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Geostatistical analysis of the vineyards in the canton of Geneva in relation to soil and climate

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ABSTRACT
Soil and climate maps at the 1:10000 scales exist for more than 12'000 ha of Swiss vineyards. The use of these maps as consulting tools for growers remains difficult due to the complexity of the relationship between terroir and the large number of grape varieties planted. The current distribution of varieties and rootstocks is the result of a long optimization process. This study aims at analyzing the relationships between grape varieties, soil characteristics and climatic conditions.
The study was performed on the 1365 ha of Geneva's vineyards with 3885 digitalized parcels. The 19 grape varieties planted on at least 5 ha were matched with the soil and potential radiation maps. The surface of each variety-soil combination and the mean radiation were calculated for each parcel.
The analysis showed that grape varieties were primarily planted according to meso-climatic conditions. Late ripening varieties, like Syrah or Merlot, were always planted on parcels receiving higher amounts of radiation than those planted with Pinot noir or Gamaret. Minimum radiation was calculated for each variety. Traditional grape varieties (e.g. Gamay or Chasselas) were planted in all meso-climates, indicating that the warmest plots were not judged to be too warm for early varieties. Regarding soil characteristics, early varieties were more present on BRUNISOL, which mainly represented flatter areas of the vineyards (10% mean slope) and late varieties on steeper areas (mainly CALCOSOL with 16 % mean slope).
The present study revealed actual practices and criterions used by growers to make planting decisions. It might indicate minimum climatic and soil requirements for a given variety in the canton of Geneva. Continued monitoring may show the adjustments made by the growers to correct unsuccessful planting decisions. The analysis of these adjustments provides useful information for vineyard consultants.

Keywords: grape varieties, soil, climate, terroir, SIG, geostatistic, Geneva.

1 INTRODUCTION

Climatic conditions, soil type, ecological and cultural objectives possibly lead to a diversification of planted grape varieties, if permitted by law. Of the many terroir surveys conducted, some focused on mapping soils or geological factors (1, 2, 3) others on the grapevine's reaction to different climatic conditions or soil characteristics (4, 5). Recently, terroir studies using Geographic Information Systems were performed in order to visualize spatial patterns of climate and soil properties (6, 7, 8). However, none of the studies used detailed partitioning of the varieties in the landscape in an extended area. The possibilities of performing experiments to test all soil-variety combinations are limited. Despite the large amount of information available, choosing the right grape variety remains a main concern to the producers.
The vineyards in the canton of Geneva were mapped with high precision (9). In addition, the planting partitioning of the grape varieties was digitalized and covers almost 95% of the surface for official purposes.
The aim of this study was using the considerable amount of information in order to gain knowledge on the adaptation potential of a grape variety within a region. This analysis may add information to the minimum requirements necessary for sufficient fruit quality and the best variety-rootstock combination for the climatic conditions and soils of the region. Two main questions were assessed: (i) do the parcels planted with the same grape varieties and/or rootstocks have something in common regarding climatic conditions or soils? (ii) Is this proposed analysis method helpful in the decision making process concerning variety-rootstock combination for a given parcel?

2. MATERIALS AND METHODS

Soil maps (1:10000, soil type and geology) and digitalized maps of the 3885 parcels in the canton of Geneva (showing variety, rootstock, and planting year) were used. A digital elevation model (DEM) with 1m resolution was extrapolated to a 5m resolution map to simplify the calculations.
The surface planted each year and the partitioning by variety was calculated from the parcel vector file. Mean potential radiation for April and June, integrating

slope and exposition, was calculated from the 5m DEM for each parcel (solar analyst and extraction functions of the spatial analyst tool, ArcView 9.3, ESRI). A matching procedure of the vector file, containing the parcel data, and the soil map was performed using the overlay function (spatial analyst tool, ArcView 9.3, ESRI). The resulting 9295 polygons were completed with variety, soil type and geology data and analyzed.

3 RESULTS AND DISCUSSION

During the past 50 years, grape variety choices had evolved. Until 1983, Chasselas, Gamay and Pinot Noir represented 85-90 % of the varieties planted each year. After 1983, the choices greatly diversified and between 10 and 18 varieties were planted each year. Today, a total of more than 50 different grape varieties are cultivated. In 2008, 19 varieties with a minimum of 5 ha were in production on a total of 3549 parcels covering 1180 ha. These varieties are showed in the next sections.

