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LUÍS MÁRIO RIBEIRO

Agricultural fires in France: a first national overview from data mining

Lilian Vallet[1] ; Florent Mouillot[1] ; Jean-Marc Ourcival[2]

[1]IRD, UMR CEFE, 1919 route de mende, 34293 Montpellier Cedex 5, France
{lilian.vallet@cefe.cnrs.fr, florent.mouillot@ird.Fr}
[2] CNRS, UMR CEFE, 1919 route de mende, 34293 Montpellier Cedex 5, France
{jean-marc.ourcival@cefe.cnrs.fr}

**Corresponding author*

Keywords

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Abstract

Introduction

- Even if the agricultural fires can affect a high proportion of burned areas, their inventory is insufficient.
- Considering the importance of agriculture in France, understanding agricultural fire regimes appears to be central to the objective of food security.
- Most cropland or rangeland fires are directly or indirectly related to human activities, facilitating their control.

Material and methods

- A data mining analysis of non-scientific literature was conducted between 2000 and 2021 to study the temporal and spatial evolution of agricultural fires.
- This database is compared to MODIS hotspots in order to validate this active detection method and to define its limits.

Results

- The data mining study allowed the inventory of more than 500 fire events per year.
- The national heterogeneity of agricultural fires is mostly explained by the variation of crop types across the territory as well as by climatic conditions.
- Crop fires occur primarily during the summer months when weather and fuel conditions are most favorable. Pasture fires, mainly prescribed fires, occur before and after winter to limit their spread. Fires in infrastructures occur throughout the year.

Discussion

- This first attempt at inventorying agricultural fires in France allowed us to describe spatial and temporal patterns specific to these types of fires.
- Remote sensing data only partially capture these small fires.
- Carbon emissions from these fires are currently largely underestimated.

1. Introduction

Agricultural fires account for a significant proportion of the annual burned area under temperate and Mediterranean climates (van der Werf et al., 2010).However, these cropland and rangeland fires are generally not included in current fire inventories and their consequences are severely underestimated (Shi et al., 2015). The characterization of these fires in terms of temporal and spatial variability as well as the associated carbon emissions are therefore largely unknown (Hunter and Robles, 2020). This lack of knowledge is partly attributed to the limitation of remote sensing technologies to capture agricultural fires for three main reasons: (1) Many harvested or ploughed croplands have similar spectral characteristics to burned areas. (2) The temporal behavior of harvested or burned cropland is similar to that of grassland fires (sudden decline followed by gradual recovery in NDVI, interannual variation in NBR) (Alonso-Canas and Chuvieco, 2015). (3) Many agricultural fires are human-caused and are generally small and short-lived, making them difficult to capture by satellite sensors (Vilar et al., 2015).

In France, where usable agricultural areas represent 30 million hectares (i.e., 52% of the country), and although croplands and rangelands have relatively lower biomass density than forests, the fire risk of these ecosystems should not be underestimated (“World development indicators,” n.d.). First, current climate change is increasing the number of days when climate-fuel conditions are critical for fire ignition and spread, increasing the vulnerability of these environments (Bowman et al., 2020). Second, because these ecosystems are central to the agri-food production system, the lack of knowledge about the behavior of these fires may pose a threat to food security (O’Mara, 2012). Third, lack of monitoring of these fires can lead to uncontrolled spread of fire to adjacent forests and even to human infrastructure (Dether and Black, 2006).

Most agricultural fires are human-induced, although their ignition may or may not be deliberate. Deliberate fires, called "prescribed fires," are intended to provide many benefits to ecosystems and human society: transforming arable land, cleaning crop residus, providing pasture production, providing habitat for wildlife, reducing hazardous fuels (Hunter and Robles, 2020; McLauchlan et al., 2020; Pausas and Ribeiro, 2017). In order to change land use and improve agricultural production, humans have therefore developed fire control techniques such as "burn-beating" or "stubble burning" approaches (Bowman et al., 2011; Prichard et al., 2017). In contrast, unintentional fires, called "wildfires," are caused by unauthorized ignitions, escaped prescribed fires, arson, or technological malfunctions (McLauchlan et al., 2020). Agricultural fires can also, less frequently, be caused by natural causes such as lightning (Amatulli et al., 2007; Coughlan et al., 2021).

Active detection of thermal anomalies during combustion by remote sensing is the primary source of information used to capture agricultural fire occurrence (Giglio, Louis, 2000), but suffer from a return time interval (6hrs) longer than most small-fire durations. It is therefore essential to assess the accuracy of these hotspots, based on reference data that we performed with datamining in national newspapers.

