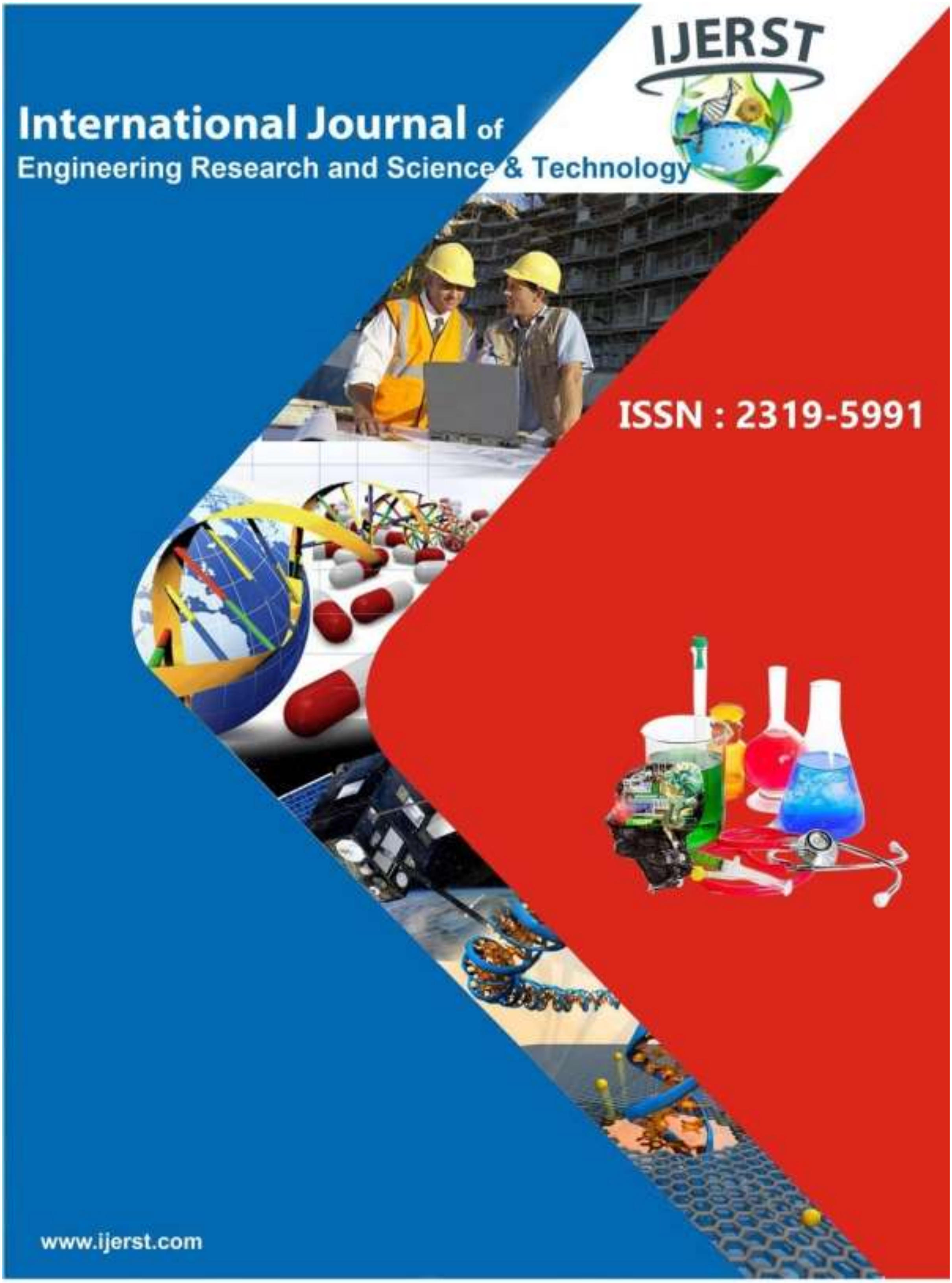

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SPATIO-TEMPORAL ESTIMATION OF THE CARBON FLOW EMITTED BY BUSH FIRES IN SUB-SAHARAN AFRICA

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ABSTRACT: Several greenhouse gases are seeing their concentration increased, but carbon dioxide (CO2) is by far the most significant. Apart from the quantities emitted by industrial activities and its corollaries, bush fires contribute remarkably to the increase of this gas in the atmosphere. Nowadays, the exact estimation of these CO2 emissions still remains problematic given the complexity of the measurement procedures.