Figure 1 shows that early varieties like Chasselas and Gamay or Pinot Noir were planted on parcels with the lowest radiations. These early varieties were also present on parcels with higher radiation since they represented the largest production volumes of the area and the growing conditions were still suitable. Late varieties like Syrah, Cabernet franc or Viognier were planted on parcels with higher mean radiation.

The minimum radiation on a parcel turned out to be the selective parameter for choosing to plant a variety. This variety's minimum radiation requirements may be used to select planting zones using potential radiation file. Figure 2 shows, for a similar region, the zones with different level of radiations. Zones with enough radiation (yellow and red) are much more extended for Gamaret (> 164 kWh m^{-2}) than for Syrah (> 175 kWh m^{-2}). This is due to the lower radiation requirements for Gamaret. The zones in blue are too cool for a given variety. The zones in red show a higher potential than the canton's average.

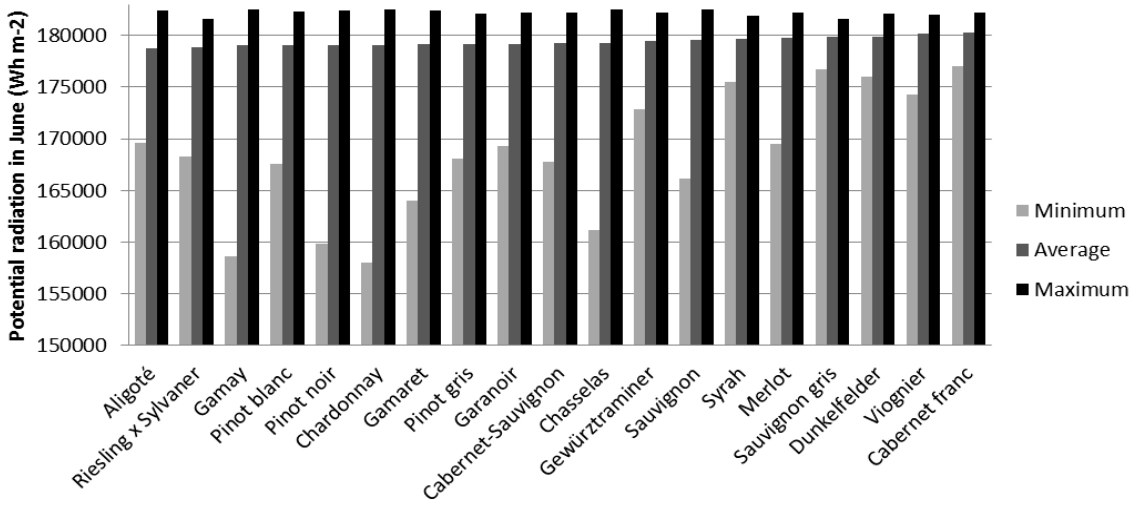

Figure 1. Minimum, maximum and average potential radiation income for each parcels and variety.

