A Web Client for fire monitoring in support to protected area management in Africa

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Abstract. Vegetation fires are widespread in Africa and are a key component of many ecosystems. They can be a cause of threat and damage for ecosystems not adapted to them, but for many African habitats fires are just as important as rain. As a consequence of this, dedicated fire programs are often included in the protected area conservation plans to maintain or improve the ecosystem structure and the habitat diversity that are essential to biodiversity. Information on fire activity becomes therefore critical for the implementation of conservation programs and the management of protected areas. With the support of Earth Observation (EO), fire monitoring is possible in near real-time, at global level, over long time periods. However, the use of EO products requires technological know-how which is often limited for many ecologists and park managers. In this study we present a new tool for fire monitoring that we developed especially for people working in conservation and park management. The tool is a web client that provides historical and near-real time indicators of the fire activity derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) burned area and active fire products. The MODIS products are distributed by NASA-FIRMS and the University of Maryland and cover more than a decade going from late 2000 to present. The web client is available on-line and produces, on the fly, graphs, tables and maps of the fire activity, for a selected protected area and period of time. The content and its graphical representation have been designed to provide a synthesis of the fire in support to decision making and management.

Keywords. fire indicators, biodiversity, park management, MODIS, web client, Africa.

1. Introduction

1.1. Background

Globally between 3.5 and 4.5 millions Km2 burn every year, particularly in the tropical regions, and Africa alone accounts for more than half of the total area [1].

Besides the negative effects on landscape, human health and safety, fire has also an important ecological role since it is essential for the well-being of many ecosystems. Moreover, in the tropical regions, it is also widely used as a land management tool. For example, in Africa and Australia, controlled burning during the dry season is used to prevent more destructive fires during the late dry season when the fire risk is higher.

In Africa, North America and Australia, park managers apply prescribed burning to maintain and promote a variety of healthy natural habitats and high levels of biodiversity in their protected areas. For example fire is used to regenerate palatable grass for the herbivores, control bush encroachment and invasive species. Therefore the successful implementation of conservation programs in the tropical regions depends also on the correct understanding of fire as an ecological process and the appropriate design and application of fire plans.

1.2. Study Objectives

Nowadays Earth Observation (EO) provides reliable data on fire activity worldwide, however satellite data require processing and analysis capacity which are not always accessible to park managers. In order to overcome this limitation we developed a fire monitoring system based on EO that presents information in the form of environmental indicators and maps that do not require further processing to be used.

The tool provides near-real time data and covers more than ten years from late 2000 to present, at global level. The analysis of the time series helps scientists to improve their understanding of fire ecology in protected areas and the spatio-temporal trends or changes in the fire activity. Anomalies in the fire regime (e.g. change in fire frequency, seasonality and burned area extent) can be either an indicator of land cover change or habitat loss, or more generally an indicator of land use change [2]. This information is therefore important to apply effective conservation plans and also evaluate the management of a protected area (PA). This fire monitoring tool has been specifically designed for people working in protected areas. It aims at supporting park managers and scientists in understanding fire patterns and their ecological implications. It can be used to implement conservation programs, in the decision making activities, as well as for the prevention, plan and control of fire.

2. Methods

2.1. Datasets

The tool is based on web services developed at the JRC to provide historical and near-real time information of the fire activity derived from the satellite-borne Moderate Resolution Imaging Spectroradiometer (MODIS) fire products. These products are distributed by the NASA Fire Information for Re-source Management System (FIRMS, [3]) and the University of Maryland [4] and cover more than a decade going from late 2000 to present. The tool includes all the protected areas listed in the World Database on Protected Areas (WDPA) of the United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC, http://www.wdpa.org/).

The MODIS fire products consist of two types of datasets: the active fire (MCD14DL, [5]) and the burned area (MCD45, [6]). The active fire product provides information on the fire occurrence (time and location of burning), with four observations per day, we distribute it in near-real time 48 hours after the satellite overpass; the burned area product, instead, informs on the extent of the fire affected area and since it requires longer processing we distribute it about 2 months after the satellite acquisition. Despite the delay in its distribution, the burned area product is still useful for management because it provides synthetic and quantitative information about the fire activity. We included in the analysis the assessment of the vegetation type affected by fire, for this we use the Globcover 2005 [7] which is based on ENVISAT MERIS data with 300m spatial resolution.