2. Materiel and Methods

A data mining analysis of the non-scientific literature was carried out for the period 2000-2021 over the whole France. This study was based on a systematic screening of regional and national online newspapers with keywords such as "fire", "agriculture", "fields", "residue", aiming at obtaining an overview of fires occurring on croplands or rangelands. For each fire event, the date and the location of the administrative unit are identified. Depending on the quality of the information source, vegetation type (crop type and status as residue or whole plant) is referenced. Where information is available, the estimated area of pasture or crop burned is recorded. In addition, fires in agricultural storage buildings are also considered, some of which provide a mass of burned dry matter.

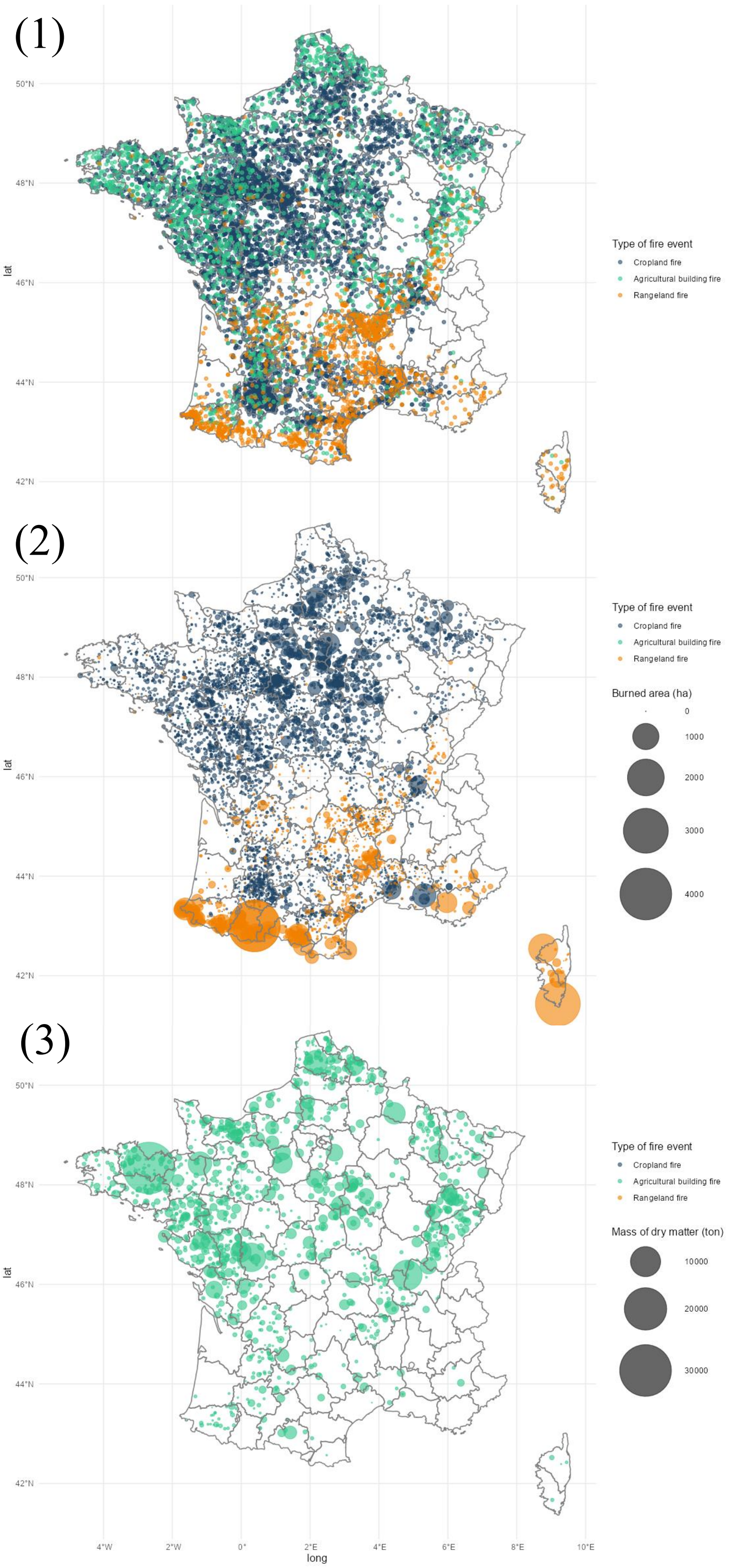
This database was then analyzed to describe the temporal evolution, seasonality, and spatial heterogeneity of agricultural fires. This analysis provides an understanding of the spatial and temporal fire patterns associated with cropland and pasture.

