Use of the soils information system for detailed vineyard soil surveys and as a component of precision viticulture

Utilisation du système d'information sur les sols pour les études détaillées des sols de vignoble, et en tant que composante de la viticulture de précision

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Abstract: Vineyard soil surveys can be costly and time consuming. The Soils Information System (SIS) provides a set of tools to do a quick evaluation of soil physical properties in the vineyard. First, a system equipped with GPS and EM38 equipment, provides a very precise DEM and a soil electrical conductivity map. Specific sampling points are located for a tractor-mounted geotechnical probe to make soil physical measurements. Sensor readings are used to make precise estimations of soil texture, compaction, moisture and resistivity in the field. The probe reaches a depth of 1.2 to 1.5 meters. The data obtained are used to construct thematic maps, such as soil texture, soil compaction, and soil moisture availability maps. Finally, soil cores can be collected and sent to the laboratory to validate the SIS measurements and perform further analyses when required. This system has been used in vineyards located in different terroir regions of California, France and Spain. Results demonstrated a more precise delineation of soil map units than traditional survey methods using pits and augers. This approach allowed a more precise mapping of soil depth to the underlying rock layers. It also provided the information necessary to design an irrigation system in a newly planted vineyard. In summary, SIS provides a rapid and effective approach to precision mapping of terroir components and will have broad applications for precision viticulture.

Key words: electrical conductivity, soil mapping, Digital Elevation Models (DEM), terroir, soil probe

Introduction

Detailed and accurate soil and topography information at the vineyard block scale is necessary to implement vineyard management models or precision agriculture methods. Vineyard managers are very aware of vineyard variability and try to adjust their management practices to obtain greater uniformity in fruit quality and ripening time. Greater availability and accuracy of GPS, used in conjunction with GIS, has helped with more precise localization of problematic spots. Problems are often caused by the spatial variability of soil characteristics. Traditional techniques for mapping soils require frequent excursions in the field, the collection of soil samples, their laboratory analysis, documentation and association with landscape position for the creation of maps. The procedure is time consuming, expensive and subjective. The data collected are often not sufficient to characterize the variability in soil properties at the required scale. The same observation applies to existing Digital Elevation Models (DEM), often too imprecise to be useful at the vineyard level.

The development of accurate GPS systems, and new probe-mounted sensors, coupled with existing equipment such as soil bulk EC or resistivity meters (Bramley *et al.*, 2001; Bramley, 2003) has allowed for new approaches in the mapping of soil physical properties at the vineyard scale. An example of such equipment is the Soil Information System (SIS) developed by John Deere and functioning commercially in a number of viticultural areas in France, Spain and the USA.

Materials and Methods

To map vineyard soils, two sets of equipment were used consecutively. Initially, an all-terrain vehicle (ATV) dragging a sled containing an EM38 conductivity meter was used to map the vineyard block electrical conductivity. Hundreds of measurements were taken between vineyard rows. A GPS system was also mounted on the ATV, and recorded elevation. The system used was the John Deere Starfire RTK GPS, with a base station at close proximity of the site. Lateral accuracy was 1 to 2 centimeters, and vertical accuracy was 3 to 4 cm. A DEM was constructed from the recorded elevations to produce topographic, wetness, slope and slope aspect maps. EM and topographic maps were used to evaluate apparent soil variability in order to precisely determine the location of the probe soundings.
The SIS soil probe included the Physical Property Penetrometer (PPP), which is a miniature version of a geotechnical probe to the specifications of the American Society of Testing and Materials (ASTM). Measurements were obtained from the tip and also from a sleeve sensor and recorded using a data acquisition system. The measurement of the force exerted on the sleeve was used to assess whether the tip force was increasing due to a change in texture within the soil profile. The depth of penetration was recorded as the probe entered the soil profile at a rate of 2 cm/sec. The data were recorded in the Data Acquisition System (DAS), processed in real-time, and the operator could read directly some of the parameters on a computer screen during the probe sounding. A test to a depth of 1.4 meters required about 70 seconds.
In addition, the probe also recorded soil moisture and resistivity using sensors in the probe that were in direct contact with the soil material (figure 1). A third passage of the equipment in the field may be done for taking soil cores when this is deemed necessary for solving a particular problem or for taking samples for laboratory analysis when requested. Additional features including a soil color probe were not used during this fieldwork.

Results

The results of observations and data analyses are presented here for three areas that were recently studied; these serve as examples of some of the types of terrain and conditions that may be encountered in vineyards.