This present article proposes the spatio-temporal estimation of the distributions of the carbon flux emitted by bush fires in sub-Saharan Africa by analysis of two types of data (Special observation and modeling). The main objective is to highlight the contribution of bushfires in sub-Saharan Africa in terms of CO_2 emissions. The method used is based on a comparative analysis of the distribution of fires and the carbon flux emitted for the same area and during the same period (2001-2005) using two sets of data, namely: MODIS images for the analysis of the distribution of active fires in the study area and the flux of carbon emitted from the outputs of the ORCHIDEE model to estimate the quantity of CO_2 emitted in these areas. The principle consists of producing distribution maps of active fires and carbon fluxes for the same area and the same period in order to verify the correlations between active fires and carbon fluxes emitted and to estimate the quantities emitted. The results obtained made it possible to notice a spatio-temporal similarity in the distribution of fires and carbon flux. Even if the temporal dynamics on a monthly scale show a small shift, the seasonal one is in perfect harmony between fires and emitted fluxes. The simulations show that the quantities of CO_2 emitted per season are between 5.10-9 and 2.5. 10-8 kg/m^2.s or approximately 7,884 tonnes/hectare/year. These results can be consolidated by other, more in-depth work on fires.

Keywords - Bushfires, carbon flows, Climate change, Sub-Saharan Africa.

INTRODUCTION

It is clear that the increase in greenhouse gases (GHG) in the atmosphere and the resulting climate changes will have major effects in the 21st century. According to several analyses, even if the exact scenarios are still uncertain, negative effects due to climate change are anticipated and it is essential that several actions be taken to reduce GHG emissions and increase their sequestration [1].Many African regions are undergoing increasingly rapid radical transformations of their landscape. These changes are mainly due to unsuitable agricultural systems, the anarchic exploitation of tropical timber and strong demographic pressure and secondarily, to the desire for industrialization of countries leading to an increase in anthropized surfaces and a reduction in natural landscapes [2].In the Sudanese and sub-Saharan landscapes set ablaze during the dry season, the significant changes caused by agricultural intensification are reshaping spaces and associated management methods. In this context, fire, a symbol of forest degradation, becomes an ecological engineering tool for the now threatened savannahs [3]. The negative perception of the effect of fires on vegetation emanates from numerous studies carried out by foresters, managers, biologists and socio-

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economists since the beginning of the 20th century [4]. A significant literature exists on various aspects related to bushfires; but it is often very general and remains limited to particular ecosystems. Despite numerous undesirable effects, bush fires have been considered as a factor dependent on agricultural and savannah management practices [5, 6]. In other words, in the absence of other socially accepted and economically viable alternatives, fires will continue to be an endemic phenomenon in tropical countries [7].

According to the work of Chuvieco (2009) on the global distribution of vegetation fires estimated by satellite, we now know that nearly 30% of the planet is significantly involved in these fires [8]. Every year, millions of hectares of vegetation burn across the world, half of which are in sub-Saharan Africa. This generic expression “vegetation fires” brings together all fires involving plant matter (forest fires, burns, agricultural fires, etc.) [9].

The amount of carbon sequestered in terrestrial ecosystems is approximately 3 times higher than that in the atmosphere [10]. This soil carbon is 700 times greater than the annual increase in CO2 [11]. Consequently, even small changes in the sequestration capacity of this enormous reservoir could have decisive repercussions on the evolution of the atmospheric CO2 level.

Bush fires, despite all these negative effects, also contribute to global warming through the emission of energy, CO2 and other particles as well as the stunting of vegetation which constitutes the main sink. of carbon [12].

Today, beyond a simple theoretical approach, environmental problems require practical responses that match the challenges and threats. This is the main reason which led us to undertake this study relating to the estimation of the contribution of bush fires in terms of climate change [13].

The data and methods used as well as the results obtained made it possible to better understand the contribution of fires in terms of CO2 emissions, the main greenhouse gas.

