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Methods for the automated in-situ measurement of dead fine fuel moisture dynamics

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Dead fine fuel moisture content has been in the focus of forest fire research from its very start. This is mainly because it is one of the critical determinants of ignitability and fire behavior. A range of applications, such as planning of prescribed fires, diurnal fire danger rating and model validation, require knowledge of the in-situ fine fuel moisture dynamics. However, fine fuel moisture dynamics are not easily measured since standard techniques, e.g. destructive sampling and oven-drying, are very cumbersome and labor-intensive. Results of these measurements often become available with a long delay (e.g. drying time) and are therefore not suitable for real-time decision making. This paper aims to present techniques which might be suitable for measuring dead fine fuel moisture content automatically. Two of those techniques (electric resistance and dielectric permittivity measurements) are tested in the field.

Presented methods include gravimetric, relative humidity/equilibrium moisture content, electric resistance and dielectric permittivity techniques. Of those, the performance of electric resistance and dielectric permittivity measurements are evaluated against traditional destructive sampling and oven-drying. All measurements were made in the litter layer of a 160 year old European beech (Fagus sylvatica L.) forest stand close to Freising, Bavaria, Germany. They were conducted on a daily basis from April to October 2010. Within the approximately 200 measured events, conditions ranged from 13 to 395% gravimetric moisture content (odw). The evaluation of the automated measuring techniques is based on the coefficient of determination and standard error of the respective calibration equations linking the sensor raw values to actual fuel moisture. This type of analysis is conducted on the whole dataset as well as on subsets using moving regressions with a variable period length. Furthermore, correlation of calibrated automatic values with manual measurements is examined.

Results show relatively good to excellent correlations between manually measured fuel moisture and sensor raw values. However, standard errors appear to be quite high, possibly reflecting the high spatial variability of litter moisture. Coefficients of determination reach a maximum when the period length is kept relatively short (10-20 days).

On the basis of these results, we conclude that especially dielectric permittivity sensing can be used for automated measurement of dead fine fuel moisture content in porous fuel beds. However, on-site calibration of each individual sensor and the use of a certain number of such sensors are required. Calibration equations should not be used over extended time periods since changing external conditions (such as fuel decomposition and changing bulk density) preclude the long-term use of such equations. The best application of this type of automated measurements would be the temporal interpolation of manually measured values, which could be useful for prescribed fire planning, validation of litter moisture models and other purposes.