2.1.1. Fire indicators

2.1.2. Fire Season

An important feature of the fire activity is the timing of burning. This changes with the weather and the vegetation conditions at different locations. We wanted to define a reference fire season [8] for each protected area to provide the typical temporal pattern of fire. To do this we derived, for each grid cell (0.25 degree) the average fire counts, over 10-day periods, using the time series from 2003 to 2012: we excluded the years 2001 and 2002 because they only report the fires observed from the TERRA satellite, whereas from the year 2003 onwards the active fire product contains the observations from both TERRA and AQUA satellites. The improved observation frequency (from two to four times a day) roughly doubles the number of active fires detected, therefore the seasonality was derived using only the years when both sensors were operational. We also worked at a different spatial resolution from the original product aggregating the 1km fire pixels over grid cells of 0.25 degree. At this lower spatial resolution we could get a representative temporal pattern of the fire activity and define the fire season. We also tested the criteria to define the fire season at a finer spatial scale of 0.10 degree grid cell, but we had to discard this option because, at this resolution, there were spatial inconsistencies in the fire season durations and it was not possible to identify the fire season in many grid cells. The reason for this is that the smaller cell size limited the observation of the fire activity (fewer fires were sampled in each grid cell) giving a partial or insufficient representation of the fire occurrence which prevented to determine the fire season.

Therefore we continued the analysis on the 0.25 degree grid cells, and derived a reference year from the time series: this was computed by assigning the average number of active fires in each 10-day period of the time series (2003-2012) on the 0.25 grid cells.

The reference year represents a conservative time reference of the fire activity, because it includes all the 10-day periods with fire activity in at least one year of the time series. To identify the fire seasons we applied different morphological filters to the reference year so that we exclude short discontinuities in the fire occurrence due to short periods of fire/no fire activity [9]. An example of the filtering effects is shown in figure 1. We first converted the number of fires into binary values (1=fire, 0=no-fire; fig. 1B), and applied a closing filter with a kernel size of four 10-day periods: this filter filled in the gaps with no fire activity if these were lasting maximum three 10-day periods and were consecutive to periods of fire activity (fig. 1C). The effect of this filtering was to extend the periods with continuous fire activity and remove isolated interruptions in the fire occurrence. After the closing we applied an opening filter to remove the periods of fire activity shorter or equal to three 10-day periods (fig. 1D). Then we determined the number of fire seasons in each grid cell. If we found more than one fire season we applied an additional sequence of filters with a longer kernel to keep only multiple fire seasons with more than four 10-day periods. As a result we obtained a grid with the number of fire seasons and their start/end date. This information and the average counts associated to each grid cell were used to assign the fire season to each protected area. The protected areas were assigned the fire season duration of the grid cell with the highest average fire counts found inside their limits. If no fire season was defined for the grid cells inside the protected area border, we considered the 25-km buffer surrounding the protected area and took the fire season of the closest grid cell. In case the grid cell had two fire seasons we merged them together and assigned the protected area a single fire season of longer duration. Since we considered the whole time series the fire seasons can go across two calendar years, which is often the case in many African regions north of the equator.