DATA AND METHODS

Two types of data were used for this analysis:

- The carbon flux data used are outputs from the ORCHIDEE model.
- This atmospheric carbon flux data in format. Netcdf have low spatial resolution (3.75°×2°) however the temporal resolution is one month. They cover the entire globe and are available for the period 1850 - 2005.

MODIS data: MDC14ML in .shp format of active fires, spatial resolution 1kmx1km, and temporal (daily) available from 2001 to the present were collected for the period 2001-2005.

To arrive at an estimate of the carbon flux emitted, we used the outputs of the ORCHIDEE model.

ORCHIDEE (Organizing Carbon and Hydrology In Dynamic EcosystEms) is the surface diagram of the climate model of the Institut Pierre Simon Laplace (IPSL). It explicitly resolves the water and energy balances of continental surfaces, as well as the phenology and carbon cycle of the terrestrial biosphere.

The R application running under Linux made it possible to visualize the spatial and temporal distribution of the carbon flow based on data from the ORCHIDEE model for the sub-Saharan zone and for the period 2001-2005; Maps of the spatial distribution of CO2 flux were designed. An interpolation to better visualize the distribution was made. Figures were generated as well as temporal evolution curves with a monthly step.

Regarding the MODIS data, they were reprojected in UTM-WGS-1984 using the ArcGIS application running under Windows for the organization, and the spatial and temporal distribution of fires for the study area. Monthly aggregations of all fire pixels were made. For better spatial observation, we carried out an interpolation by ordinary kriging.

The study period was chosen based on data availability. The CO2 flux obtained dates from 1850 to 2005, while the MODIS data that we were willing to use because of their good spatial and temporal resolution only covers the period 2001 to the present day. This is the main reason for choosing the 2001-2005 cross-period for the analysis.

Maps of distribution of fire and carbon flux per year were generated for the years 2001, 2002 and 2003 for illustration. The temporal evolution of the fire and the carbon flux over the month was traced and thus, the results on the spatial and temporal distribution were obtained and will be the subject of analysis and interpretation.

RESULTS AND DISCUSSIONS

SPATIAL DISTRIBUTION OF BUSHFIRES AND CO2 FLUX FROM 2001 TO 2003.

