

# 3D CHARACTERIZATION OF SOIL VARIABILITY AND ITS APPLICATION TO THE MANAGEMENT OF VINEYARDS (ARP SYSTEM)

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Knowledge of spatial variability of soils for Precision Viticulture® (PV) is one of the first but most important parameters that has to be known precisely all over the vineyards. The concept of PV aims first at improving the quality and quantity of the grapes and second at minimizing the impact on the environment.

It is observed that yield can significantly change over space even down to a meter scale. Like with Precision Agriculture (Pag) which was developed some 15 years ago in Minnesota, US, the coming of harvester with GPS positioning enable the first yield maps to be drawn. Monitoring this variability is the first stage of PV. The second stage is to explain the reasons of this variability and thus to give the winemakers the possibility to improve the quantity and quality of the grapes. Without such a knowledge, prediction of yield becomes uncertain and the delivery to the winery of inconsistent quality grapes becomes a major drawback. The process of winemaking is now well controlled all over the world: quality of the wine could not be improved too much at this stage. On the contrary, selective vintage for example, can improve very rapidly the production of premium wines. Precise knowledge of yield help to tailor the production in real time, in order for example to make compatible the production to the storage facility of the winery. At least, a deep knowledge of the factors controlling the quantity and quality of grapes, will help to reduce the environment impact of the vineyards.

Making again the comparison with what happened in Pag is interesting: Management zones for variable rate seeding or modulation of N, P K were supposed to be based on yield maps. But what is observed is that yield maps vary every year. Making the definition of the management zones from these data is consequently a very difficult problem: it is not possible to infer the definition of management zones if the zones derived from yield mapping vary spatially from year to year. This is a consequence of the fact that yield is the sum of 3 factors: soil, climate and land use. From these 3 factors, only the soil is not time (and weather) dependent. As a consequence, yield data in Pag are now considered only as a verification for the management processes undertaken over the agricultural plots. Soil parameters are far more stable parameters. Since two years, they are more generally accepted than yield data to give

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the basic “layer” of information needed for any agricultural management. Among the soil parameters that can be measured, soil electrical resistivity (ER) or its inverse soil electrical conductivity (EC) is one of the most important because it can be quickly measured and is cost-effective, spatial resolution is high and its correlation with many agronomical parameters interacting with the plants is well known.

Yield maps in PV, less than 5 years ago, have also given the first impetus for this new field of research and development. Gaining the knowledge of what happened with Pag, application of ER/EC mapping is now growing fast. Australia, US, New Zealand and recently France are now adopting this technology.

Of course remote sensing (air photos, satellite images, multi and hyper spectral images) is another way of mapping the within-block variability. Airborne methods are very quick and can be very cost-effective. Besides the problems of ground resolution, interpretation of such documents is not evident as a result of two factors: time and penetration.

An aerial or satellite document represents a signal which is variable through time. The time of flight is very important and consequently no stable signal can be acquired (time-variability). Only by looking at different photos of the same area, one could derive a possible “stable” signal in relationship to the soil parameters. Up to this point, this means several flights and heavy processing. The cost is consequently increasing.

Moreover, aerial photos of bare soils are sensitive only to the uppermost layers of the soil (several centimeters): we see only what is at the ground level and we have no (direct) idea of what is in the soil. The depth of investigation is too low compared to the depth of ordinary soils and/or to the depth of penetration for the roots. Even using thermal images is not sufficient given the depth of penetration of the diurnal variation of temperature (7cm for an ordinary soil). By using the color and reflectance of the leaves, it is possible to indirectly sense down to the depth of penetration of the roots. This means a very careful choice for the time of flight and the existence of long term weather changes for the hydric stress. Of course, airborne methods are perfect for the following up of diseases or any pest infection.

Ground based methods like ER and EC are more time consuming, and perhaps more expensive to carry out but have several advantages.

Electrical Conductivity (EC) can be measured quite easily with commercially available instruments (mainly EM38 from Geonics) but suffers from well known drawbacks: a depth of investigation which cannot be changed easily, very poor stability of the electronic signal in a harsh environment, low signal for resistive soils, long time response and specifically for vineyards electromagnetic interference with metallic wires.

Since fifteen years, CNRS (Centre National de la Recherche Scientifique) has developed a prototype system, which can measure the Electrical Resistivity (ER) in the field for numerous applications (pedology, archaeology). Using this experience, GEOCARTA S.A has designed a commercial system specifically for PAg in 1999 and some measurements were made for PV in 2000. The system is patented and is now modified specifically for vineyards.

As opposed to EC, Electrical Resistivity (ER) can be measured easily with a very simple equipment and is very robust to the above mentioned interferences. We have developed a resistivimeter for making measurements of ER with two specific points: a very quick time response (better than 10Hz), a good rejection of industrial currents and a good tolerance to contact resistance. The injected current can vary from 0.1 to 20 mA. Generally, ER is

measured with 4 electrodes inserted manually in the soil. One pair of electrode is injecting the regulated alternative current and the other pair is measuring the resulting potential. The ratio is the electrical resistance of the soil. Knowing the geometry of the electrodes, this resistance is converted to an ER. If the soil is homogeneous, this ER is constant. Changing the depth of the soil, the water content, the texture, the clay content or the mineralization of the water will alter the ER.

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. If we imagine a system with more than 4 electrodes, it will be possible to investigate the soil down to different levels.

But ER suffers from the fact that electrodes need to be inserted manually. This is why we have developed the named MuCEP© (Multi-depth Continuous Electrical Profiling) system, which can be towed by a tractor, a 4-wheel car or an ATV which was further declined in ARP (Automatic resistivity System) for Pag. Three different generation of the system exist nowadays.

**Fig. 1.(erased) ARP system in operation (version 1).**

The two main advantages of this system is that the rate of sampling enable measurements of ER nearly continuously (sampling at 10cm interval) using this specific resistivimeter and that several depths of investigation (3 actually) are measured at the same time. Data are referenced in real-time by a dGPS. This means that at the same time, the DEM (Digital Elevation Model) can be computed. Using DEM or derived parameters like slope has proved to be important ancillary information in the definition of management zones.

**Fig. 2.5erased ER (0-1m) data measured in March 2002 – 14 ha - Alsace, France  
(Acquisition time : 1 hour, 151 590 data)**

Main factors affecting ER are water content, depth of soil, porosity /clay content and CEC and salinity. A ER map defines where and to what extent the soil texture differs across the block. This information should be followed up with sampling and other observations in order to understand what soil parameters are varying and correlate sampling and ER data. For example, a study in “Graves” wine-producing area showed a good correlation between coarse fragments and ER (P. Chéry et al., 2002). It has been shown that this coarse fragment content is highly correlated with the quantity of grapes . For the first vintage in 2002, we have been able to develop a model predicting number of grapes as function of this parameter.

As a conclusion, applications of ER maps in vineyards are :

- selective vintage
- maturity controls locations
- directed sampling
- improve crop forecasting
- varietal selection
- block and irrigation layout
- efficient use of inputs like lime and other soil amendments.