This database was then compared with VIIRS-SNPP hotspots (Schroeder et al., 2014) over the 2012-2021 time period. To do this, the VIIRS-SNPP hotspots were filtered out on cropland, grassland and pastures vegetation types (Corine Land Cover), and matched with referenced fires, in order to estimate the accuracy produced by this observation technique, as well identifying potential local or temporal caveats in fire reporting by the litterature. We estimated the fraction of fire events captured by hotspots as a function of fire size, and the relationship between fire events burned area and hotspot numbers. A final model relying hostspots to burned area, and omission errors allowed to provide an objective burned area data base for agricultural fires in France with its associated uncertainty for carbon emission studies.Current results and discussion

The database from the literature review identified 10453 agricultural fire occurrences between 2000 and 2021, i.e. more than 500 per year. These data correspond to 6808 crop fires, 2068 infrastructure fires and 1577 rangeland fires.

2.1. Spatial distribution

Figure 1.1 shows the spatial distribution of agricultural fires, which are present over almost the entire territory, including temperate and mediterranean environments. The least affected regions may correspond to the large French wine-growing regions, whose flammability is very low (Bordeaux, Burgundy and Alsace regions). High altitude regions (Alps) and those largely covered by forests (Landes) seem also less affected by agricultural fires.



Crop fires seem to be concentrated in the major French rainfed agricultural production areas, namely the Beauce plain south of Paris and Brittany to the west. Fire size (Figure 1.2) appears to be particularly large in the agricultural regions surrounding Paris, mainly composed of large cereal fields.

Fires in agricultural infrastructures largely follow the distribution of crop fires. The mass of dry matter burned seems to be particularly important in the West of France, a region where livestock and therefore fodder storage are important. As storage buildings are generally located close to livestock buildings (e.g. piggeries), these fires can lead to the death of a large part of the livestock and have severe economic consequences.

Rangeland fires particularly affect the high plateaus, especially in the Pyrenees, Corsica and the Massif Central. This distribution corresponds to the continuation of the practice of "stubble burning" in the south of France. This government-regulated practice involves the burning of standing plants to fertilize the soil and facilitate grazing. The fires that are particularly widespread in the Pyrenees are probably mixed fires (partly affecting the forest), probably escaped prescribed fires or involuntary fires.

Figure 1: (1) Distribution of agricultural fire occurrences in France between 2000 and 2021. (2) Spatial variability of cropland and rangeland burned areas (ha). (3) Spatial variability of dry matter mass (ton) burned in agricultural building fires. (Blue = Cropland fire, Green = Agricultural building fire, Orange = Rangeland fire).

2.2. Temporal trend

Figure 2 shows the evolution of agricultural fires over time. There is a strong seasonality and the appearance of particularly extreme years. Specifically, the years 2015 and 2019 for crop fires and the years 2012 and 2019 for rangeland fires show a very high number of fires. These years are characterized by particularly high temperatures related to heat waves early in the season. These climatic conditions lead to early droughts, reducing the moisture content of vegetation and increasing its flammability.

The amount of information available over the study period appears to vary. Indeed, the data available before 2006 do not seem to match the occurrence of agricultural fires in France after this date. The bibliographic review seems to be temporally biased, when there is a strong coverage of fire events by the local media. Our data do not allow us to conclude on a potential increase in agricultural fire events.