Bushfire Density and Atmospheric Carbon Flux in Sub-Saharan Africa

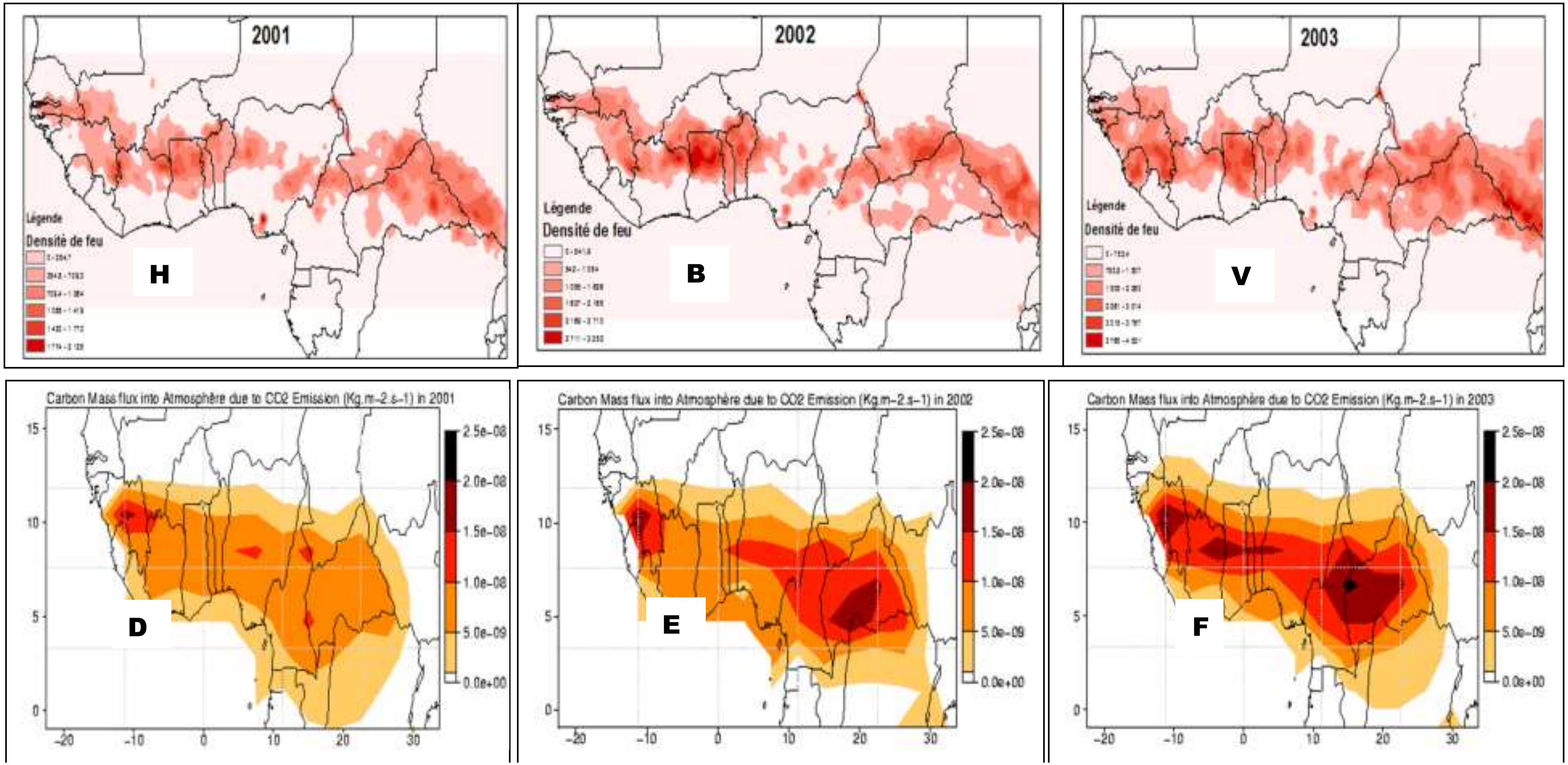

Figure 1 : A, B and Cspatial distribution of active fire densities and D, E and F estimation of the spatial distribution of the carbon flux emitted by the fire 2001 to 2003 in the sub-Saharan African region.

The estimate of the density of active fires in sub-Saharan Africa made by counting the pixel potential of fires per km2 shows places reaching nearly 4000 pixels.

From a spatial point of view, we see in these figures a similarity between the distribution of fires and the emission of the CO2 flow.

Indeed, the analysis of the results of simulations carried out by different models is an important element for identifying robust results or, on the contrary, for identifying and understanding the origin of differences between models.

These figures show good agreement between the results of the IPSL model and those of satellite observation in the study of the dynamics of bush fires.

Satellite observations show that fires are very recurrent during the dry period (October-March) (figure 2).

TEMPORAL DISTRIBUTION OF BUSHFIRES AND CO2 FLUX (MONTHLY AVERAGE).

The analysis of MODIS data for a period of five (5) years revealed that maximum fires are observed between December and January in sub-Saharan Africa (figure 2).

