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GAMMA-RAY SPECTROMETRY IN BURGUNDY VINEYARD FOR HIGH RESOLUTION SOIL MAPPING

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Abstract

Aim: A soil mapping methodology based on gamma-ray spectrometry and soil sampling has been applied for the first time in Burgundy. The purpose of this innovative high-resolution mapping is to delimit soil areas, to define elementary units of soil for terroir characterization and vineyard management. The added value of this integrated approach is a continuous geophysical mapping of the soil with an investigation depth of 60cm.

Methods and Results: The principle of the gamma-ray spectrometry is a record, by a crystal of Cesium Iodide, of the natural radiation produced in soils (U, K, Th, Cs). The interpretation required the calibration of the natural gamma ray using soil samples description and analysis. The agricultural practices feedback of the winegrower is also fundamental for the interpretation.

Our soil mapping approach depends on the surface of the study area. For a parcel, the sensor is carried on a man's back. For an entire vineyard, the sensor is fixed on a drone. This low elevation does not impact significantly on the intensity of the signal.

Conclusions: We have investigated 18 parcels of the Domaine de la Tour Bajole (Saint Maurice-les-Couches), Domaine de la Chapelle (Pouilly-Fuissé), Domaine du Mas des Tines and Sources d'Agapé (Saint-Amour). These parcels are representative of the soil diversity of this region: soils issues from granites, granitic arena, Triassic clays and sandstones, Jurassic marls and limestones and deep argillaceous soils. The gamma-ray signal analysis allowed to discriminate and map these seven soil types, as well as colluvium and anthropic features.

Significance Impact of the Study: The application of gamma-ray spectrometry for vineyard soil characterization has been initiated in South Africa by Mlwilo (2010) (sensor fixed on an all-terrain vehicle, to investigate soils issued from shale, granitic arena and metamorphic rocks). Our study is the first use of gamma-ray spectrometry for vineyard mapping in France. It confirms the relevance of this integrated method for improving the resolution of soil mapping. The resolution is metric, and this tool separates elementary soil units at the scale of the sub-parcel ("sub-climat"). Today, the miniaturization of sensors and the carrying capacity of drones allows quick gamma-ray spectrometry to capture new high-resolution soil heterogeneity mapping on large areas.

Keywords: Vineyard soil characterization, gamma-ray spectrometry, high-resolution sol mapping

Introduction

One of the main challenges of precision viticulture is to quantify the spatial and temporal variations in factors that influence grape yield and quality. High-resolution soil mapping allows to visualize in the field the great variability of factors that affect vine growth and grape ripening, to optimize the performance of a winery. Precision viticulture depends on new and emerging technologies such as "high tech" remote sensing to define spatial soil variability.

In this paper, authors present a new soil mapping methodology based on gamma-ray spectrometry acquisition and soil sampling, applied for the first time in France, in the Burgundy region (Figure 1). This is an interdisciplinary approach integrating petrophysics, geology and pedology. The purpose of this innovative high-resolution mapping is to delimit soil areas, to define elementary units of soil for an accurate terroir characterization and vineyard management (precision viticulture). The added value of this approach is a continuous geophysical mapping of the soil with an investigation depth of 60cm to 100cm.

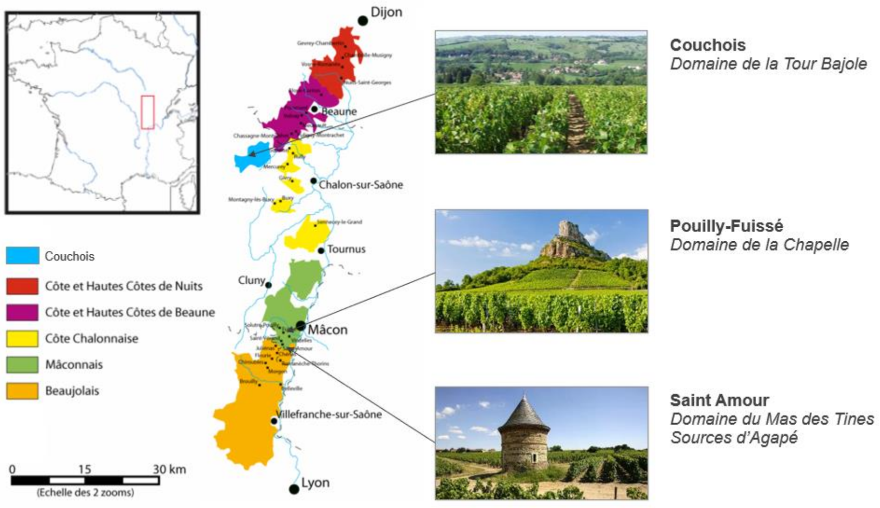

Figure 1: Location of the study areas on the map of the Burgundy region (without Chablis, further North).