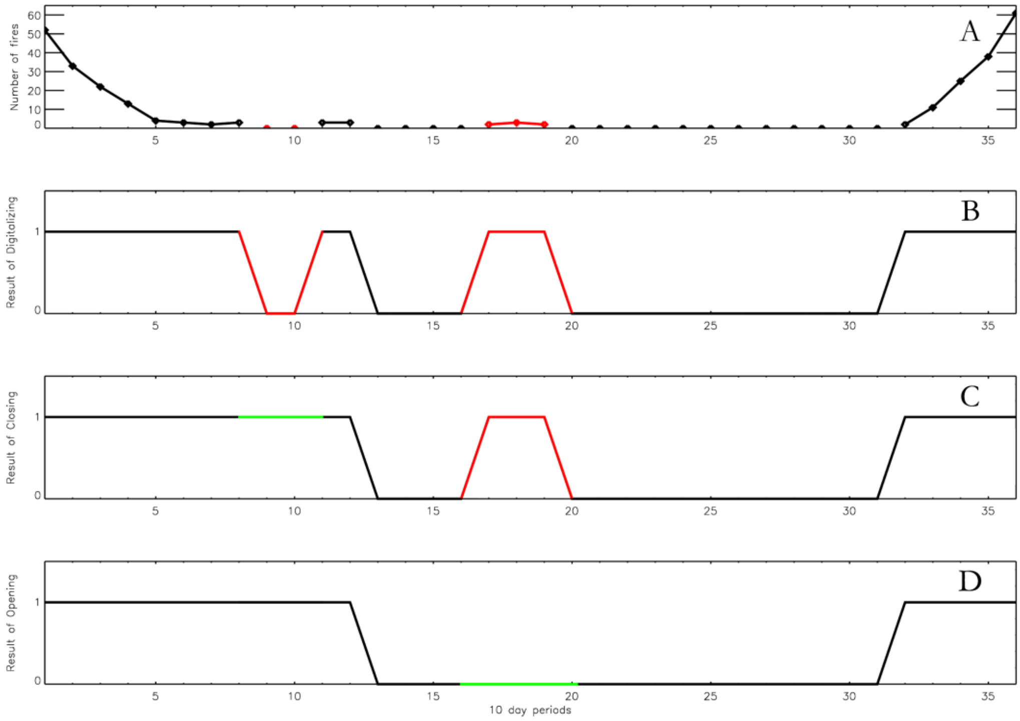


Figure 1. The morphological filtering applied to the active fire time series to identify the fire season. a) fire counts along the reference year. b) binary profile of the fire counts. c) closing filter result. d) opening filter result.

2.1.3. Other indicators

In addition to the fire season we derived other fire indicators that identify key features of the fire activity relevant for their effects on ecosystems and therefore important from a management point of view [10, 11]. We derived indicators that are useful to describe the current fire activity and the spatio-temporal trends throughout the time-series [12]. The indicators are the following: the fire density (number of fire pixels per 1000 ha), the fire density difference between the protected area and the buffer, the cumulative burned area, the increments of the totals (fire density and burned area) at each quarter of the fire season, the daily average fire counts and burned area (2003-2012), the burned area by land cover type.

Besides the daily and seasonal values, some of the indicators are also expressed as average using the whole time-series; in this way they can be used for comparison with the current fire season for the analysis of trends and anomalies.

3. Results

The fire indicators and their use in protected areas management are shown in table 1. The fire density, defined as the number of fire counts per 1000 ha in a given area, is used to assess the fire activity in a protected area over time, but also to compare fire occurrence among protected areas of different size and fire regimes. In addition to the fire density we derived the increments of the total fire counts and also of the total burned area throughout the fire season. This facilitates the interpretation of the cumulative values and helps identify the peak of the fire activity during the fire season.

The information about the fire occurrence and the burned area is also provided for a buffer of 25-km around each protected area. We extended the analysis beyond the park boundaries to identify possible threats and pressures coming from outside the protected area and to assess the level of ecological specificity of the protected area compared to the non-protected surrounding. Moreover we provide comparisons of the fire activity during a specific season and the average values (2003-2012). This indicator can be used to identify anomalies in the fire activity. Since the information about the active fires is updated in near-real time the possible anomalies can be identified at an early stage.

The indicators and the maps are available on the web client at: http://acpobservatory.jrc.ec.europa.eu/content/fire-monitoring. They can be used by a park manager or any person involved in environmental monitoring for the analysis of the fire dynamics in a particular park. The fire indicators are shown in tables and graphs for each protected area; the maps refer to the central six months of the fire season, because this period captures the core of the fire activity. We also provide maps of the fire occurrence, fire density and burned area that can be downloaded. These maps can be opened in a Geographic Information System (GIS) for further analysis.

Table 1. Key fire indicators used for quantifying the burning activity inside the protected areas and in their buffer zone.

