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Evaluating the influence of Live Fuel Moisture Content on Fire Behavior and Fire Activity

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Abstract

Live Fuel Moisture Content (LFMC) – the ratio of the water mass to the dry mass of live fuel - is increasingly recognized as a critical factor of fire behavior (Rossa *et al.*, 2016; Martin StPaul *et al.*, 2018b; Pimont *et al.*, 2018) and hazard (Dennison and Moritz, 2009; Ruffault *et al.*, 2018; Martin StPaul *et al.*, 2018b). This fuel parameter is obviously affected by drought and thus climate change. Here, we present some recent findings regarding how LFMC affects both fire behavior and activity based on statistical analyses applied to three datasets: a shrub fire experiment dataset (Anderson *et al.* 2015) for fire behavior and two extensive spatial datasets in Mediterranean France: LFMC ("Réseau Hydrique") and fire activity ("Promethée"). Our results show that LFMC would be a significant factor of fire behavior and activity, especially below 100%, leading to an increase in fire rate of spread and fire occurrence by ≈200% in driest conditions (LFMC=43%), and by ≈400% for the occurrence of large fires, when compared to moister summer conditions (LFMC=100%).

Impact of LFMC on fire activity

We interpolated on a daily basis, the LFMC values of the different sites of the "Réseau Hydrique", where LFMC was measured during the fire season on a weekly basis (Martin StPaul *et al.*, 2018a). We then assigned to each daily value the corresponding fire activity[1] occurring in 10 km buffer zone around measurement sites. This process led to a dataset in which each LFMC value is associated with fire numbers (>1ha), large fire numbers (>100ha) and burnt areas in its surrounding area.

We first applied the "cumulative burnt area" method (Dennison and Moritz, 2009), which aims at identifying "elevated fire danger thresholds" (Fig 1). We found such a threshold at 83%, as well as a saturation threshold at 56%, as reported in some earlier studies. But we also found similar breakpoints when applying the method to a dataset in which burnt area is constant (neutral), which strongly suggests that this method is biased by LFMC frequency distribution. We therefore recommend not to use the thresholds derived from this method for research or operational purposes.

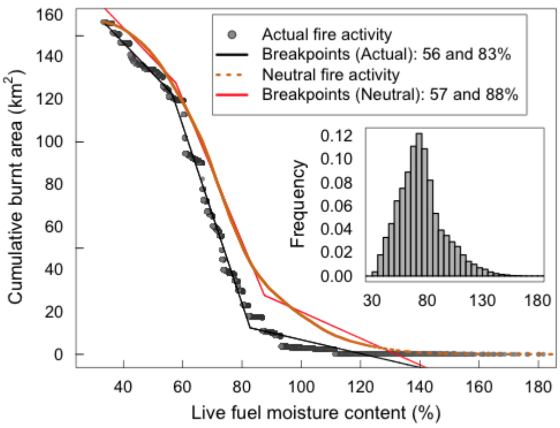

Fig 1 – Application of the « cumulative burnt area » method to RH dataset (in black) and a neutral dataset (in orange).

[1] http://www.promethee.com/en/incendies

We then used a generalized additive model (GAM, Hastie *et al.*, 2009) to fit the fire occurrence model assuming a gamma distribution of the residuals, in a framework similar to Preisler *et al.* (2004):

$$log(N) = log(S_f) + s(LFMC) \quad (1)$$

where N and S_f are the number of fires and the forest area in the buffer area and s is smooth function.

The –multiplicative- response function of fire occurrence (and confidence intervals) are plotted in Fig. 2 for fire larger than 1 ha and fires larger than 100 ha. The reference is LFMC=100%, so that a response of 2 corresponds to twice as more fires as when LFMC is equal to 100%. Both curves reveal a pronounced effect of LFMC below 100% and no evidence of saturation, as LFMC reaches its minimum values. LMFC effect seems stronger for large fires than for all fires, since the magnitude of the response is larger. Colored arrows show the occurrence increases (in %) associated with three thresholds used by French fire prevention and fighting managers.