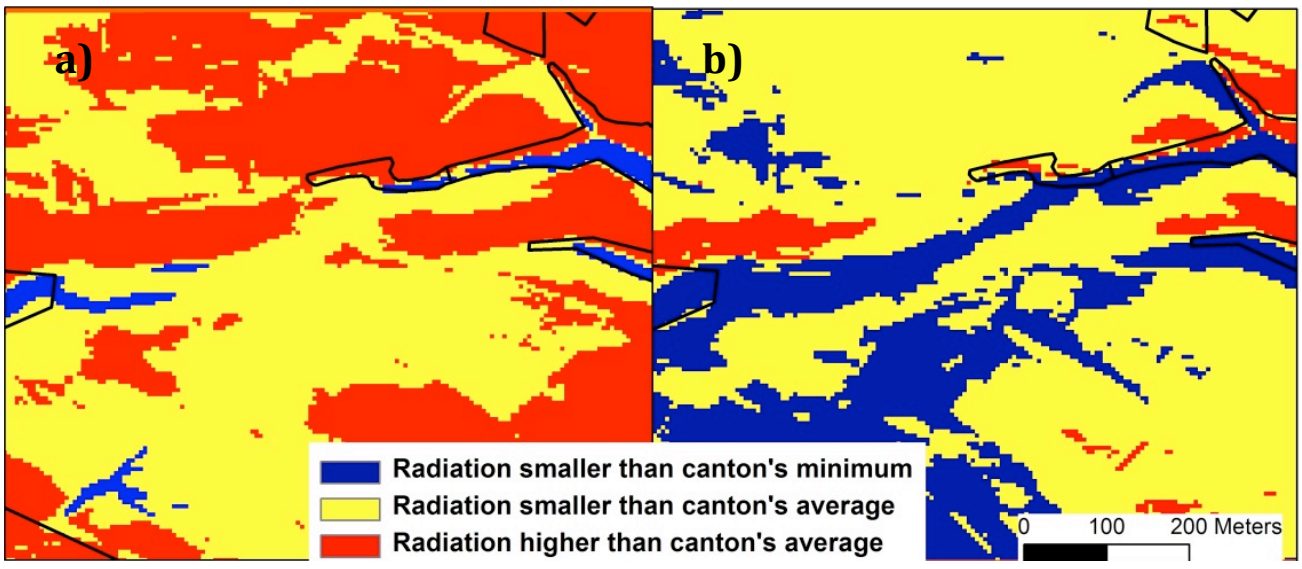

Figure 2. Example of a similar region with zones showing lower radiation than the canton's minimum (blue) lower (yellow) and higher (red) than the canton's average for a) Gamaret, b)Syrah.

Figure 3 indicates that varieties like Sauvignon Gris, Sauvignon, Syrah and Merlot were rarely planted on more evolved, non-calcareous soils, like BRUNISOL or LUVISOL, than other varieties. This was probably due to the location of these soils in the landscape. They were mainly on flat areas (10) and received lower amounts of radiations than soils located on slopes, which were mostly calcareous. No clear relationship between rootstock and soil type were found. The results showed that distribution of grape varieties and rootstocks were due to a long optimization process. Late ripening varieties like Syrah were always cultivated on parcels with higher radiation. They were less present on evolved soils, located in flat areas. Late varieties were found more often on calcareous soils on the slopes. The choice of a variety was more correlated to the meso-climate than the soil. Potential radiation was one of the best factors explaining earliness of different areas of Geneva's canton (11). Soil types are taken into when the climatic conditions match the varieties requirement.

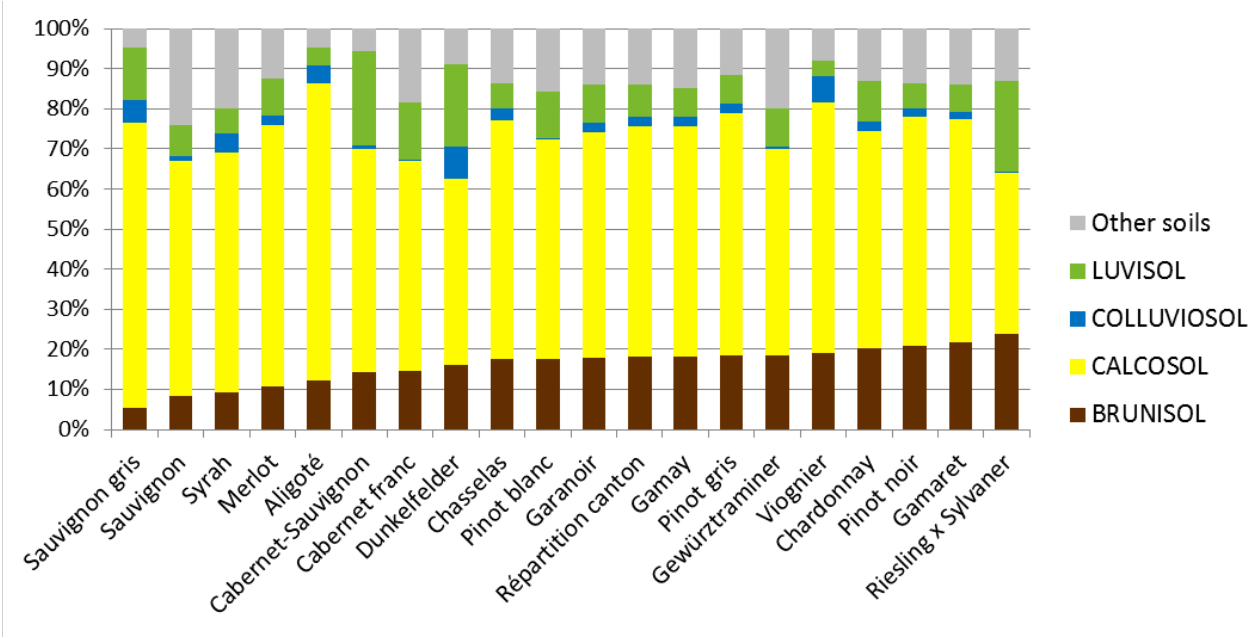

Figure 3. percentage of each variety in relation to soil type.