Gamma-Ray Spectrometer Principle

Gamma-ray spectrometers are invaluable tools in the field of soil analysis, where they are commonly used for geological mapping and mineral exploration. The sensor of the gamma-ray spectrometer contains a crystal of Cesium Iodide. It is able to measure the concentrations of the natural occurring radionuclides contained in soil and rocks (U, K, Th, Cs). The system collects gamma spectra with sufficient resolution to perform full spectrum analysis (Figure 2) and determine variations in geophysical soil parameters (Van Egmond *et al.,* 2010). The monitoring platform can autonomously process data giving real-time insights.

Recent technological advances in airborne geophysics domain introduce a new platform for gamma-ray surveys: Unmanned Aerial Vehicles (UAVs) or drones. (Figure 3). These rapid technical evolutions result from the optimization of the weight and power of drones and sensors. The combination of the last generation of drones and gamma-ray spectrometers is the matching of two technologies, to maintain the measure at a high resolution and simultaneously increase the ease of sensor use.

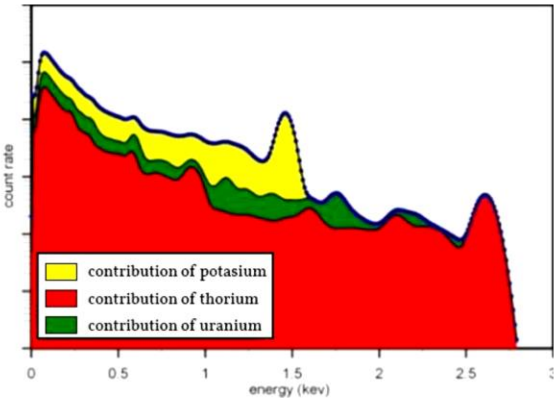

Figure 2: Example of Full Spectrum Analysis from a gamma-ray spectrometer recording (Van Der Veeke *et al.,* 2018).

Figure 3: Gamma-ray spectrometer used under a drone in the St Amour vineyard (©CVA 2020).

Materials and Methods

The method combines measures of the natural radiation produced in soils and rocks (U, K, Th, Cs) with a gamma-ray spectrometer and field calibrations (Figure 4).

The gamma-ray spectrometry survey strategy is adapted to the topography and to the surface of the investigation area. At the scale of few parcels, surveyors carry the spectrometer on their backs. To cover the larger surface of a wine appellation, the sensor is fixed under a drone which flies at an elevation of 10 meters. This protocol does not impact significantly on the intensity of the signal. However, the acquisition spot size is larger, resulting in a light smoothing effect.

The interpretation of the gamma-ray signal in terms of pedology required a field calibration using shallow cores (auger sampling), trench flank descriptions and soil sample analysis (granulometry and X-ray fluorescence). Winegrower's feedback is also fundamental for the interpretation, regarding the agricultural practices, the vine stock liveness and the history of soil reworking.

Figure 4: The method combines gamma-ray spectrometer collection and field calibrations (©CVA 2020).

Results and Discussion

We have investigated 18 parcels of three vineyard domains: la Tour Bajole (Saint Maurice-les-Couches, 71), la Chapelle (Pouilly-Fuissé, 71), Mas des Tines and Sources d'Agapé (Saint-Amour, 71). These parcels were chosen because they represent the soil diversity of Burgundy: soils resulting from the weathering of Jurassic marls and limestones (Figure 5), Triassic clays and sandstones (Figure 6), arkose, granites and volcanoclastic rocks (Figure 7). The gamma-ray signal analysis, calibrated on field observations (outcrops, trenches and augers), allowed to discriminate and map these seven types of soils, as well as colluvium and anthropic features (digging and backfilling).

The three figures below illustrate surveys in Burgundy. Soil maps are based on the total gamma-ray spectrometry and soil samples analysis. In Figure 5, the blue color corresponds to sub-cropping marls, and hottest color to thick argilaceous soils. In this area, total gamma emissions come from the soil clay content. On Figure 6, the alternation of claystones and sandstones is clearly marked by the measurement of potassium by gamma spectroscopy, this signal coming from the feldpars observed in sandstones. In Figure 7, the strong contrast between east and west total gamma signature is due to the high emissions from granite located in the southwest of the pilot. In all cases, the gamma contrasts make it possible to precisely delimitate the types of soil and rocks.

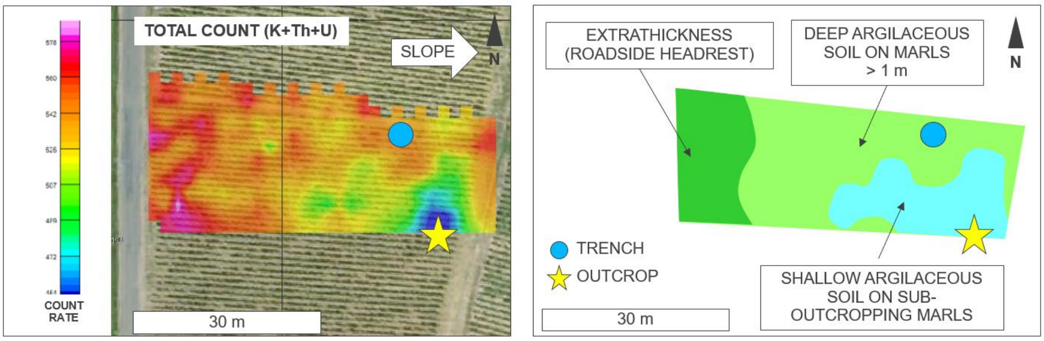

Figure 5: Man's back spectrometer survey, argilaceous soil on marls, Domaine la Chapelle (Pouilly Fuissé).

