Download Id: 6256;
- Data Source: MODIS C6;
- Start Date: 2008-01-01;
- End Date: 2017-12-01;
- Output Format: shp;
- Area of Interest: Angola.

The naming convention of file is M6 stands for MODIS Collection 6.

Step 5: Interception of National Park and hotspots data

In the fifth step, with ArcGis software, the data generated in the second step (shapefile of Angolan NP) and the previous step (shapefile of hotspots) were intercepted and a new vectorial file was created with information on hotspots recorded between 2008-2017 in Angolan NP.

Step 6: Evaluation of forest fires or hotspots occurrences recording in Angolan NP

SIG techniques were used to evaluate the occurrence of hotspots in Angolan NP, taking into account the time scale (2008 to 2017), the period of occurrence of heat (day and night) and the occurrence number of hotspots in each park.

All this led to an analysis and information of recording hotspots within the Angolan NP between 2008-2017, which led to the results described below and their subsequent discussion.

## 3. Results

The first result of this study is related to the characterization of Angolan NP according to the calculation of land area (km²), geographic bounding box and know the establishment date as NP of each parks. Besides that from results obtained to some studies (IUCN and UNEP-WCMC, 2018; MA, 2018; TARR, 2016) was described the many animal species and prevailing ecosystem of the Angolan NP. All of this can be seen in the Table 1.

**Table 1-** Characterization of Angolan national parks.

| Name | Land area (km²) | Location (province) | Geographic bounding box | Many animal species | Date of establishment as NP | Prevailing ecosystem |
|---|---|---|---|---|---|---|
| *Bicuar NP* | 7.900 | Huila | 14.2214, 15.3031 | *Loxodonta sp.*, *E. quagga burchellii*, etc. | 1930 | Miombo woodland and dominated mainly by the genera *Acacia*, *Sterculia* and *Commiphora*. |
| *Cameia NP* | 14.450 | Moxico | 20.7995, 22.5475 | *C. crocuta*, *P. pardus*, *A. jubatus* and *H. amphibious* | 1938 | Miombo woodland, with an ecosystem of flooded pastures, meadow and the |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Loudetia sandy plateau. |
| *Cangandala NP* | 630 | Malanje | 16.5606, 16.8313 | *H. niger variani*, *C. moschata* and *Ungulata* mammals | 1970 | Open Miombo woodland dominated by *B. boehmii*, *U. benguelensis*, *E. abyssinica*, *Dyospiros sp.* |
| *Iona NP* | 15.150 | Namibe | 11.7324, 13.3443 | *A. marsupiales*, *O. gazella*, *N. meleagris*, etc. | 1964 | Diversified flora, including *Welwitschia mirabilis*, an endemic plant in the Angolan Namibe Desert. |
| *Luengue-Luiana NP* | 22.610 | Kuando Kubango | 21.9536, 23.4263 | *O. afer*, *S. caffer*, *C. civetta*, *L. africana*, etc. | 1966 | Open woodland, Dense woodland, Aquatic vegetation and Open grassland. |
| *Mavinga NP* | 46.072 | Kuando Kubango | 20.2936, 21.5726 | *L. pictus*, *P. pardus*, *D. bicornis*, *E. quagga*, *H. equinus*, etc. | 1966 | Mosaic of grassy savannah with shrub and patchwork of Miombo woodland; and even savannah mosaic with and without trees and shrubs. |
| *Mupa NP* | 6.600 | Cunene | 15.2104, 15.9740 | *G. camelopardalis angolensis*, *P. leo*, *Hyaenidae* family, etc. | 1964 | Forest-savannah mosaic, Miomo woodland and dry savannah with shrubs. |
| *Quiçama NP* | 9.600 | Bengo | 13.1523, 14.0839 | *Loxodonta sp.*, *S. caffer*, *Cheloniidae* family, etc. | 1957 | Zambezi phytogeographic region. |

