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Deriving soil function maps to assess related ecosystem services using imaging spectrocopy in the Lyss agricultural area, Switzerland

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Introduction

Soils play an important role in the benefits offered by ecosystems services. In densely populated Switzerland, soils are a scarce resource with high pressure on services ranging from urban expansion to over-utilization. Key change drivers include erosion, soil degradation, land management change and (chemical) pollution, which should be taken into consideration. Therefore there is an emerging need for an integrated, sustainable and efficient system assessing the management of soil and land as a resource.

The use of remote sensing can offer spatio-temporal and (semi-) quantitative information of extended areas [1]. In particular imaging spectroscopy (absorption features in Fig. 1) has shown to complement existing sampling schemes as secondary information for digital soil mapping [1]. Although only the upper-most layer of soil interacts with light when using reflectance spectroscopy [1,2], it still can offer valuable information that can be utilized by farmers and decision makers. Another challenge is to deal with partly to fully vegetated areas [2].

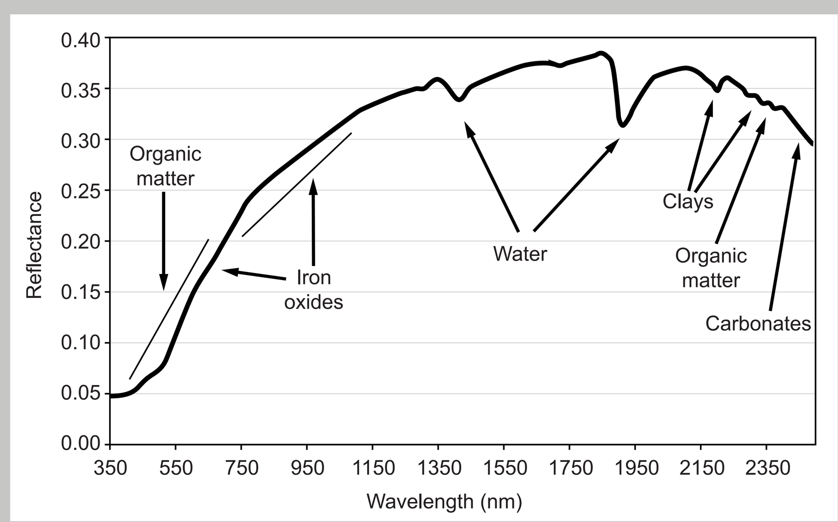

Figure 1 Soil spectra throughout the VIS-SWIR spectrum. Arrows indicate absorption features related to specific soil properties. (based on Chabrillat et al. [3])

Results

Correlations

A significant negative correlation was found between SOC and clay content and the DEM. Iron content had a positive correlation with the DEM. These correlations explain the spatial variance limited (R^2's between 0.00 and 0.01), because height differences are small in the area (440 - 570 m). The correlation between SOC and the DEM was used to interpolate the SOC data for all agricultural soils.

Soil properties

The positive correlation between SOC and bare soil ($R^2 = 0.06$) and negative correlation between SOC and bare soil bright ($R^2 = 0.13$) indicate that the SOC algorithm is strongly dependend on soil colour (focus in spectrum on 400 and 600 nm). This means that although the visual check gave a good first impression of the SOC in the area (Fig. 3c), a better validation is necessary to check this correlation between colour and SOC. Furthermore, significant positive correlations were found between SOC and the presence of winter wheat, winter barley, sugar pea, rapeseed, meadow and spring barley. Negative correlations were found for the presence of Alfalfa and meadow young. For al of these the R^2's were low (between 0.000 and 0.004).

Ecosystem services

There was a significant positive correlation between the total ecosystem services map and the SOC map (Fig. 3d). In total, 10.9% of the variance is explained by the SOC. Striking in the total ecosystem service map iare the low values for bare soils, this is mainly caused by the presence of green biomass used in the agronomic ecosystem services.

