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Strategies of ARP application (Automatic Resistivity Profiling) for viticultural precision farming

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Introduction

Viticultural precision farming needs detailed soil information, which can be obtained by means of remote as well as proximal sensors, besides traditional invasive soil survey. Nevertheless, the use of the new technologies is still in its infancy, because of their costs and the lack of knowledge about the detail actually needed for the viticultural husbandry.

The main aim of this work was to test the sensitivity of the ARP methodology (Automatic Resistivity Profiling) in supporting soil survey for viticultural precision farming. In addition, we tried to optimize the detail of geoelectrical measurements and soil sampling to reduce the cost of the integrated survey, maintaining a significant information accuracy for viticulture.

Materials and methods

Two vineyards in coastal Tuscany (central Italy), about 3.5 ha each, were selected. Vineyard 1 was cultivated with Cabernet Sauvignon and Cabernet Franc, while vineyard 2 only had Cabernet Sauvignon. Soil survey and geoelectrical investigation were conducted in may 2007. The ARP methodology consists in the injection in soil of electric current through one pair of electrodes mounted on teeth wheels and measuring the resulting potential with other three pairs of electrodes, placed of the same mobile equipment. The electrical resistance of the soil (ER) is expressed as ohm per m. The depth of investigation is a function of the geometry of the electrodes and the soil being probed. Increasing the distance between electrodes will increase the depth while decreasing the measured potential. The innovative character of the ARP technique is represented by the passage of a mobile machinery, able to perform 30,000 measurements per hectare, with a measurement every 0.2 m. The ARP system, equipped with a digital encoder and DGPS system, is transported by a four-wheeled vehicle. It is fitted with three sensors that contemporaneously analyse three distinct levels of the soil, the values of which are represented by maps of apparent resistivity, from the surface to 0.5 m, 1 m and 1.7 m depth respectively.

Soil sampling at 0.1-0.3 m and 0.5-0.7 m was carried out with hand auger on a regular grid sampling scheme (35-40 m per 20 m). Soil samples were analysed for moisture, particle size, and electrical conductivity in water. The spatial viticultural behaviour was appreciated in both vineyards through image analysis of aerial photographs and, in vineyard 2, by means of a grape sampling and analysis of the must at harvest. The vines chosen for the sampling were selected according to the results of the geoelectrical survey.

Results and discussion

Laboratory analysis showed that the most frequent texture class in both vineyards was clay loam, followed by clay. ER spatial variability however was different in the two vineyards. In vineyard 1, the occurrence of low ER values at 0-0.5 and 0-1 m depths correlated with the presence of clayey and saline soil horizons. In vineyard 2, only ER at 0-1 m depth correlated with clay and soil water content.

In vineyard 1, the relationship between ER and clay content allowed the evaluation of the loss of accuracy caused by the reduction of the number of analysed soil samples. Passing from the initial 51 samples, to 25, 12, and 6, the accuracy in clay prediction passed from 100% to 79.4, 79.1, and 74%, respectively. The reduction of accuracy of ER prediction at less intense surveys, was limited, in spite of the relatively high soil variability. In fact, doubling the distance between the passages of the machinery between the vine rows, the accuracy of ER prediction was still

of 74%, and even widening it at 24 m, from the initial 6 m, the accuracy remained 64%.
The density of vegetation in vineyard 1 was positively correlated with ER, while it was inverse in vineyard 2. The opposite behaviour was due to the soil salinity of vineyard 1, which inversely correlated with ER and vegetation vigour. In vineyard 2, on the other hand, the lack of soil salinity enhanced the relationship between vine vigour and water content. In the same vineyard, the sugar content of berries was positively correlated with ER and negatively with clay, in spite of the fact that grape yield resulted independent from resistivity and texture, probably because of the intensive vine pruning.

Conclusions

The ARP methodology can fruitfully support precision viticulture for both soil survey and vineyard agricultural zoning. The cost of the geoelectrical investigation and soil sampling and analysis can be reduced considerably applying combined sampling schemes, differentiated according to site characteristics. Aerial photographs, as well as other ancillary spatial information, can be used to provide for a preliminary assessment of the site variability of the vineyard.