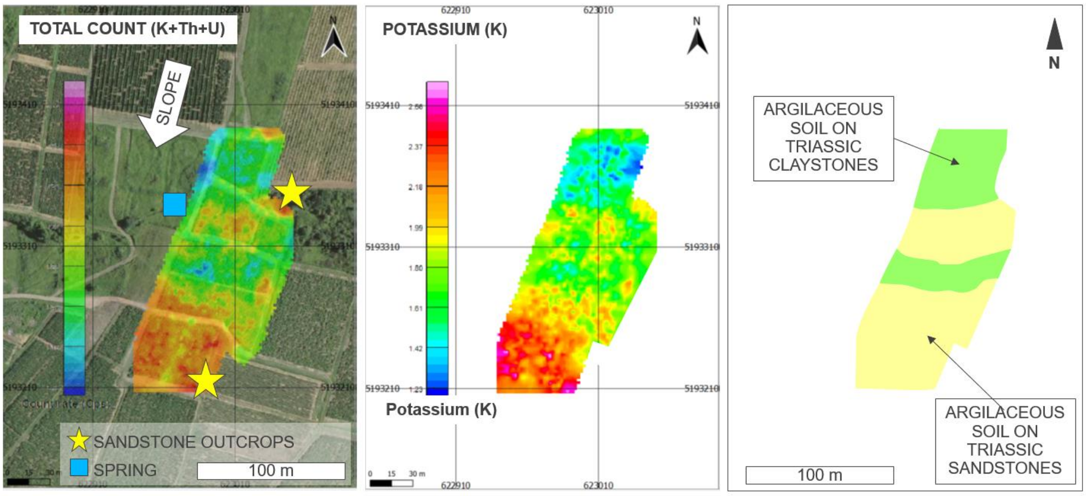

Figure 6: Man's back spectrometer survey, argillaceous soil on sandstones and claystones, Domaine de la Tour Bajole (Couchois).

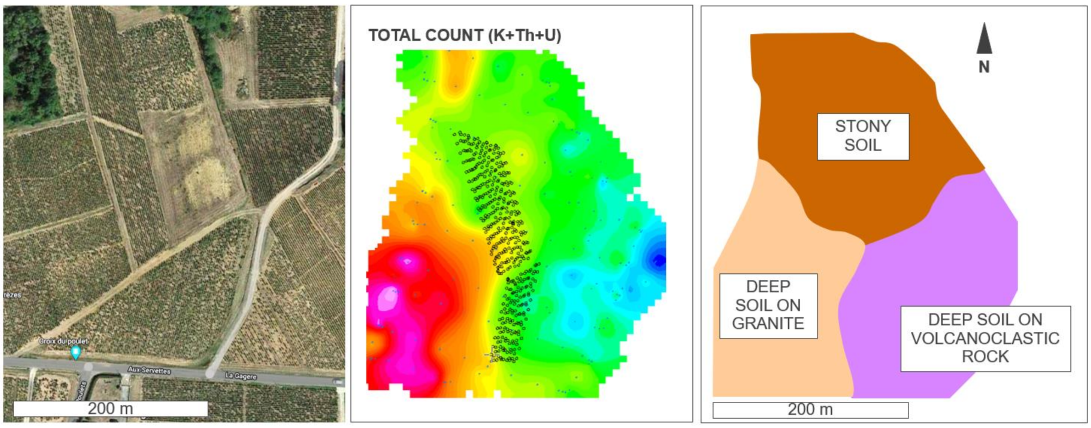

Figure 7: Drone spectrometer survey, deep soil on granite and volcanoclastic rock, Domaine de la Tour Bajole (Couchois).

Conclusion

The application of gamma-ray spectrometry for vineyard soil characterization has been initiated in South Africa by Mlwilo (2010), specifically sensor fixed on an all-terrain vehicle, to investigate soils issued from shale, granitic arena and metamorphic rocks. Our study is the first use of gamma-ray spectrometry for a vineyard mapping in France. The results confirm the relevance of this integrated method for improving the resolution of the soil mapping and its potential for discriminating between the different lithological units. The resolution is metric, and this tool separates elementary soil units at the scale of the sub-parcel ("sub-climat" in Burgundy). Today, the miniaturization of sensors and the carrying capacity of drones allows quick gamma-ray spectrometry that led news high-resolution soil heterogeneity mapping over large areas.

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