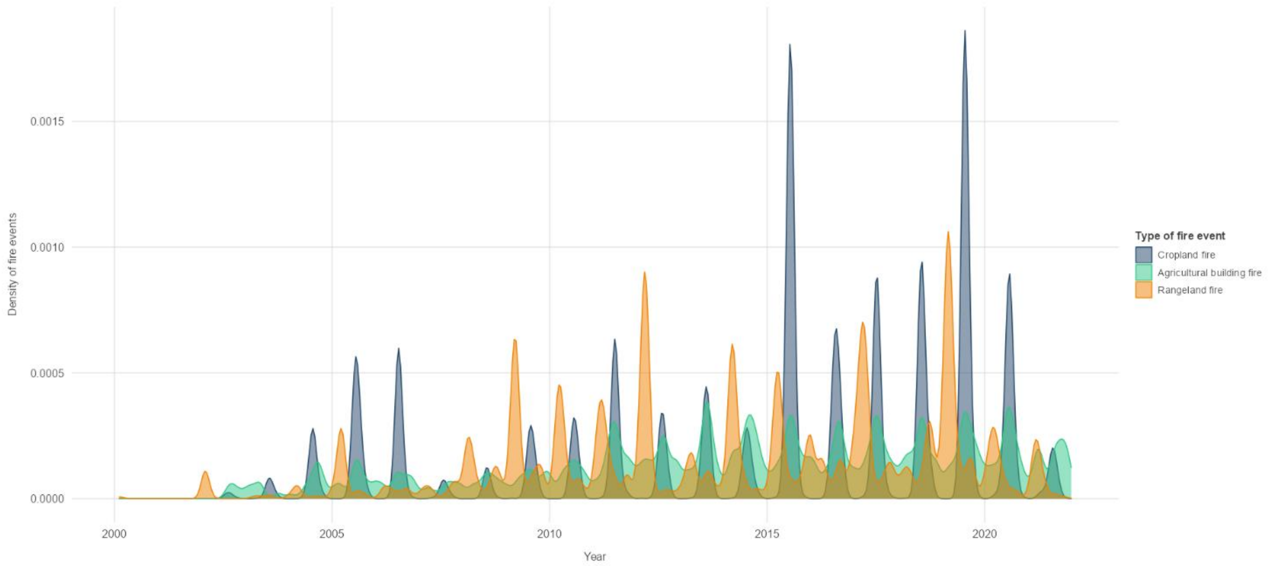


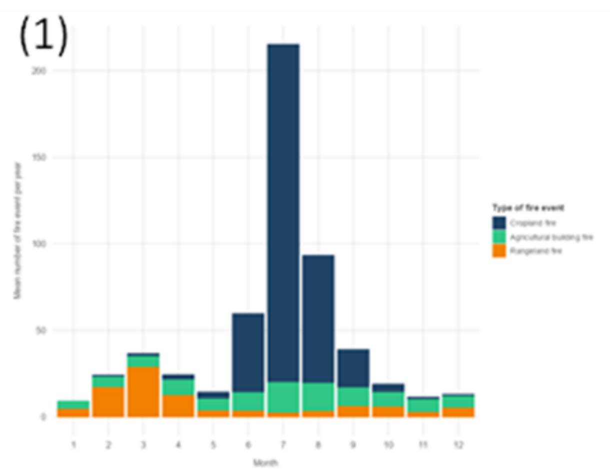
Figure 2 : Temporal evolution of agricultural fire occurrence over the period 2000-2021 in France. (Blue = Cropland fire, Green = Agricultural building fire, Orange = Rangeland fire).

2.3. Seasonality

Agricultural fires are marked by strong seasonality, with the peak occurrence in July with an average of over 200 agricultural fires per month (Figure 3.1). This peak is mainly due to the sharp increase in crop fires from June to August. This period is characterized by a strong increase in temperatures and a decrease in precipitation, particularly around the Mediterranean basin. These climatic conditions favor the burning of plots whose biomass has accumulated since early spring.

Fires in infrastructures occur almost uniformly throughout the year. While climatic conditions may account for their occurrence during the rest of the year, winter building fires can probably be attributed to mechanical and technological malfunctions leading to fire ignition.

The rangeland fires occur particularly in February-March, but also in September-October, especially for the years 2007, 2016, 2018 (Figure 3.2). These fires correspond largely to prescribed fires subject to authorization delivered only during this period when fire weather is less conductive to fire spreading.