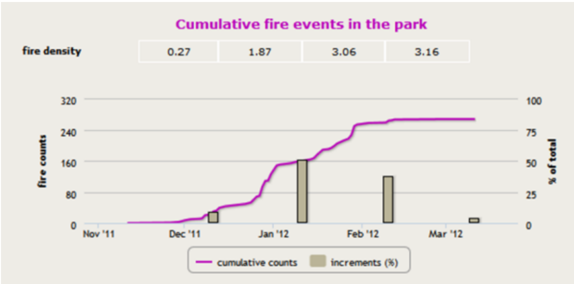
Indicator	Definition	Input Data	Temporal Frequency	Spatial Coverage	Benefits for PA Management
Fire Season (FS)	the length and timing of the fire activity (start/end)	MODIS fire product (MCD14DL) by NASA-FIRMS	the season is derived from the whole time series	- Protected Area (PA)	- implementation of fire plans - verification of effectiveness of Fire Management Plan - detection of trends and/or anomalies
Fire Density (FD)	number of fire pixel(s)/1000 ha in PA and buffer zone	MODIS fire product (MCD14DL) by NASA-FIRMS	seasonal and by quarter of fire season	- Protected Area (PA) - 25-km buffer zone	- comparison of fire activity in time and space - quick detection of illegal activities such as poaching
Fire Density Difference (FDD)	Difference between the FD in the PA and the buffer zone	MODIS fire product (MCD14DL) by NASA-FIRMS	seasonal	- Protected Area (PA) - 25-km buffer zone	- comparison of fire activity in time and space - quick detection of illegal activities such as poaching
Burned Area (BA)	extent of the area burned as total (ha) and in percentage	MODIS fire product (MCD45) by University of Maryland	daily, totals per season and as annual average since 2003	- Protected Area (PA) - 25-km buffer zone	- verification of effectiveness of Fire Management Plan
Land Cover Burned (LCB)	distribution of the total area burned in the land cover classes of the PA	MODIS fire product (MCD45) by University of Maryland	seasonal	- Protected Area (PA)	- assessment of the land cover type most affected by burning - detection of land cover change associated with burning - identification of threats

3.1. Fire Indicators

The web client shows, by default, the indicators during the last complete fire season. However, the user can select other periods of time than the fire season, for example, a 12 months period starting in January or in July. The user can also navigate in the time-series choosing any year between late 2000 and present time (fig. 2).

Figure 2. An example of the tool interface, a protected area is selected as an example. The interface is available in three languages: English, French and Spanish.

The cumulative fire counts and burned area are shown in figure 3 a) and b) with the increments at each quarter of the fire season. The correspondent fire density and the percentage of the total area burned are also indicated at quarters of time, this way the peak months can be easily observed from the graphs. Finally the information from the selected season is shown with the average values and this highlights possible temporal shifts, in the start/end of the fire activity, or in their absolute values (fig. 4). The possibility to look at time-series and the seasonal fire activity allows also the comparison with other information types, for example rainfall data or vegetation indices like the NDVI.

a) 

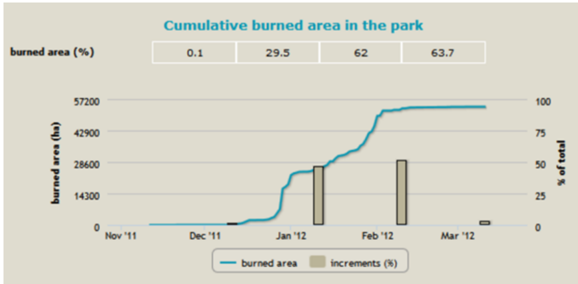
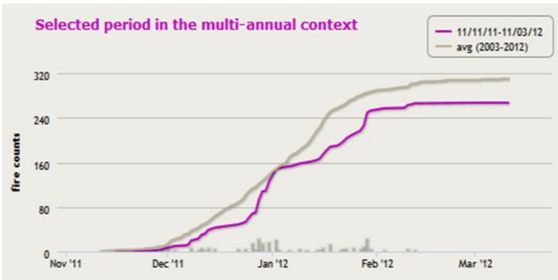
b) 

