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The potential of active and passive infrared thermography identifying dynamics of soil moisture and microbial activity with high spatial and temporal resolution

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Spatio-temporal analyses of soil properties are important for more profound insights into soil processes. Up to now, non-invasive approaches analyzing physical and biological soil properties and dynamics on the microscale are not established due to methodological, instrumental, and analytical challenges.

In this study, we evaluate the use of active and passive Infrared Thermography (IRT), a non-invasive and non-contact technique, for the detection of surface temperature-based parameters in soil samples. The potential and possibilities of active and passive IRT were analyzed with a focus on the detection and calibration of soil moisture using active IRT and the determination of microbial activity using passive IRT. The active IRT technique, in contrast to passive IRT, uses an external heat source to measure the induced thermal contrast on the measurement object.

A pool of 51 soil samples was used to cover a wide range of chemical, physical and biological soil properties. The soils were rewetted to 16 different moisture contents, filled into vessels, and placed in an air-proof glove box with an adjusted relative humidity of about 92% to reduce soil drying. Immediately after rewetting, the soil surface temperature was determined using active and passive IRT procedures at a high temporal resolution (one minute for passive IRT, hourly for active IRT) and a spatial resolution of 0.283 mm. Soil material was also sterilized by γ-irradiation in order to obtain microbially inactive samples for validating the passive IRT procedure.

The active IRT measurements proved to be reliable in determining the soil surface moisture content due to the effect of water on specific heat capacity. Depending on the soil sample, the mean active IRT values were explained by up to 88% by the mean volumetric water contents, which is a very good approximation for applying this to differences in the spatial and temporal distribution of moisture contents.

With the passive IRT measurements, increases of soil surface temperatures by up to 0.5 K were detected in the non-sterile samples immediately after soil rewetting. In the sterile samples, rewetting did not result in heat production. With regard to the commonly observed “Birch“-CO_2-pulse in rewetted soil samples, these results strongly suggested that the heat evolution on the surface of the non-sterile soils is associated with the rapidly increasing microbial activity from consuming dead and easily available soil biomass.

In conclusion, IRT is a promising mapping tool of soil surface processes especially for undisturbed soil samples, since IRT techniques allow studying moisture and microbial activity of intact soil structures.