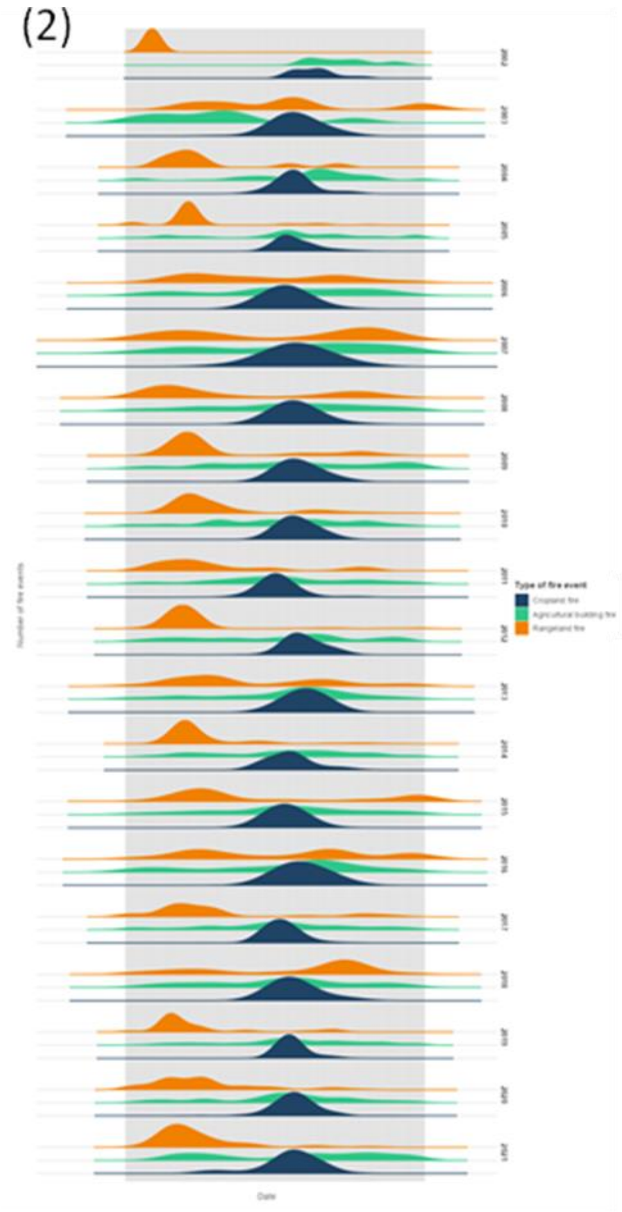


Figure 3 : (1) Average annual distribution of agricultural fires over the period 2002-2021 (2) Distribution of agricultural fire occurrences for each year between 2002 and 2021. (Blue = Cropland fire, Green = Agricultural building fire, Orange = Rangeland fire).

2.4. Remote Sensing

Figure 4 represents the hotspot density map over croplands/pastures in France from VIIRS S-NPP over the 2012-2020 period. We observe a similar national pattern as from datamining, with high fire activity captured where the largest fires are referenced, and the highest fire activity in the southwest mountainous pastures fires. Fires smaller than 100ha and 50ha were however only captured respectively at 50% and 25% (Figure 5), leaving a high uncertainty in small fires detection from remote sensing compared to datamining. The relationship between hotspot number and fire size for each fire event followed a logarithmic increase (figure 6) with remaining high uncertainty in large burned areas estimates (Liu et al., 2019).

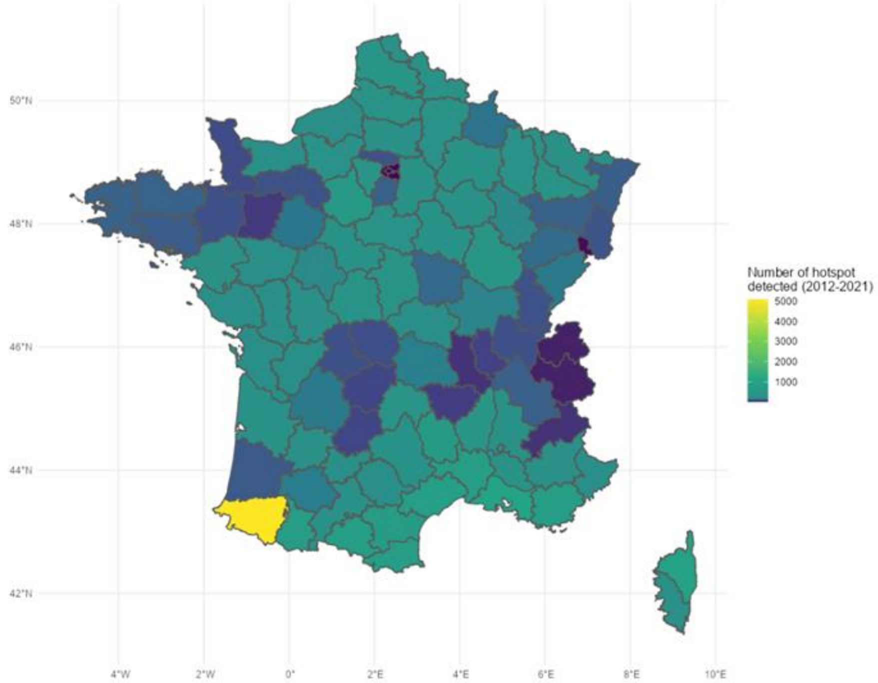


Figure 4 : Number of hotspots detected in croplands by VIIRS Suomi NPP from 2012 to 2021 for each department in France

