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Supplementary Material

Calculating fire danger of cured grasslands in temperate climates – the elements of the Grassland Fire Index (GLFI)

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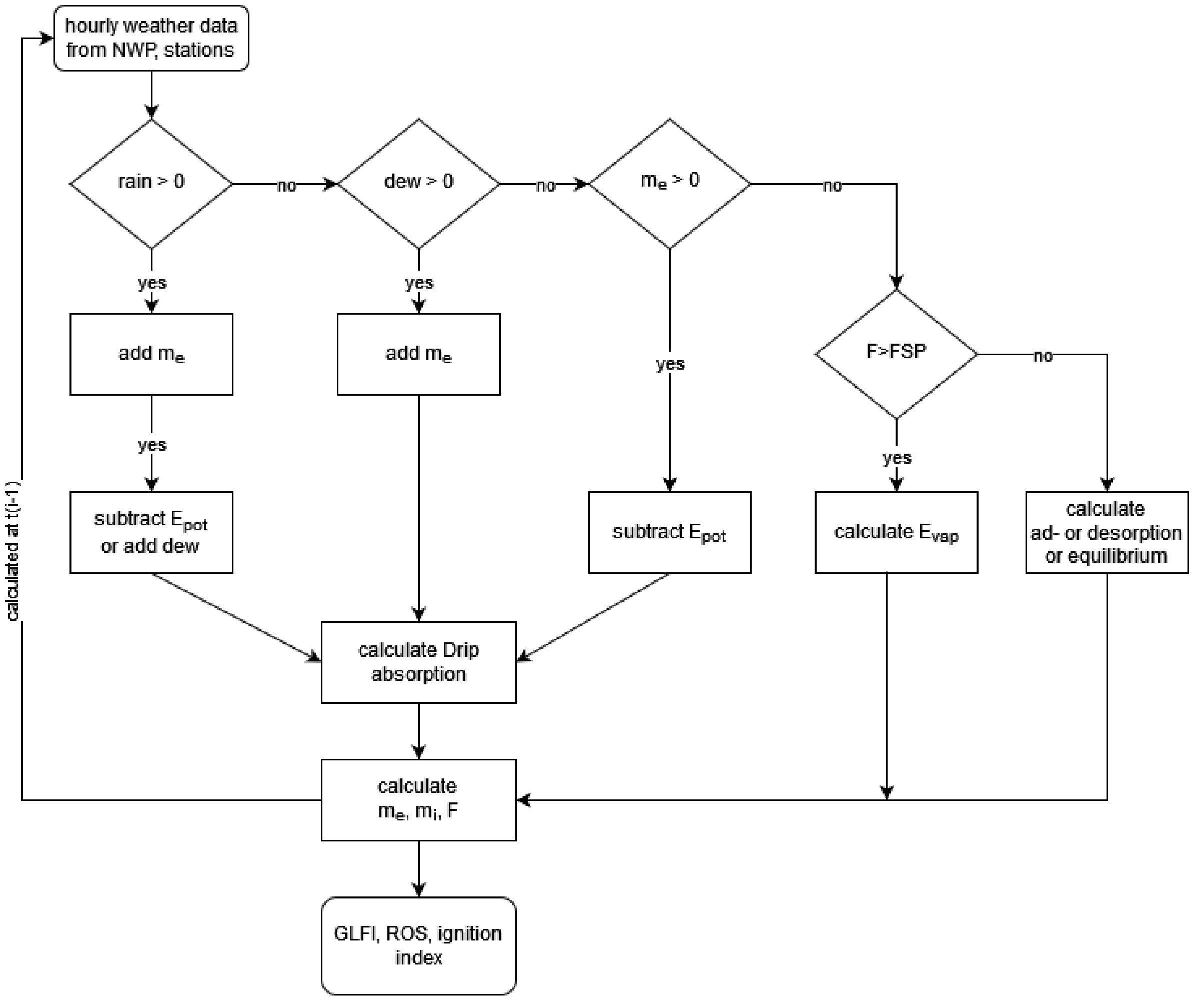
Flow chart of key hydrological processes



Ignition probability and laboratory ignition test

According to Schroeder (1969), the probability of ignition is governed largely by fuel moisture. The probability curve reveals a reverse *s*-shaped dependency described by the logistic distribution function

$$p_{ig} = \frac{1}{1 + \exp(a + bF)} \quad \text{(S1)}$$

with $0 \leq p_{ig} \leq 1$. The empirical parameters *a*, *b* can be estimated using binary logistic regression analysis (included in the SYSTAT software package, Version 13, 2009). For this, 129 ignition experiments were performed in still air in the laboratory. Grass samples were used which were affected by previous outdoor (dry, dew, rain) conditions for at least 12 hours. Prior to the start of each ignition experiment, the fuel sample was divided into two parts, one was used for the burning experiment, and the other was taken to gravimetrically measure its moisture content by oven-drying according to **Eq. 1**.

