# Damage to the Ecosystem and Emissions to the Atmosphere during Subsurface Wildland Fires

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## 1. SUBSURFACE FIRES

When a layer of organic soil ignites, it burns steadily without a flame, propagating slowly through surface and subsurface layers of the forest ground (Fig. 1). Large smouldering fires are rare events at the local scale but occur regularly at a global scale (Fig.2). Subsurface wildfires can linger for very long periods of time (weeks or years) and represent a large contributor to biomass consumption and carbon emissions to the atmosphere.

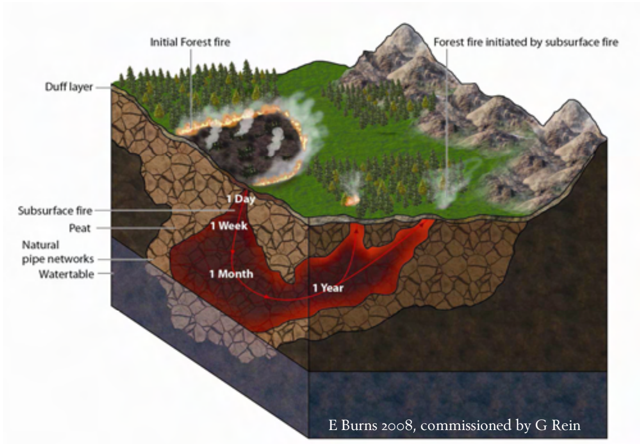


**Figure 1 – Illustration of a subsurface fire initiated at the surface that propagates into the ground and emerges months later**

**Figure 2- Adjacent forest stands at 2006 Rothiemurchus peat fire in Scotland. Left: Not affected by the fire. Right: Trunks charred by flames and soil destroyed by smouldering fire.**

## 2. SMOULDERING

Smouldering is the flameless form of combustion of a solid fuel where the oxidation reaction occurs on the <u>surface</u> of the solid (Fig 3). The characteristic temperature (500-700°C) , spread rate (1-50mm/h) and heat release rate (~8 kJ/g) are significantly lower than in the flaming.


**Figure 3 – Flaming vs. smouldering**

## 3. SMALL-SCALE EXPERIMENTS [1,2]

This work reports on the recent experimental studies of ignition, mass loss, thermal effects and the carbon emission from peat fires using small-scale experiments with samples 100 x 100 x 50 mm³ in size (Fig. 4).

Ignition results show that the critical moisture content for ignition is a sharp transition separating low and large mass losses at 125±10% in dry base (Fig. 6).


**Figure4 – Small-scale experiments in 100 x 100 mm samples. Snapshots of peat front propagating (time elapsed is ~1 h).**

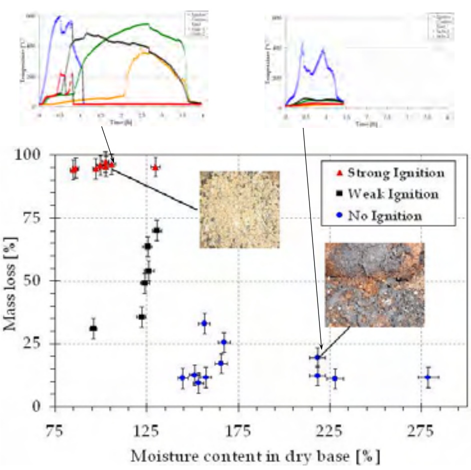


**Figure 6 - Results for total mass lost in the peat sample vs. moisture content showing the critical moisture content for ignition at 125 ±10%(in dry base). Above: exemplar thermocouple traces for dry and a wet samples.**

## 4. DAMAGE *to the* ECOSYSTEM [1]

Physical, chemical and biological changes induced in the soil are caused by the fire severity. It is proposed that the fire severity on the soil is given by the thermal severity and the mass loss. Results show that measured mass losses are up to 90% resulting the destruction of the soil layers (Fig. 6). The measured thermal severity in terms of temperature threshold vs. residence time show that smouldering leads to soil sterilization (Fig. 5).

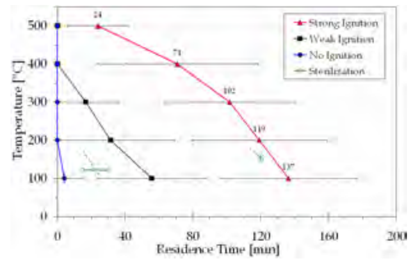


**Figure 5 - Thermal fire severity measured as average residence times above a given temperature threshold. Three ignition regimes observed. Sterilization limits are indicated in green.**

## 5. CARBON EMISSIONS [2]

Peat samples were smouldered in the cone calorimeter apparatus. Moisture content and the external heat flux were varied to establish different burning regimes. Measured emissions (Fig. 7) show that carbon mass flow rate is equivalent to 3,000 times the natural decomposition rate in peatlands. Results suggests that smouldering of biomass at lower moisture contents develops wider pyrolysis fronts.

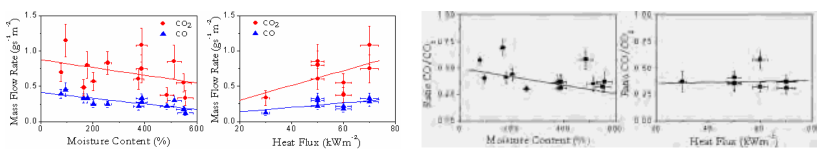


**Figure 7 – Left) Measured CO and $CO_2$ mass flow rates at steady-state. Total CO and $CO_2$ yield is of 59±15% g/g. Right) Measured $CO/CO_2$ ratio. Average ratio is 0.43±0.12.**

[1] G Rein, N Cleaver, C Ashton, P Pironi, JL Torero, "The Severity of Smouldering Peat Fires and Damage to the Forest Soil", *Catena* (in press), 2008
[2] G Rein, S Cohen, A Simeoni, "Carbon Emissions from Smouldering Peat in Shallow and Strong Fronts", *Proceedings of the Combustion Institute* 32 (in press), 2008.