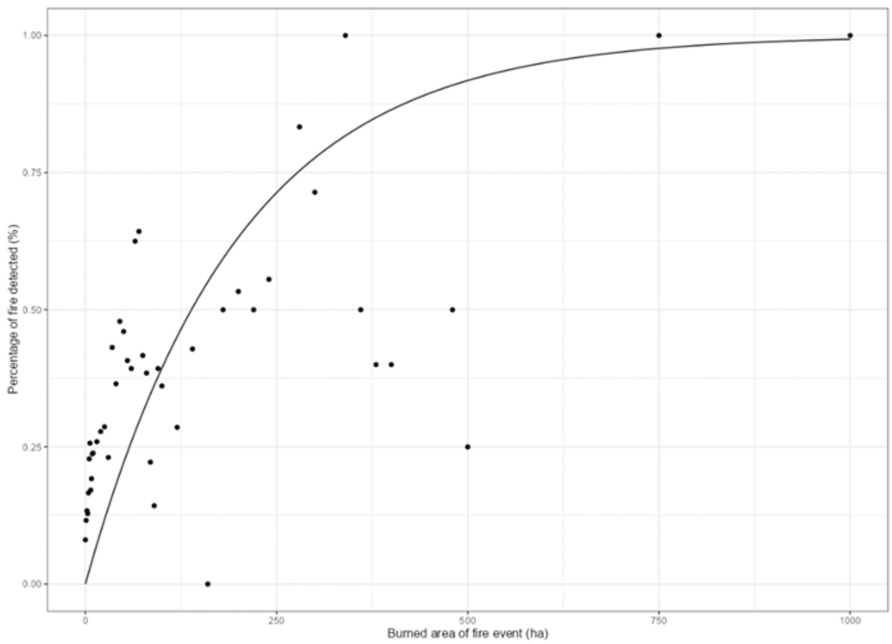


Figure 5 : Fire detection rate (%) with at least one hotspot from VIIRS S-NPP for burned area of fire events (ha) referenced in the datamining References

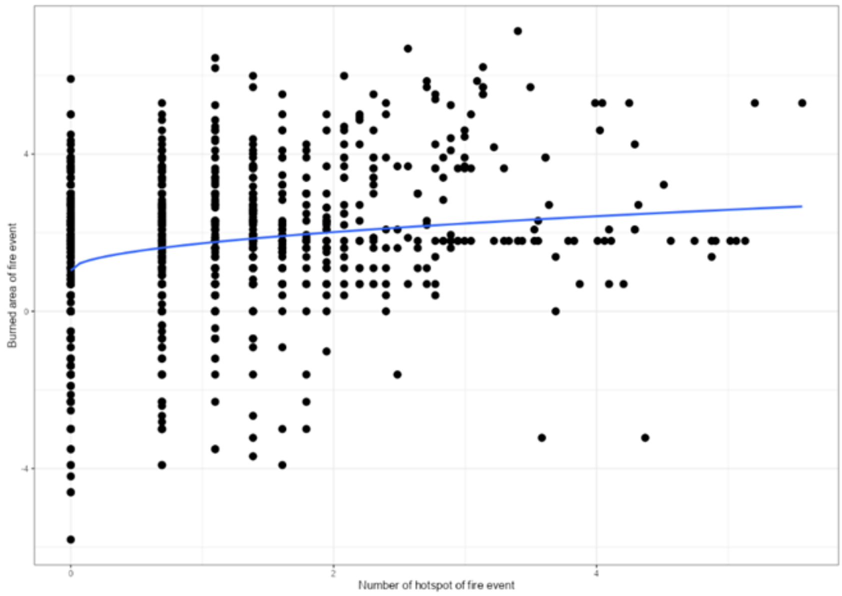


Figure 6 : Relationship between the number of hotspots (log scale) detected and the burned area (log scale) for each fire event (n=1620)

3. Conclusion

This study represents the first attempt to inventory agricultural fires in France. The data mining analysis allowed to highlight spatial and temporal patterns specific to cropland and rangeland fires. Remote sensing data provided a poor improvement for these small, low intensity fires, highlighting the need for better referencing of cropland fires and methodological developments from new sensors (Deshpande et al., 2022).

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