Machine Learning algorithms for soil texture prediction from airborne radiometric surveys

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Abstract

Soil texture is a key parameter influencing soil functioning, agricultural productivity, and sustainable land management. Accurate texture maps are essential for cultivation planning, soil conservation, and environmental assessment, but traditional surveys often lack the resolution to capture fine-scale variability. To address this gap, we evaluate the use of Airborne Gamma-Ray Spectroscopy (AGRS) combined with machine learning technique as a framework for soil texture mapping.

The study was conducted in the Mezzano Lowland (Emilia-Romagna, Italy), a 189 km² reclaimed agricultural plain investigated through a dedicated AGRS survey. Potassium (K) and equivalent thorium (eTh) abundances derived from the radiometric data were correlated with soil texture information from the regional 1:50,000 soil texture map. A multi-approach methodology was adopted, including Simple Linear Regression (SLR), Multiple Linear Regression (MLR), and Non-Linear Machine Learning (NLML) algorithms based on deep neural networks. Models were trained and validated to test their ability to predict clay and sand fractions.

The results confirmed negative correlations between sand content and K and Th abundances and positive correlations between clay and both elements. While regression approaches reproduced large-scale patterns, the NLML model provided higher predictive accuracy, enabling the generation of high-resolution maps of clay and sand distribution. These maps also revealed geomorphological features absent from existing soil maps, such as paleo-channels that as reported by historical hydrographic records, shaped the Mezzano Lowland during the Etruscan and Roman periods.

This study demonstrates that AGRS, particularly when combined with machine learning technique, is an effective tool for digital soil mapping. The proposed framework enhances the resolution of soil texture information, supports the reconstruction of paleo-hydrography, and provides valuable insights for precision agriculture and sustainable soil management.