First study site. The first site was located in a vineyard in the Pessac-Léognan appellation in Bordeaux (Château Olivier) (figure 2). One objective of the study was the precise delineation of gravel mound terrace deposits, considered more favorable for growing high quality red grapes. The soils had been recently surveyed by a team of pedologists, using traditional methods. The terrain was located in the Graves area. Locally, the Gunz age alluvium formed a thin veneer over a series of Miocene age marls and limestone (Wilson, 1998). The terrace was eroded and the terrain was sloping. Results of EM survey and probe soundings showed that the much sought gravel layer was very thin on the slope shoulder while the toeslope had a thicker colluvial mantle, as well as slower drainage. Those observations were confirmed by the core samplings. The map prepared by the professional pedologists identified three soil types, as did the map prepared by SIS. The boundaries on the SIS map were more accurate, however, due to the higher sampling density.

Second study site. The second study site was located on a recently planted Merlot vineyard in the Roussillon area (Domaine Cazès) (figure 3). Because irrigation was possible for this specific varietal in the area, a determination of soil texture and solum depth was important information for proper vineyard management. The vineyard was established on a terrace of Villafranchian age, cutting across the Corbières limestone (Delfaud *et al*., 2003). Terrace remnants were very thin and the soils formed mostly on residuum from weathering of the underlying limestone, at shallow depth. The maps obtained clearly showed very different solum depths at opposite ends of the vineyard, as well as strong textural differentiation of horizons where solum depth was greater.

Third study site. This site was situated in an abandoned valley of the Rio Adaja, near Valladolid, Spain, in the Rueda appellation area (figure 4). The vineyard block cut across terrigenic deposits of Miocene-Pilocene age in the upper part, and two terrace levels of the old Rio Adaja in the lower part of the slope (Portero *et al*., 1982). Soil texture and permeability of the soil profile varied significantly along the slope. Eroded soils with heavy surface textures upslope contrasted with colluviated lighter textured soils downslope. The EM and probe survey delineated with precision those differences, confirmed by the core samplings (figure 4). The newly installed drip irrigation system had been redesigned to take into account factors such as soil profile textural contrasts, water holding capacity and soil permeability of the surface and subsoil horizons.

Discussion

The Soil Information System provided a better sampling density than traditional soil survey methods, which are also inherently more time consuming. The SIS was operational and effective in delivering accurate maps of soil variability as well as a number of derived interpretative maps. The presence of hard subsoil layers impeding soundings at sufficient depths did not prevent, in most cases, the acquisition of soil data at a sufficient depth within the root zone. The use of traditional methods, such as gathering information from pedological trenches, can be used as a complement to automated systems in order to provide ground verification and direct observations, especially of root systems, in planted vineyards. Soil pits also allow for direct observation of deeper subsoil geological materials when hard soil layers prevent probe penetration to sufficient depths. However, traditional pedological methods are quite narrowly focused and therefore do not permit accurate measurement of the true soil variability at the vineyard block scale. They can, however, be an effective complement to SIS maps. The SIS equipment was able to deliver a complete characterization of soil spatial variability in a very short time, as well as a number of thematic maps, such as plant available water, water at the permanent wilting point, soil compaction maps, and rooting depth maps.

Conclusion

In summary, SIS provides a rapid and effective approach to precision mapping of terroir components and will have broad applications for precision viticulture. In the future, the addition of color probe and other chemical sensor systems should allow more direct observations of underground soil properties. Viticulture is an activity well suited to precision agriculture methods, and management tools such as SIS will be very useful to grape growers.