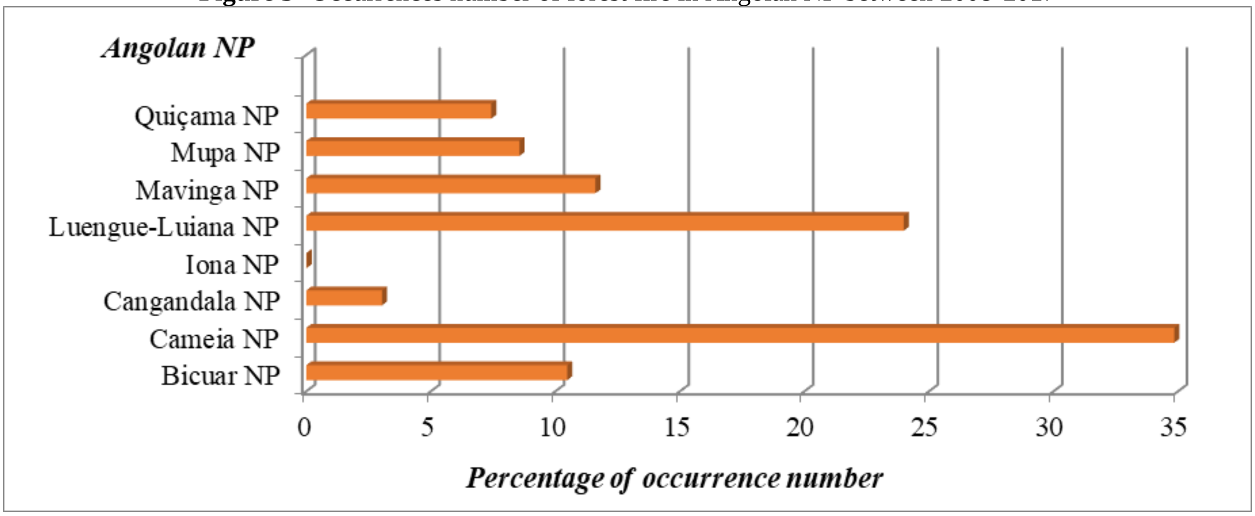
**Source:** Authors (2021)

On other hand, as is known according to the origin, fires can be classified as forest fires (when they occur in terrestrial ecosystems), household fires (those occurring in homes) and industrial fires (those occurring in industrial zones, schools, shops, etc.).

Considering the above idea and according to the nature of the study area (Angolan NP) in this article, all the hotspots recorded in NP were considered as forest fires.

Through a spatial analisys between two vector layers (from Angolan NP and Forest Fires occurred between 2008-2017 in the areas mentioned above), there were 170 773 hotspots, that is, forest fires in the eight Angolan NP. Cameia, Luengue-Luiana and Mavinga NP had higher forest fire records in the time scale considered in this study, as can be seen in Figure 3.

**Figure 3-** Occurrences number of forest fire in Angolan NP between 2008-2017




**Source:** Authors (2021)

It notices in the previous figure that the Iona, Cangandala Quiçama and Mupa NP recorded a lower occurrence number of forest fires. The total number of forest fires occurring in each Angolan park, the period of occurrence, as well as the percentage value that these occurrences represent can be seen in detail in table 2.

**Table 2-** Datas of number, percentage, and period of forest fire occurrence in Angolan NP between 2008-2017.

| **Name of National Park** | **Occurrences** | | **Occurrences by periods** | | | |
|---|---|---|---|---|---|---|
| | **Number** | **Percentage** | **Rainy Season (September to May)** | **Dry season (May to September)** | **Day** | **Night** |
| Bicuar | 17 903 | 10,48 | 3 581 | 14 322 | 16 316 | 1 587 |
| Cameia | 59 521 | 34,85 | 13 095 | 46 426 | 58 403 | 1 118 |
| Cangandala | 5 199 | 3,04 | 936 | 4 263 | 5 098 | 101 |
| Iona | 42 | 0,02 | 5 | 37 | 31 | 11 |
| Luengue-Luiana | 40 975 | 23,99 | 7 785 | 33 190 | 39 654 | 1 321 |
| Mavinga | 19 827 | 11,61 | 3 172 | 16 655 | 19 401 | 426 |
| Mupa | 14 618 | 8,56 | 2 193 | 12 425 | 14 378 | 240 |
| Quiçama | 12 688 | 7,43 | 1 649 | 11 039 | 12 524 | 164 |
| TOTAL | 170 773 | 100 | 34 155 | 136 618 | 165 805 | 4 968 |

**Source:** Authors (2021)

In the table above, it is possible to note that although the dry season has a short duration throughout the year, it was the one with the highest number of hotspots recorded in the period under study, having recorded, in general, 80 to 82% of the total record of hotspots in relation to the rainy season with records ranging from 12 to 13%.

