Abstract

The soil resources management is fundamental to maintain a productive economy and sustain society. The first step to manage soils is to understand the distribution of its properties across a landscape. Digital Soil Mapping (DSM) techniques are a promising alternative for conventional soil mapping (CSM). DSM includes proximal soil sensing (PS), like soil spectroscopy, remote sensing (RS), and data mining methods which have significant potential for soil mapping.

This research aimed to advance the use of soil spectroscopy, RS and data mining for assessing soil properties and DSM studies. The main objectives of this study were to develop predictive models to estimate and map soil properties from soil reflectance and measured soil parameters, and to evaluate the quality of the produced digital soil maps.

Soil samples were collected in 2006 and 2012 from the El-Tina Plain located on the northwestern Sinai Peninsula, Egypt. Samples were analysed for soil salinity expressed as electrical conductivity (EC_e), OM and clay content and were scanned in laboratory conditions with an Analytical Spectral Devices (ASD) spectrometer (350–2500 nm). Three spectral formats were used in modeling: (1) raw spectra (R), (2) first-derivative spectra smoothened using the Savitzky–Golay technique (FD-SG) and (3) continuum-removed reflectance (CR).

In the first stage, various spectral indices of all band-pair combinations, for the three types of spectra, were applied in linear regression analyses with EC_e. A ratio index for 1483 nm and 1918 nm (FD-SG spectral format) produced the best predictions of EC_e out of all the band-pair indices. Partial least-squares regression (PLSR) models using CR spectral format resulted in R^2 = 0.77. The multivariate adaptive regression splines (MARS) calibration model with CR spectra had the best performance (R^2 = 0.81) for estimating the EC_e.

To use modeling results in soil salinity mapping, PLSR and MARS models were modified based on the measured soil EC_e and laboratory soil reflectance spectra resampled to the spectral resolution of Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+). The models were subsequently applied on a pixel-by-pixel basis to Landsat TM and ETM+ images acquired in 2006 and 2012 to generate soil salinity maps for the study area. These maps were validated by independent samples with satisfactory accuracy. The results revealed that the MARS technique was superior to the PLSR method for the modeling and mapping of soil salinity.

A potential of combining PS and RS in mapping soil properties with a sufficient accuracy for a large agriculture area was finally demonstrated using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery. For the pre-processed ASTER image (2006) covering the study area MARS and PLSR models estimating the selected soil properties (EC_e, OM, and clay content) were constructed. The results of MARS models (R^2 of 0.80 to 0.94) were again better than those of the respective PLSR models. The independent validation results were close to the modeling step and showed better performance of the MARS models in comparison to PLSR models.

The methods based on the integration of PS and RS developed in this thesis were found to be reliable and accurate to map soil properties in arid environments, contributing in this way to the wide domain of DSM. These methods can be used in future for other new optical and hyperspectral satellite data that will increase the accuracy of soil mapping and monitoring.