Figure 3. The cumulative fire counts (a) and burned area (b) in Vassako-Bolo Nature Reserve (Central African Republic). The fire density for each quarter of fire season is reported above the graph.

a) 

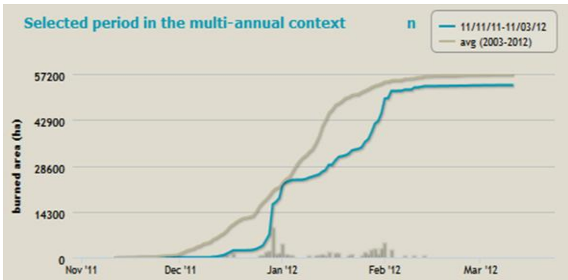
b) 

Figure 4. The cumulative fire counts (a) and burned area (b) during the fire season 2011/12 in Vassako-Bolo Nature Reserve (Central African Republic), the grey line shows the average values for the period 2003-2012.

3.2. Maps and download

The monthly maps of the active fires, burned areas and fire density (fig. 5) can be visualized and downloaded in different standard formats for geospatial data – as raster (geotiff) or vector (shapefile). For basic users the content can be explored in excel tables: they report the location of the fires (latitude, longitude), the date, time and intensity of burning; whereas more advanced users can open the maps using a Geographic Information System (GIS) tool.

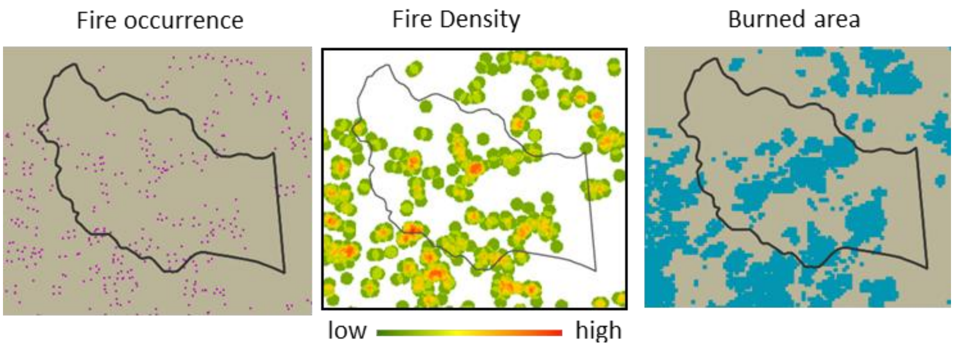


Figure 5. The maps of the fire products.

4. Conclusions and Perspectives

The Fire Monitoring Tool we developed allows to monitor the daily fire activity and learn about the fire history using the time series. In fire dependent or influenced ecosystems, the tool provides park managers with up to date information on burning patterns in and around their area of interest. They can, on the basis of these patterns, detect any anomaly in the implementation of the fire management plans. Anomalies can be indicators of illegal activities, such as poaching or grazing inside the parks, or simply show if fire management plans are addressing their objectives effectively. The Fire Monitoring Tool gives the managers the possibility to improve their planning and management of prescribed burning and to react more effectively to illegal activities.

In fire-sensitive ecosystems, such as the tropical moist forests, the tool provides park managers a rapid and systematic way to detect human induced threats and supports the patrolling activities in and around the protected areas.

More generally, the tool provides decision makers, at local, national and regional levels, with up-dated information which can be used to identify priority areas, strengthen conservation programs and improve fund allocation.

Future developments will include the implementation of an additional interactive map viewer to visualize the fire occurrence and the burned area products, it will be possible to choose any period of time from late 2000 to present. We will also add a reporting functionality to the tool so that the user can download all the views about the different products and indicators and share this information or use it for reporting activities.

In the future we will also include indicators about the fire intensity, since this information is very useful to understand the effect of burning on the ecosystem, and we can derive it from the active fire product using the Fire Radiative Power (FRP).

We are also planning to extend the statistics on the fire activity to other areas of interest like the administrative units at national and regional levels to support decision makers in their planning activities.

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