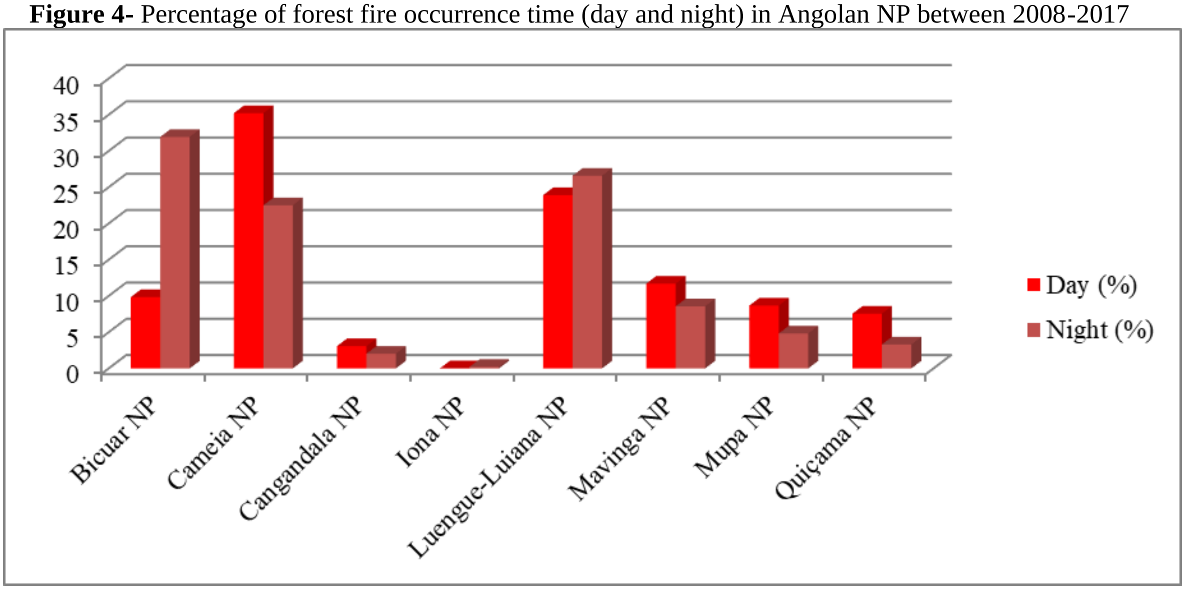
It was estimated that the average occurrence of forest fires in the Angolan NP between 2008-2017 is 21347, which can be translated into 2135 forest fires per year, 178 per month or 6 per day in each Angolan

NP. According to the occurrence period (day or night), was obtained an average of 20726 (97 %) forest fires that occurred during the day and 621 (3 %) at night in the area and time scale under study.

It can be considered that a large part of these fires was caused by resident personnel in the vicinity or even during poaching activities that use fire to frighten the animals. However, since most forest fires in the park occurred during the day, it is advisable to take measurements in loco, to know the real causes involved in them.

The usual occurrence time of forest fire in each park área: Bicuar NP on 8, 9, 12 and 13 hours; Cameia (8, 9, 11 and 12 hours); Cangandala and Luengue-Luiana (8, 9, 11, 12 and 13 hours); Iona and Quiçama NP (9, 12 and 13 hours); Mavinga and Mupa NP (9, 12 and 13 hours).

**Figure 4-** Percentage of forest fire occurrence time (day and night) in Angolan NP between 2008-2017




**Source:** Authors (2021)

According to the data from table 2 and figure 4, records of nocturnal forest fires were observed in Bicuar, Iona and Luengue-Luiana NP, to the detriment of others NP (Cameia, Cangandala, Mavinga, Mupa and Quiçama) that records a greater number of forest fires daytime.

## 4. Discussion

This study investigated forest fire monitoring in Angolan national parks in the period 2008-2017, allowing to know the occurrence level of forest fires, the percentage of occurrence per day or nighttime, the Angolan NP with higher and lower occurrences, among others. Thus, after the presentation of the results follows the discussion related to the same results.