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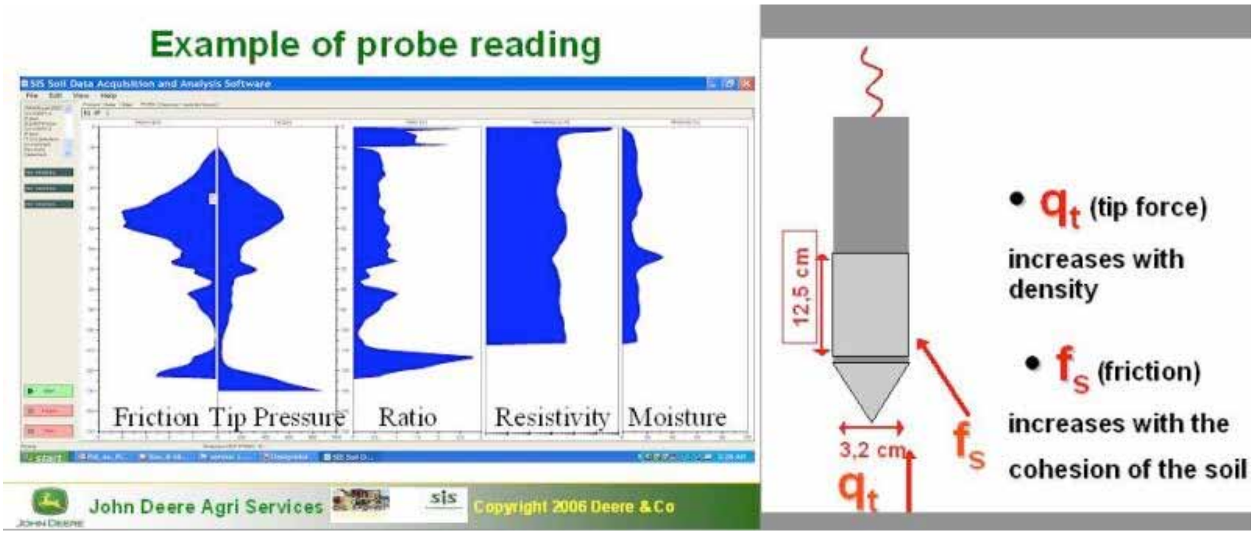