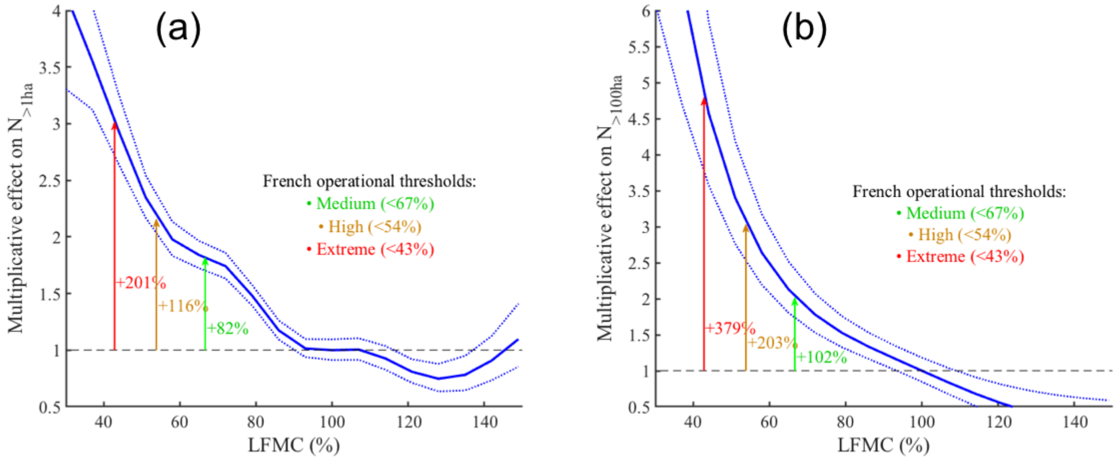

Fig 2 – Multiplicative response of fire occurrence as a function of LFMC for (a) number of fires larger than 1ha (b) number of fires larger than 100ha as a function of LFMC.

Impact of LFMC on fire behavior

We used a shrub fire experiment dataset (Anderson *et al.* 2015) to fit a model for rate of spread (ROS) as a function of LFMC.

$$ROS = aU^b e^{-cDFMC} H^d s(LFMC) \quad (2)$$

where s is smooth function. The model fit is a generalized additive model (GAM, Hastie *et al.* 2009) using a "log" link and is described in details in Pimont *et al.* (2018).

The –multiplicative- response of ROS to LFMC shows a strong effect on fire rate of spread when LFMC is below 100%, but negligible above it (Fig 2). Unfortunately, the range of the confidence intervals strongly increases below 67 %, as the experimental fires were hold in LFMC conditions above 67% (between 67 and 256 %). This highlights the critical need for fire experiments in drier conditions to get a better estimation of the response function in the range that is really important for operational services.

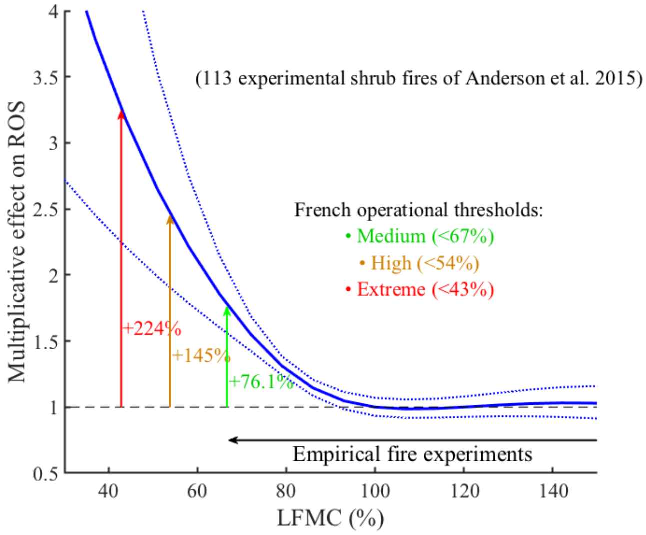

Fig 2. Response of fire rate of spread as a function of LFMC, derived from Eq. 1, fitted over the fire experiments described in Anderson et al. (2015). A strong increase in ROS is observed below 100%, even if the confidence intervals strongly increase below 67% because of the lack of experimental data in this range

Conclusion

Despite that our analyses were performed on fire characteristics from different scales, our results show a consistent and important effect of LFMC on both fire behavior and fire activity. These findings suggest that some efforts should be dedicated to understanding of LFMC impact on fire, especially during the driest conditions where uncertainty remains important. These results motivate further researches to investigate the mechanisms driving LFMC effects on fire behavior and activity.

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Presenter’s bio:

François Pimont currently works at the Department of Forest, Grassland and Freshwater Ecology, French National Institute for Agricultural Research in the Fire Physics and Ecology team. François does research in Fire Science and Remote Sensing. He is especially interested in Fire Behavior and Activity and their different factors, as well as in Fuel modeling.