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The use of NIR for estimating wildfire-induced heating of forest topsoil

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It is commonly accepted that fire severity plays an important role in post-fire erosion risk. This reflects not only also the degree of consumption of the protective vegetation and litter cover but also heating-induced changes in soil properties, which can increase soil erodibility as well as decrease infiltration. Fire severity is therefore also a key input factor for the Erosion Risk Management Tool (ERMiT) for the Western U.S.A. The input map of soil burn severity is based on a preliminary map derived from satellite, which is then verified in the field using severity indicators that are related to broad classes of vegetation damage, and ash and topsoil characteristics.

This work wants to explore the use of Near Infrared Spectroscopy (NIR) as an alternative tool for estimating wildfire severity, having the potential of providing more quantitative estimates of wildfire-induced soil heating than the above-mentioned approach. This was done in the framework of a PhD study on the effect of fire severity on vegetation recovery and, in particular, the role therein of the seedbank, in which fire severity was also assessed using classical indicators based on vegetation damage.

The study area was located in the Arganil municipality, north-central Portugal, in an area of 60 ha that burnt during August 2008. The site corresponded to a single, west-facing slope covered by a Pinus pinaster plantation that was partially burnt. Two broad classes of fire severity could be distinguished visually from the opposite part of the valley, i.e. a "high" severity (almost) entirely consuming the pine crowns and a "low" severity leaving the pine trees with scorched crowns. Across the burnt slope section, three zone were identified where adjacent transects could be laid down in adjacent "high" and "low" severity patches, thereby allowing an experimental design of paired observations to address possible spatial patterns in fire behaviour, soil and/or vegetation across the burnt slope section. Along each of these transects, three sampling sites were located at fixed positions, where vegetation plots were installed and topsoil samples were collected for seedbank assessment (0-3 and 3-6 cm depth) as well as NIR analysis (3 samples per site; 0-3 cm depth). An additional transect was laid out in the unburnt slope section immediately adjacent to the burnt area, where a composite sample of the unburnt topsoil was gathered.

The NIR analysis was done using the methodology of Guerrero et al. (2007). Its main steps were as follows. Unburned samples were subjected to a wide range of controlled heating treatments in the laboratory, using an electric oven and recording the real temperature with thermocouples. After cooling, the NIR spectra (830-2630 nm) of heated samples were obtained by diffuse reflectance spectroscopy (FT-NIR, MPA Bruker). These spectra were used to construct statistical models relating spectral characteristics with the maximum temperature reached (MTR) in the oven. We used partial least squares (PLS) regression as method to construct the models. The R2 of the leave-one-out cross-validated models were above 0.90, and RMSECV below 30ºC. These models were then used to estimate the MTR for the wildfire-burnt soil samples, by feeding them with the samples' NIR reflectance spectra.

Most of the obtained MTR estimates ranged from 50ºC to 150ºC, indicating that the fire was of medium to low severity. While this fitted in with the expected impact of medium-to-low fire severities on overall germination rates, further work was done to explore the relationship of the NIR-based estimates with the "low" and "high" severity classes, on the one hand, and, on the other, with severity estimates based on the minimum diameter of burnt twigs. This included an analysis of the spatial variability in NIR signal, using the soil seedbank samples, and the development of alternative models, taking into account the observed MTR range.