Figure 3 Series of images aquired **a**: APEX true color image; **b**: land cover map; **c**: soil organic carbon based on indices (range); **d**: total ecosystem services values for the area (range). The area is approximately 4.0x2.5 km, APEX image was taken on 03.09.2013.

Methods

Imaging spectroscopy data

For the analyses we used fully processed airborne imaging spectrometer data from APEX taken on 03.09.2013 (Fig. 3a). The image has a spectral resolution of 0.6 - 11 nm and a spatial resolution of 2 m.

Land use map

Detailed ground truth was acquired in Lyss on 26.06.2013. 299 agricultural fields have been classified in 10 classes (Fig. 3b). For each field a region of interest (ROI) was build manually. Mixed pixels were avoided by excluding field boundary pixels and disturbing objects. The distinction between bare soil vs. bare soil bright and meadow vs. meadow young was made visually, based on the true color image.

Soil properties

Bare soil properties (soil organic carbon (SOC), iron content, and clay content) were derived based on existing automatic soil algorithms and methodologies (HYperspectral SOil MApper, [3]). SOC in partly to fully vegetated areas was interpolated using regression kriging (DEM) based on 1000 randomly selected points.

Ecosystem services

Ecosystem services (agronomic and cultural ES and carbon sequestration) were calculated based on the plant trait-based modelling approach from Lavorel et al. [4], which was adapted for IS data by Homolova et al. [5]. Linear combinations of properties (green biomass, litter mass, crude protein content, species diversity and soil carbon) derived from IS data with linear regressions [5] resulted in the three ecosystem services. SOC was used as input for the soil carbon property.

Correlations

The estimated soil properties were correlated to the DEM. Soil organic carbon was after interpolation correlated to land cover using a logistic regression. An additional correlation was made between the interpolated SOC map and the total ecosystem services map.

Conclusion & outlook

Soil properties are an important contribution in the caluclation of ecosystem services. Results of SOC, iron content and clay content derived from imaging spectroscopy data for the Lyss agricultural area gave a good first impression based on field experience. Additional validation is necessary to give a more quantitative indication of the performance of the algorithms. Although there is a significant correlation of all these properties to the DEM, the spatial variance was limited explained.

We will further develop the algorithms in order to derive soil properties from imaging spectroscopy data, especially in areas that are partly to fully covered with vegetation. Additionally, we will further explore the combined usability of soil properties and vegetation parameters to assess related ecosystem services.

The use of ecosystem services and/or soil functions helps to give an impression of the (non-) sustainable use of the soil and to explore the effects of land management and land use changes. This offers valuable information for decision makers.

References and notes

1. Ben-Dor, E., Chabrillat, S., Demattê, J.A.M., Taylor, G.R., Hill, J., Whiting, M.L., Sommer, S., 2009. Using Imaging Spectroscopy to study soil properties. Remote Sensing of Environment 113(Supplement 1), S38-S55.
2. Mulder, V.L., de Bruin, S., Schaepman, M.E., Mayr, T.R., 2011. The use of remote sensing in soil and terrain mapping - A review. Geoderma 162(1-2), 1-19.
3. Chabrillat, S., Eisele, A., Guillaso, S., Rogaß, C., Ben-Dor, E., Kaufmann, H., 2011. HYSOMA: An easy-to-use software interface for soil mapping applications of hyperspectral imagery, Proceedings of the 7th EARSeL SIG Imaging Spectroscopy Workshop, Edinburgh (UK).
4. Lavorel, D., Grigulis, K., Lamarque, P., Colace, M., Garden, D., Girel, J., Pellet, G., Douzet, R., 2011. Using plant functional traits to understand the landscape distribution of multiple ecosystem services. Journal of Ecology 99, 135-147.
5. Homolová, L., Schaepman, M.E., Lamarque, P., Clevers, J.G.P.W., de Bello, F., Thuiller, W., Lavorel, S., 2013. Comparison of remote sensing and plant trait-based modelling to predict ecosystem services in subalpine grasslands. Journal of Ecology (submitted).

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