Quantitative mapping of surface soil moisture with hyperspectral imagery using the HYSOMA interface

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Research objectives

The amount of surface soil moisture (SM) is a key variable in hydrologic cycle controlling processes such as infiltration and discharge with consequences for plant growth, soil erosion and land degradation. Monitoring and modeling of these processes requires a universal approach for estimating this variable at all scales where repeatability of the results is an important prerequisite. Our research goals are to develop advanced remote sensing methods based on VNIR reflectance spectroscopy and hyperspectral imagery for the accurate prediction of surface soil moisture. Unlike SAR systems, optical systems sense the upper part of the surface (<50µm), and can benefit to hydrological research as it provides additional information on the type of water (bound or unbound) and can capture a range of soil properties in the data such as biomass cover, soil mineralogy and soil carbon content.

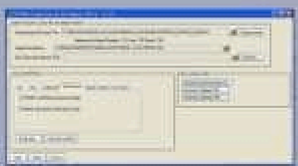
Hyperspectral imagery activities

As P.I. of the EnMap satellite science program and part of the EU-FP7 EUFAR (European Facility for Airborne Research) project, higher performing soil algorithms were developed at the Remote Sensing section at GFZ Potsdam to demonstrate the effectiveness of end-to-end processing chains with harmonized quality measures. The algorithms were built into an easy-to-use software interface entitled HYSOMA (HYperspectral SOil MApper) focused on soil mapping applications of hyperspectral imagery (Chabrillat et al., 2011). With the upcoming availability of the next generation of orbiting hyperspectral sensors, greater developments are needed towards the operational delivery of soil image products to the geoscience community. Hyperspectral sensors in preparation include:

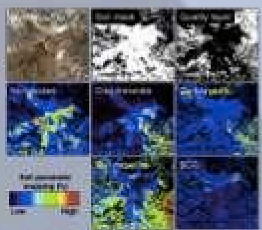
- → EnMap (Environmental Mapping and Analysis Program) – Germany – launch 2015 – GSD 30m
- → PRISMA (PRecursore IperSpettrale della Missione Applicativa)) – Italy – 2015 – GSD. 30m
- → HyspIRI (Hyperspectral Infrared Imager)) – USA – 2018/2020 – GSD 60m
- → HypXIM (Hyperspectral Imager) – France – 2018/2020 – GSD 15m
- → Hyper-X (Hyperspectral Imager) – Japan – 2018/2020 – GSD 15m

Methods

HYSOMA software interface (www.gfz-potsdam.de/hysoma)



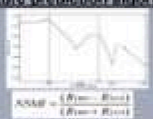
Software main GUI: "Generate Calibration File" option for fully quantitative mapping



Example of soil mapping in Mediterranean area based on software automatic outputs

Soil moisture prediction algorithms

NSMI

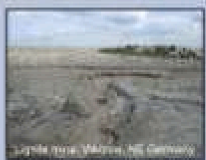


Haubrock et al., 2008 IJRS

SMGM

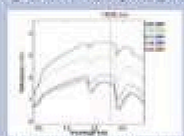
Whiting et al., 2004 RSE

Field sites



- → Reclamation zone in the Welzow-South lignite mine near Cottbus
- → Quaternary and tertiary sands, coarse textured, <4% clay
- → HyMap overflight (GSD 4m, 126 bds 440-2470nm, 13-17nm wide)
- → Two concordant in-situ GSM datasets (core and FDR probe)

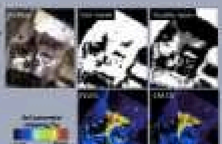
- → Cotton and tomato fields in southern San Joaquin Valley near Lemoore
- → Basin alluvium sandy clay loam through clay loam surface soils
- → Reflectance cube based on laboratory dataset (Whiting et al., 2004 RSE)
- → GSM measured from oven dry, air dry, through 34% GSM by weight, in ~5% int.



Same soil associated with each field site with increasing gravimetric soil water content

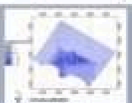
Results

Welzow field site

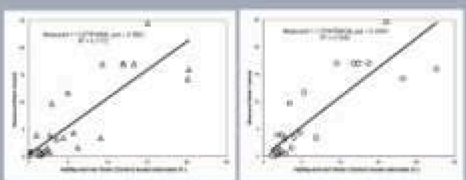


HYSOMA automatic outputs

Quantitative mapping

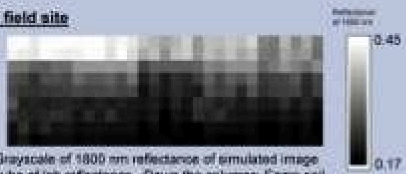


Welzow reflectance cube and in-situ data (Haubrock et al., 2008 JARS)

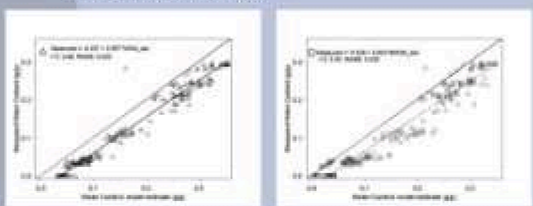


NSMI / SMGM prediction of gravimetric water content (%) vs. laboratory (soil cores) measurements

California field site



Grayscale of 1800 nm reflectance of simulated image cube of lab reflectance. Down the columns: Same soil samples with increasing GSM from oven dry (1st row) to 0.37 g/g water content (last row)



NSMI / SMGM prediction of gravimetric water content (g water / g oven dry soil) vs. laboratory measurements

Summary

The SMGM and NSMI algorithms provided consistent surface soil moisture estimates and were highly correlated to the gravimetric surface soil moisture measurements. The results of the regression analyses of HYSOMA-derived water content show high predictive accuracies for most of validation data, although the results vary slightly depending on algorithm and field environmental conditions. The regression analyses achieved a slightly better prediction using the SMGM algorithm. Overall, this work shows the capabilities of VNIR reflectance spectroscopy and hyperspectral imagery for the determination of surface soil moisture content in areas where vegetation cover is low and mineralogical surfaces are exposed.

Acknowledgments

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