If late varieties were limited to the most favored zones, early varieties were planted everywhere. Climate was not a limiting factor for these widely distributed varieties. No trend was found for choice of rootstock in a given soil type. The most important factor was probably vigor. The soils were not very calcareous and therefore not dramatically limiting for iron absorption

4 CONCLUSIONS

The first objective of this study was to analyze actual cultivation practices, in particular variety-rootstock choices in given climatic conditions and soil types. The second objective was to evaluate possibilities of such an analysis to add important information of minimum variety requirements for sufficient fruit quality. This number of cultivated grape varieties dramatically increased in the canton of Geneva since 1983, probably because of the crisis at the time, which caused a search for new varieties, if permitted by law, with high quality requirement.

Calculations revealed that late ripening varieties were cultivated in zones with higher radiations. This permitted the selection of such zones with the help of a digital elevation model. Radiation was a good integration factor where the altitude gradient was not elevated. Correlations between soil and variety showed that late varieties were preferably planted on calcareous soils, situated mainly on slopes with higher incoming radiation. Main limitation for this study was the inherent postulation of a continuing optimization process by the grape growers. Locations, which were not suitable for a given variety, were perhaps not known because planted for a short period of time, only. In general, the quality of the fruit was always sufficient to produce quality wines. Otherwise, planted varieties would have been removed or field grafted. If this type of study was repeated in time, it would be possible to follow the natural selection, showing also the disappearance of non-adapted parcel-variety matches. It should be noted that other objectives of production, clones, and cultivation methods were not taken into account and might have biased the analysis. Further research needs to include high fruit quality parcels to precisely evaluate optimum variety requirement

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An internet-based GIS application for vineyard site assessment in the U.S. and matching grape variety to site

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ABSTRACT
Vineyard site selection and determination of adapted grape varieties for a site are the most fundamental factors contributing to vineyard success, but can be challenging to ascertain, especially in developing wine regions. The objective of this research is to demonstrate, and describe the development of an internet based, scientifically objective tool to facilitate vineyard site assessment and grape variety selection in the US. The core of this tool is a spatially explicit environmental database relevant to wine grape production including climate, soil and topography data. The climate summaries are sourced from the U.S. National Climatic Data Center (NCDC) and the World Meteorological Organization (WMO). The daily elements included in our dataset are maximum temperature, minimum temperature, mean temperature, dew point, precipitation, and elevation for 1929 to present. Similarly, our soil database is derived from the Soil Survey Geographic (SSURGO) database for the continental U.S.A and the Harmonized World Soil Database for global soil data. Parameters include soil texture, pH, soil depth, water holding capacity, etc. This database was used to derive established and novel environmental indices relevant to grape production. The indices were used as inputs to mathematical and statistical models to examine the relationship between environmental factors and variety production in selected established growing regions. Finally, we incorporated both the environmental database, and the site/varietal selection models into a web-based site and grape variety selection tool. This tool enables a potential wine grape grower to either determine varieties most suited to a particular site or delineate areas most suitable for growing a particular grape variety.

Keywords: GIS, viticulture and site sélection.

1 INTRODUCTION

The US wine industry has been steadily growing over the last decades with increasing demand for high quality grapes and wine. Given the financial burden associated with growing grapes, choosing a location or variety becomes paramount. The process of matching grape varieties to environmental conditions will affect yields and profitability for the life of the vineyard and is a determining factor for economic success in wine grape production. The environmental conditions within vineyards have a large influence on the quality of grapes for wine production. The goal of this project is to develop models that relate environmental conditions to the culture of successful grapes for wine making. At the most basic level, this will allow users to select potential sites most likely to support grapes of a given variety or select the varieties that are most suitable for a particular location. The foundation of this technology is grounded upon 3 functional principles that will allow viticulturists to effectively explore, compare, and analyze a scientific approach to vineyard selection. The process of site selection or matching varieties to location is becoming an increasingly exact science that involves careful objective analysis of climate, soil, and