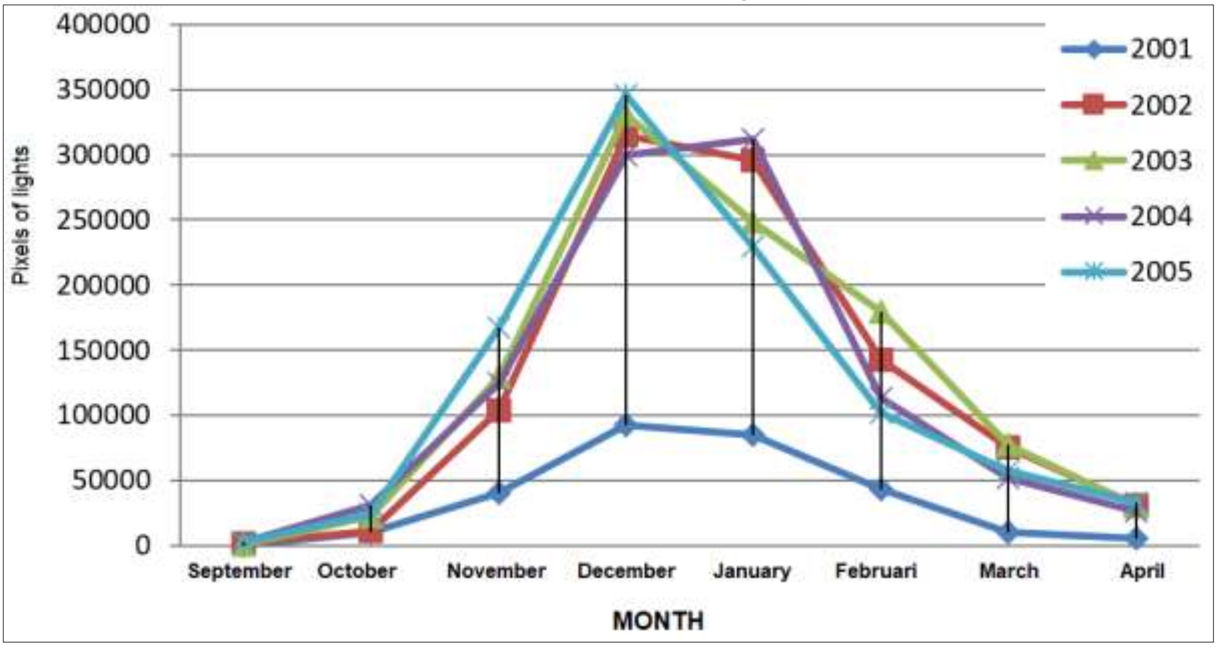

Figure 2 : Seasonal evolution of bush fires in the sub-Saharan zone from 2001 to 2005

The curves indicate that if the 2001-2002 period was marked by low cases of fires, the other periods observed experienced approximately the same episodes of fires with maximums varying between 300000 and 350000 pixels of fire. On the other hand, we notice that the fires start and fade practically periodically. The maximum CO2 emissions corresponding to the maximum number of fires is 2.5. 10-8 kg/m^2. S, i.e. approximately 7884 kg/hectare/year

Analyzing the annual cycles further (fig.3) we notice a narrowing of the pause period of active fires from the 2003-2004 season, which could be explained either by the shortening of the rainy seasons and the lengthening of dry seasons, since fires are often conditioned by the availability of a dry fuel load and by the nature of human activities carried out in the environment. This aspect can be useful in researching the main causes of fires in these areas.