Figure 1 - Probe parameters and measurements

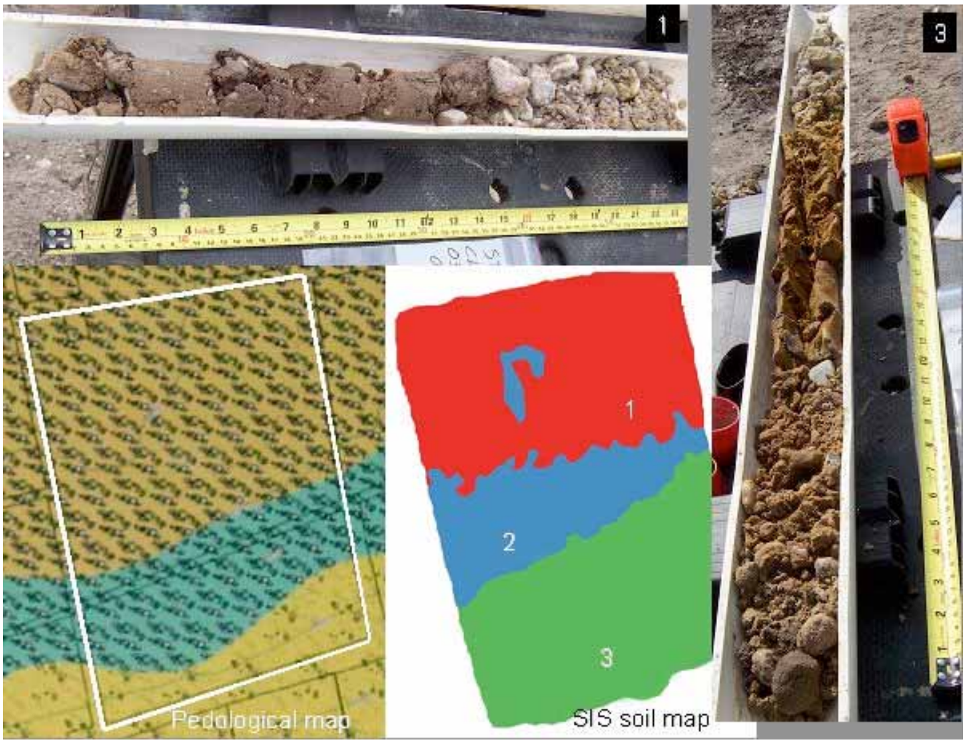

Figure 2 - Chateau Olivier, Graves Appelation, near Bordeaux, France

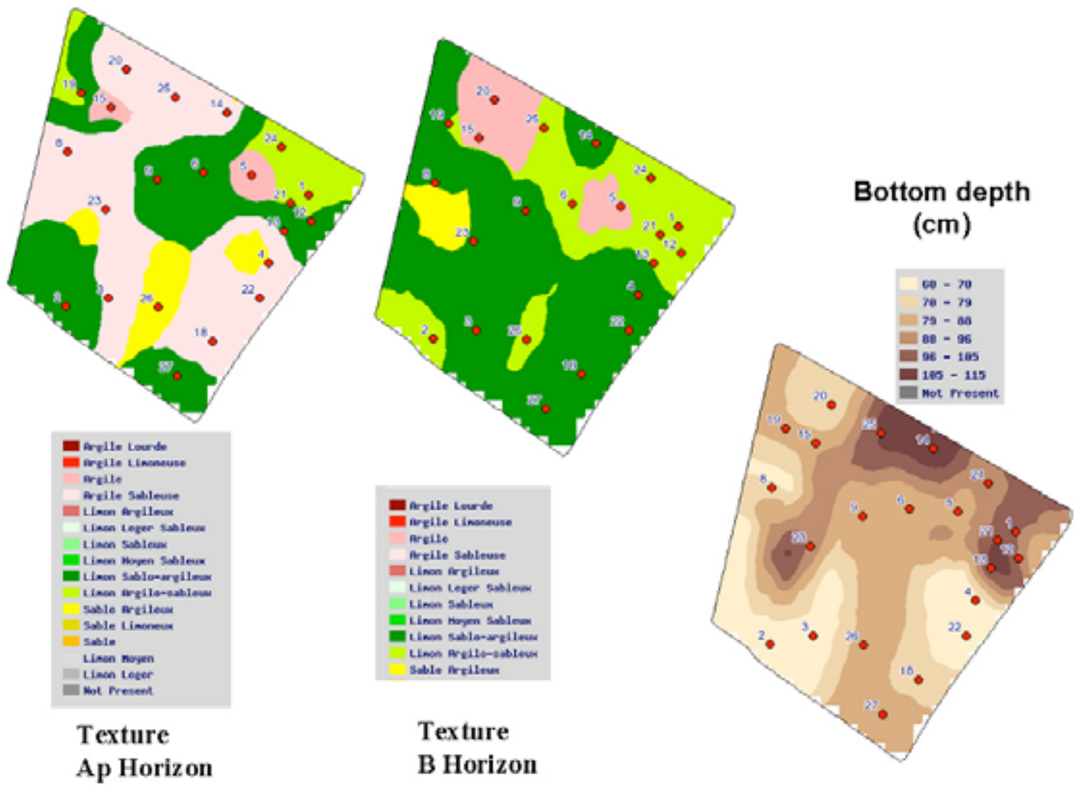

Figure 3 - Merlot vineyard, Domaine Cazes, Rivesaltes, France

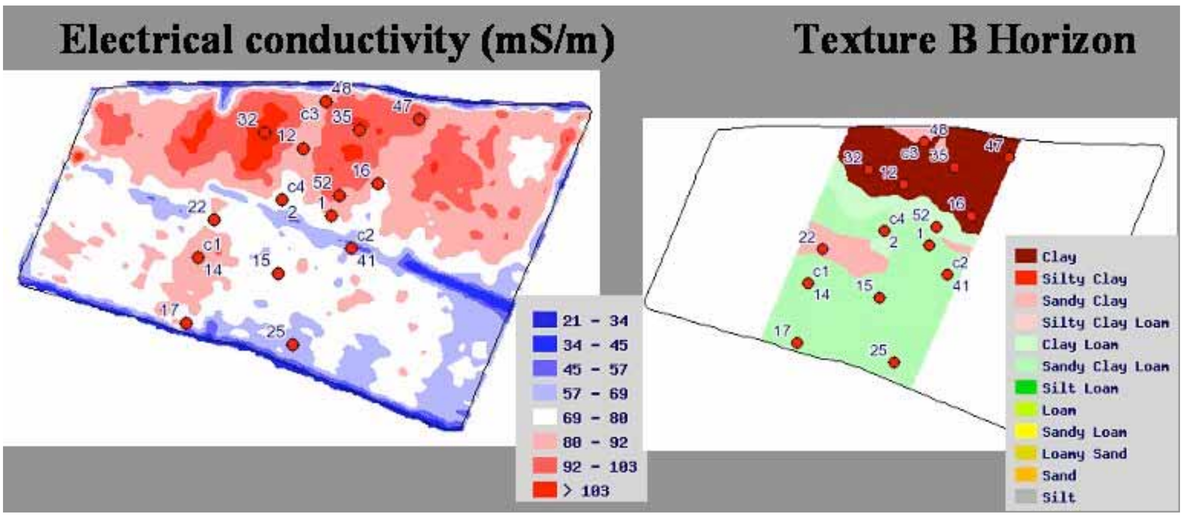

Figure 4 - New vineyard, La Castellana Cooperative, Rueda appellation, Spain