Despite being very important, both before and currently, statistics on the occurrence of forest fires in Angola or in Angolan terrestrial ecosystems are very scarce, fragmented, and unknown. According to Santos (2017), in his study on the statistics of forest fires in protected areas from 1998 to 2002, Brazil also presents scales and fragmentation of data on the occurrence of forest fires.

The Angolan territory presents only two distinct climatic seasons in the year, the rainy season (August 15 to May 15) and the cold / dry season (May 15 to August 15). The results of this work show that the season with the highest index of occurrence of forest fires in the Angolan NP corresponds mostly to the dry season, mainly between the months of June and September. Similar results were obtained in a study carried out in a tropical zone (Brazil) that shows the period between July and October as the one with the highest occurrence of forest fires, being considered as the main fire station for Brazilian protected areas (Santos, 2004). Thus, it can be considered that climatic factors intervene directly in appearance favor of hotspots.

However, good knowledge of the most occurrence seasons is important in forest fire prevention programs. According to the Rodríguez et al. (2013), it is important to determine where, when, and why forest fires occur to structure the prevention and suppression within economically viable limits.

The high number of forest fires in the study area may be is associated with the characteristic atmospheric factors of each season of the year. For example, in the dry season the climate favors the acceleration of the process of abscission by the plants, causing much plant material dead on the ground, which favors the origin or propagation of the fire. In addition to these factors, there are others such as the type of vegetation and its exposure to the sun. Paz et al. (2011), in describing the factors that affect the behavior of the fire, points the meteorological conditions as one of the main ones. However, Torres et al. (2017), submits that one factor alone does not represent a fire hazard without there being others that favor the initiation of the combustion process. According to Torres (2006), the climatic conditions and forest fires maintain a narrow relationship, from the probability of occurrences of fires, originating from of the atmospheric conditions in a die period, until the maintenance and propagation of the fire. In times of the year with low humidity of the air, as in the winter, the propensity of forest fires increases considerably, because the driest air ends for forcing a larger evapotranspiration of the vegetables. As in this station they are had an index of deficient rain, reality that can be observed in the Angolan NP.

This may be related to the results of this work, since a large part of the registered hotspots occurred during the day, moment when there is a reduction of the air relative humidity and high temperatures in relation to the nocturnal period.

To the detriment Murphy and Bowman (2012), considers that the factors controlling the extent of fire in Africa south of the equator were investigated using moderate resolution (500 m) satellite‐derived burned area maps and spatial data on the environmental factors thought to affect burnt area. The study finds that tree cover, rainfall in the previous 2 years, and rainfall seasonality were the most important predictors.

Nevertheless, due to the kind of the data used in this work, the factors that underlie the possible occurrences of forest fires in Angolan NP are uncertain.

In Africa in general and in Angola in particular the fire can be used in cultural rituals. When this activity is carried out in protected or forest areas, it may be the reason of the transformation of forest areas into savannas, due to the considerable reduction of trees. Cardoso et al. (2016), consider that the many forest–savanna transitions are experiencing a shift in the fire regime toward decreased fire recurrence because of, inter alia, fire extinction policies, rural area abandonment, and changes in traditional cultural and spiritual practices.

This data can be very useful, because it allows to know the number of fires recorded in a point, since it is possible to know the geographical coordinates of the registration place; it is also possible to know the occurrence time (hour), which helps to locate future forest fires or burned area, and thus to know the possible causes.

## 5. Conclusions

Considering the study areas and methodologies used in this study, the following conclusions were obtained:

- The Angolan NP occupy an area of of 70.340 km² and they host a large number of plant and animal species, so they require good conservation measures, even against the disorderly and illegal fire;

- Cameia, Luengue-Luiana and Mavinga NP had higher forest fire records and Iona, Cangandala Quiçama and Mupa NP recorded a lower occurrence number of forest fires;

- The average occurrence of forest fires in the Angolan NP between 2008-2017 is 21347, this allowed to know that in average per year occur 2135 forest fires, 178 per month and 6 per day in each Angolan NP;
- The forest fire in the Angolan NP between 2008-2017 occurred mostly in the day (97 %) in relation to the night (3 %) time.

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