Geophysical Research Abstracts
Vol. 13, EGU2011-10140, 2011
EGU General Assembly 2011

Bedrock and soil resistivity mapping as a tool for characterizing soil thickness on cultivated hillslopes. A case study in Seuilly, SW Parisian Basin, France

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Soil apparent electrical resistivity, or its converse soil conductivity, is a parameter commonly used to predict soil properties, such as porosity, water content, particle size, clay content... It has also been used for soil thickness mapping, but the resulting data can be misinterpreted, due to inter-relationships between soil resistivity and the physical and chemical properties of soils, which may be related to the bedrock lithology. Soil thickness mapping using resistivity measurements thus gives results only when the bedrock is electrically homogeneous and presents a high resistivity contrast related to soil. It therefore appears necessary to precisely characterise the bedrock resistivity variability before interpreting soil resistivity measurements.

In this study, the relationships between surficial apparent resistivities at different depths of investigation and soil thickness - defined as the summation of organo-mineral and structural (A+B) horizons - were tested to predict soil thickness over large areas. The study site corresponds to a 100 ha cultivated hillslope located near the village of Seuilly (SW Parisian Basin, France). It covers 3 types of the Upper Cretaceous sedimentary formations: (a) Lower and Middle Turonian white chalk, (b) Upper Turonian yellow sandy limestone and (c) decarbonated yellow sandy limestone enriched in clay by deep weathering. The site shows a wide range of soil thicknesses (from 0.3 m to more than 2 m in lynchets) due to the fragmentation by field limit networks. The resistivity of the bedrock was measured using an electromagnetic survey with an EM31 conductivity meter (Slingram method), which gives a large investigation depth (about 5m), making this instrument quite insensitive to soil variability. 35 electrical soundings were also performed along a transect covering 800 m from top to bottom of the hillslope, allowing the establishment of a 2D resistivity cross section of the bedrock. The resistivity of the soil was measured using an ARP (Automatic Resistivity Profiling) survey at 3 different depths of investigation (0.5, 1 and 2 m). Inside the study site, a 16 ha test zone representative of the whole site was chosen for the establishment of the soil thickness / resistivity correlations. Soil thickness was measured at 686 points thanks to manual augering. Soil resistivity was also measured directly on 241 soil augerings using a Wenner array and the results were compared to the ARP interpolated data. Finally, soil properties (particle size, organic carbon and carbonate content) were analysed at 248 points and compared to soil resistivity to assess the relationships between soil resistivity and each soil property.

The electromagnetic survey results and the electrical soundings show that the 3 bedrock types are characterized by different resisitivity values. The Upper Turonian yellow sandy limestone presents the highest resistivity (50 to 100 ohm.m). In this area, soil thickness / resistivity correlation is good (R2=0.66), allowing high resolution digital soil thickness mapping from ARP measurements. The Lower and Middle Turonian white chalk presents lower resistivity values (20 to 50 ohm.m) and is electrically heterogeneous, making the soil thickness / resistivity correlation insufficient (R2=0.3) to map soil thickness correctly. However, the ARP mapping gives precise information on bedrock heterogeneities. Finally, the decarbonated yellow sandy limestone is characterized by low resistivity values (< 20 ohm.m) similar to soil resistivity, making impossible soil thickness prediction. In this area the ARP results seem more correlated with the soil particle size.

These results shows the importance of characterising precisely the electrical response of the bedrock (variability and resistivity contrast related to soil) before using soil apparent resistivity as a tool for digital soil thickness mapping, and more generally for soil properties mapping.