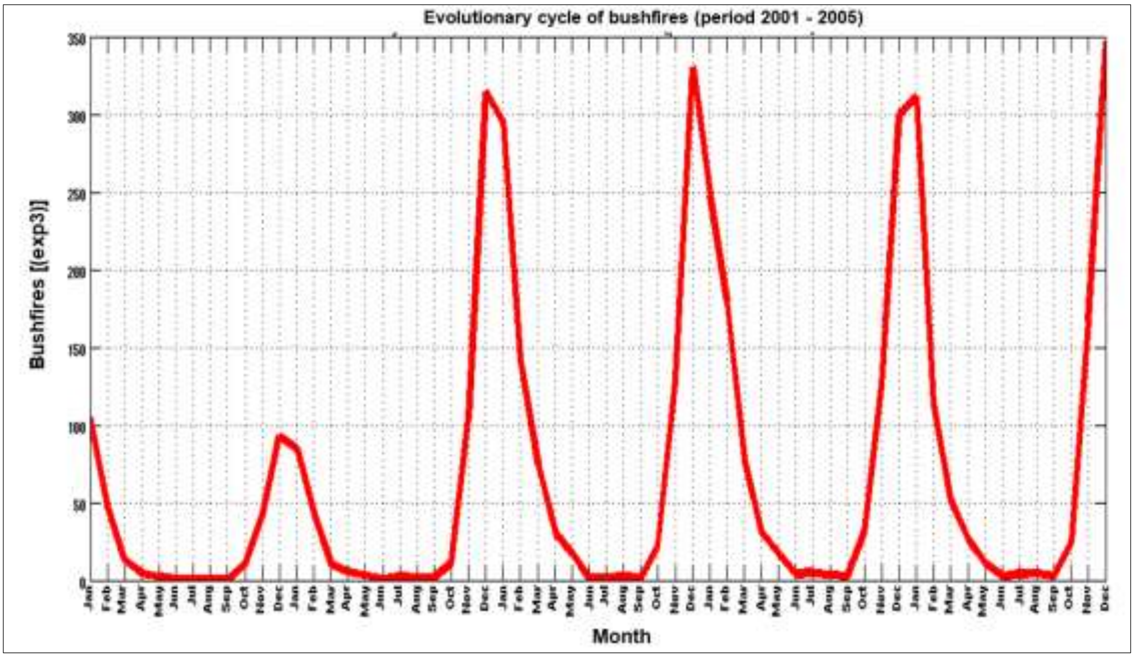

Figure 3 : Bushfire regime in sub-Saharan Africa

For the years 2001 and 2002, the break period extends over six (6) months, that is to say from April to September, and on the other hand between 2003 and 2005, this break is only worth four (4) months (June to September).

For convenience, we also observed the temporal dynamics of the CO2 flux for the same period (fig.4). The idea is to check whether the emission maximums of the carbon flow coincide over time, with the maximum fire pixels counted by MODIS.

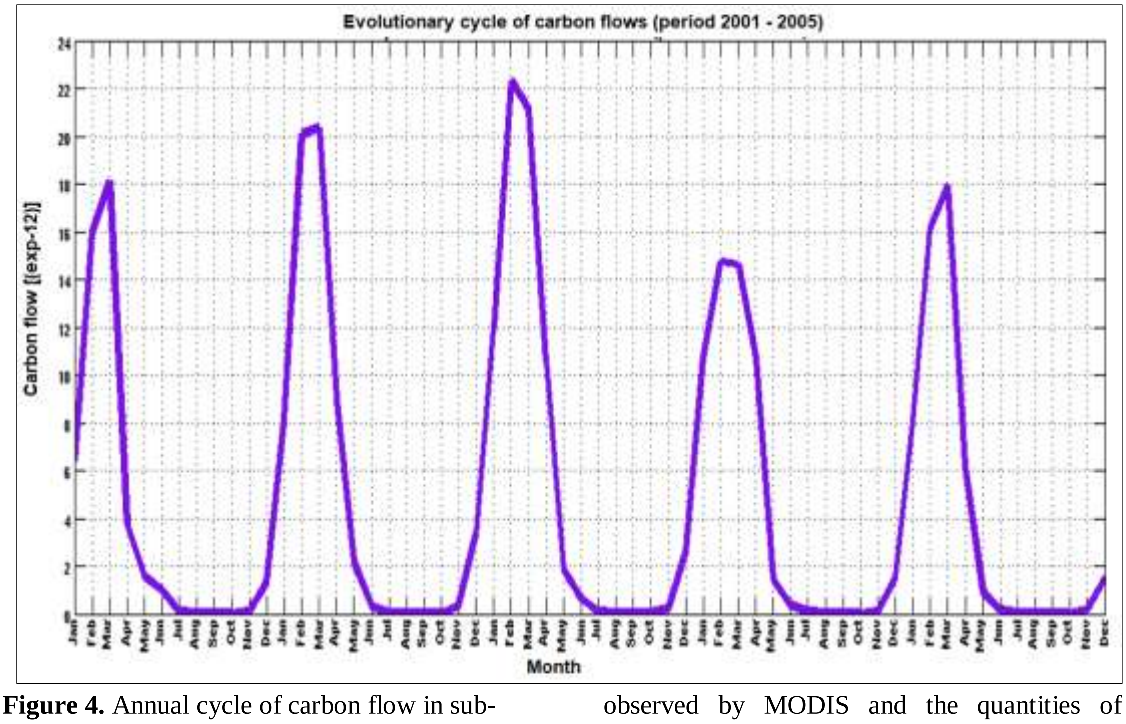

Figure 4. Annual cycle of carbon flow in sub-Saharan Africa

The temporal variation curve of the atmospheric carbon flux emitted by fires takes the same shape as that of the temporal variation of active fires. This explains the linear relationship between these two variables.

On the other hand, by observing the peaks of these two curves, we practically do not find a perfect proportionality between the number of fire pixels observed by MODIS and the quantities of the atmospheric carbon flux emitted modeled by IPSL. In this regard, we put forward the hypothesis stipulating that the quantities of carbon flux emitted do not only depend on the number of pixels burning, but also depend on the density and type of fuel. In addition, it should be noted that MODIS does not count all the fires, because some fires break out after the passage of the satellite. For a better observation of the temporal dynamics of the two variables, we superimposed them (figure 5).

