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Conventional NIR and NIR hyperspectral imaging - Analysis of soils, sediments in Archaeology

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Introduction: NIR analyses of soils and sediments have shown good results in terms of calibration and prediction of various inherent substances. In this paper, an archaeological example is presented where conventional NIR technology and NIR hyperspectral imaging are compared. Chemometrics is used to evaluate NIR spectra in order to classify different categories of archaeological soil samples collected from an excavation. PLS calibration models of NIR spectra and metal – organic constituencies are also discussed.

Soils and sediments trap chemical information on past events and thus are acting as long term archives. There is a complexity of the soil and sediment dimensions that is reflected by NIR spectroscopy, among others organic-inorganic and physical properties. However, this complexity needs careful analysis in order to provide a deeper understanding of past human activities. Archaeological soil and sediments contain material introduced by human activities. This material is in various stages of decomposition (waste biomass, artefacts, bone etc).

Conventional NIR uses average reflectance measurements on an area of interest. NIR hyperspectral imaging combines the spatial dimensions of an image (i.e pretreated soils or -sediments) and the chemical information for every pixel in the acquired image. Archaeological materials are heterogeneous by definition and therefore it may be assumed that NIR hyperspectral imaging is beneficiary to interpretation.

Materials and Methods: 22 soil and sediment samples from spatial mapping and stratigraphical units have been analysed from a Bronze Age settlement in mid Sweden dated to 1000-800 BC. Apart from analysing NIR spectra, the samples had previously been analysed for metal and non-metal content using ICP-OES and different techniques of extraction.

Three conventional NIR systems and one hyperspectral imaging system have been used to acquire NIR spectra: Technicon Infra analyzer 450 (16 wavelength bands), Foss NIRS system 5000 (1100 – 2500 nm), Tec5 HandySpec Field (400 – 1050 nm). Evince software package was used for statistical analysis. Samples were introduced in provided analytical cells for each system. The sisuCHEMA pushbroom short wave infrared hyperspectral imaging system was used to acquire images from 1000-2498 nm with intervals of 6-7 nm, on dried and sieved soil samples, flattened prior to analysis. The images were transformed to pseudo-absorbance in Evince image analysis software.

Results and Discussion: Clusters among sampled soil categories samples were identified in the PCA score plots. This allowed distinction between human affected and non (or less) human affected soils, based solely on the NIR spectra. The different NIR techniques resulted in similar classification of objects, implying that sampling is of greater importance than the actual analytical apparatus used. However, NIR hyperspectral imaging allowed the heterogeneity of the soil /sediment matrix to be evaluated from the PCA score images, which might be considered an advantage.

Meaningful PLS models could be constructed for several elements, both metals and non-metals. The explanation for this outcome needs to be elaborated further and there are several interesting possibilities for the future. The more successful PLS models could be applied to the hyperspectral images for prediction.

Conclusion: The potential of conventional NIR technology and NIR hyperspectral imaging to distinguish between human affected soils and non (or less) affected ones is demonstrated. Furthermore, the speed and simplicity of the analysis enables a large body of samples and data to be acquired which gives the possibility of having dense spatial resolution of samples. This, in turn, opens up for new insights to prehistoric settlement activities.