A small gas cartridge (length: 8 cm) enclosed in a vertically oriented shield casing (height: 15 cm) was used as an ignition device (**Fig. S1**). Approximately 9 cm above the nozzle of the gas cartridge, a horizontal wire rack (dimension: 14.5 cm × 16.5 cm) was installed which carried a sample of loosely layered dead grass leaves (layer ~2 cm heigh, dry weight: 5-6 gr, m_d: 0.20-0.25 kg m^{-2}). The porous fuel bed was piled in the centre of the wire rack and did not cover its base area evenly. Just below the wire mesh, a movable horizontal plate protected the litter sample from immediate heating when the gas flame was ignited. At time $t = t_0$ the protection plate was cast aside to expose the sample to a heat of approx. 400°C, as measured with a platinum resistance thermometer at the tip of the gas jet at plate level. The time between $t = t_0$ and the start of ignition, t_{ig}, was measured with a stopwatch. The maximum time of continuous heating by the pilot flame was limited to 30 s, which corresponds to the ignition-delay time of 20 to 40 s found by von Deichmann (1958) for dead grass. As soon as the fuel sample flamed up within the 30 s period, heating by the pilot flame was stopped and the combustion process could proceed without further external influence. Following Parrott and Donald (1970), the ignition results were classified into three categories: a) sustained burning, i.e. all fuel was consumed by the fire, b) temporary burning, i.e. burning occurred but was not sustained, and c) nil, i.e. no ignition occurred within the 30 s period of heating.

Results

In order to estimate the probability of ignition, we consider fuel samples with moisture contents of up to F = 100%. Medians of fuel moisture amounted to 18.2% (n = 64) when the fuel was burnt completely (no matter when ignition started within the 30 s period and how long the combustion process lasted), 36.05% (n = 38) when the fire went out by itself and left unburnt grass materials behind, and 41.5% (n = 27) when there were no flames within the 30 s period of heating. **Fig. S2** includes the fuel-moisture dependent sigmoid ignition-probability curve **(Eq. S1)** which is based on data split into the binary numbers p_{ig} = 0% for "ignition failure" and p_{ig} = 100% for "ignition success with sustained burning", resulting in a = -3.94077, b = 0.10417 (if F in %), and $F_{50} = F(p_{ig}=0.5) = -a/b$ = 37.8% the 50%-probability of success for sustained ignition.

Ignition probability decreases with increasing moisture content (dashed curve). A likelihood of at least p_{ig} = 96.5% to reach successful ignition and complete combustion can be expected for fuel moistures of less than F = 6%. In this dry range our small-scale trials in still air did not result in a definite ignition success, in contrast to some comparative studies. We speculate that the porous and non-homogeneous fuel bed (with unevenly distributed moisture content) and the extremely narrow gas jet, which only heated less than 50 mm^2 of the fuel-bed base area, might be responsible for the p_{ig} < 100% probability in the moisture range below 6%. Up to $F = F_{50}$ = 37.8%, which is near the median of marginal burning (36.05%), 50% of all trials showed complete combustion, while at $F \geq$ 69.6% less than 3.5% of the trials were successful, according to the statistics.

The F_{50} parameter is almost identical to 38.0% found by Dimitrakopoulos *et al.* (2010) in annual herbaceous Slender Oat grass species, and near 35.4% identified by de Groot *et al.* (2005) in tropical grasslands. The three experiments span a narrow F_{50} range although grass species and experimental setups (agents: gas flame, drip torch, matches) are different.

As a reference for our results, the model of Wilson (1985) for good and poor burning conditions of cured short grass (cheat grass, fescue) is taken. In **Fig. S2**, the left edge of the shaded area, p_s, represents the probability of sustained burning, and the right edge, p_o, is the probability of fires that burn marginally and tend to go out. Our laboratory p_{ig}-profile (dashed line according to **Eq. S1**) is within Wilson's transition zone between rigorous and poor burning conditions.

Fig. S1. Test device used in the laboratory ignition experiments. The photo shows the time after successful ignition of a grass sample lying on the wire mesh. Inflammation by the gas cartridge mounted in the vertical shield casing had already stopped as soon as combustion of the fuel bed started.

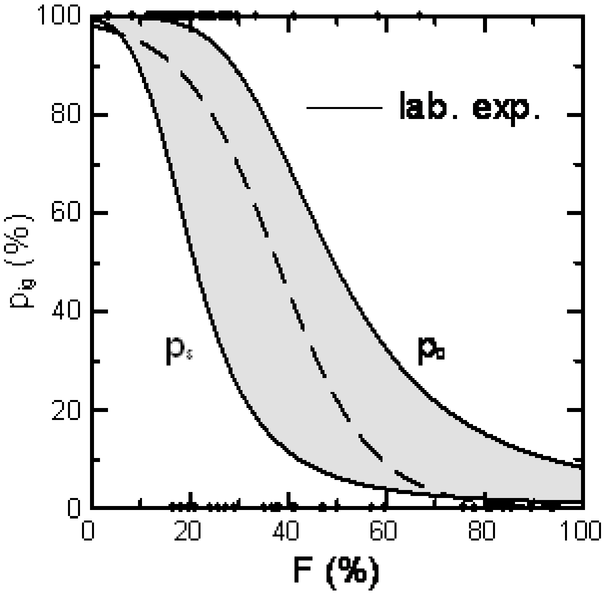


Fig. S2. Laboratory-based ignition probability (dashed curve) using the "sustained burning" and "ignition not successful" records (data points). Additionally, the marginal burning zone for cured grass is plotted according to Wilson's (1985) model for a fuel load of 0.2 kg m^{-2} (for further fuel-bed descriptors see Wilson 1985, his Fig. 8). The parameters p_s and p_0 on the left and right side of the grey-shaded transition area indicate probabilities of fires that burn steadily (left) and fires at the extinction limit (right), respectively.

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