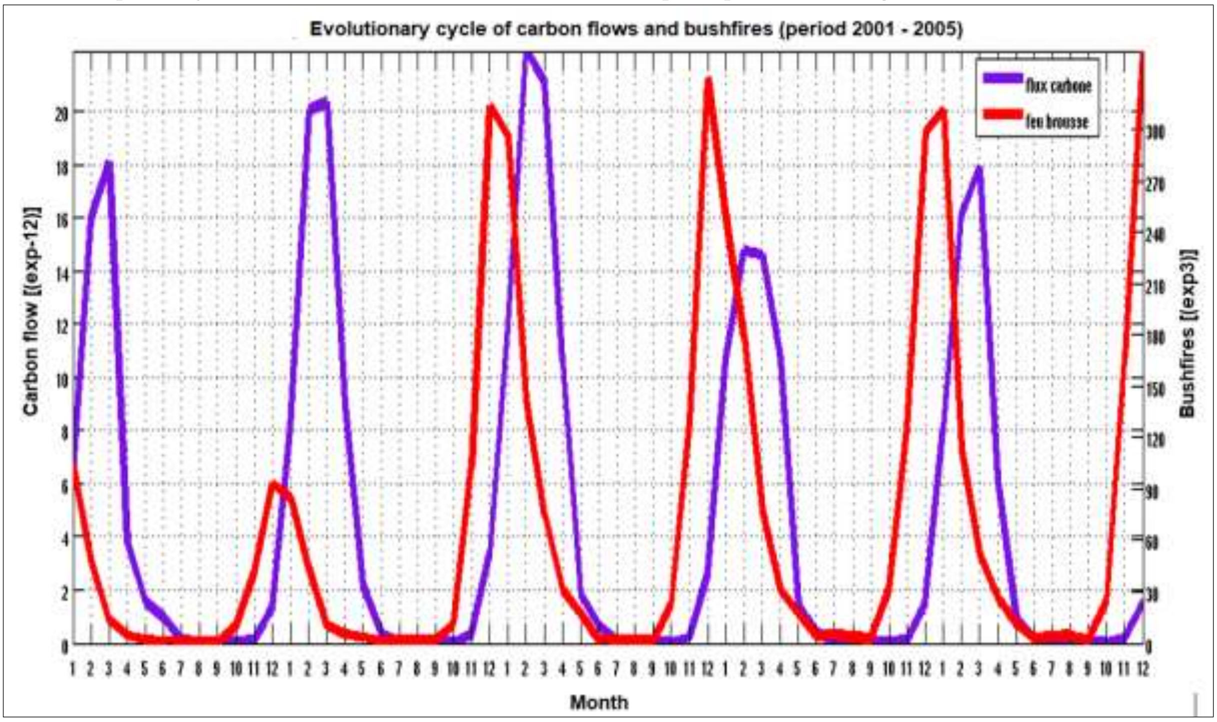

Figure 5 : Annual cycle of bushfires and carbon flux in sub-Saharan Africa

We note that if the maximum fires are recorded between December and January, the maximum carbon flow emissions are observed between February and March. This shift appears to be normal because it is after the fire has passed that the quantity of CO2 accumulates over time in the atmosphere and the flow of CO2 emitted by bush fires as well as its storage in the atmosphere is a function of the quantity emitted. This is explained by the fact that preventive fires are often recorded in large numbers, but consume little fuel due to the high humidity rate and late fires, although few in number but ravaging large quantities of biomass due to the rate of appreciable drying.

CONCLUSION

In conclusion, fires and carbon flows are strongly recorded in dry periods and attenuate during the winter season, this also explains the seasonal nature of fires in sub-Saharan Africa. These results could open up other avenues of reflection on the use of the modeled atmospheric carbon flux for the analysis of the contribution of bushfires in terms of climate change. In addition, a high-resolution experimental evaluation of the CO2 emitted by fires could be very useful to quantitatively validate the modeled flow quantities. Such work requires resources and expertise. The results obtained in this present manuscript would ultimately allow good analyzes to be made on the contribution of fires in terms of atmospheric carbon storage.

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