



Characterization and cartography of viticultural terroirs: A tool for the management, valorisation and conservation of vineyards

Etienne GOULET¹²³, Dominique RIOUX³, Vincent COURTIN³ et Sébastien CESBRON³

¹Institut Français de la Vigne et du Vin, UMT VINITERA ;

²InterLoire, Interprofession des Vins de Loire ;

³Cellule Terroirs Viticoles, UMT VINITERA ;

corresponding author:

Etienne GOULET

InterLoire

73, rue Plantagenêt - BP 52327

49023 ANGERS Cedex 02

* Tel. + 33 2 47 60 55 39

E-mail address: egoulet@vinsdeloire.fr



Introduction

Cellule Terroirs Viticoles (CTV) is an association supported by « InterLoire » (*Interprofession des Vins de Loire*) and the « Vine and Wine French Institute » (*IFV, Institut Français de la Vigne et du Vin*). It is one of four partners in the Technological Unit called VINITERA (the others being IFV, the National Agricultural Research Institute and the agricultural high school in Angers). CTV is active in the various research programmes conducted by this Technological Unit.

CTV's main activity consists in the study and cartography of viticultural terroir units (the complete growing environment) and the transfer of the results of this scientific research. Target people are consultants, cooperative structures, trade unions, wine growers and any other key players potentially interested in more detailed knowledge on the spatialization and management of terroir units. Methods for describing and mapping terroir units include large-scale (1 / 10 000) description of environmental factors using soil sampling points (one sampling point per ha, on average), with hand augers and by means of aerial photographs, calculation and spatialization of functioning indexes (vigour potential, agronomic constraints, etc.) and spatialization of the recommendations associated to each unit. The entire operations chain is digitalised (geographic information system, digital terrain model, data base management system, etc.) and the results of the studies are presented both in traditional form (atlases of printed maps) and in digital form (on-screen display, interactive maps, relief views, etc.). Studies on terroirs are presented as a tool for the wine growing profession. The aim is to achieve the best possible environmental management of a vineyard, adapting agro-viticultural and œnological practices according to the type of wine desired, the environmental potential, economical constraints and the respect of environmental standards (land management tool).

These descriptive maps of vine growing areas are based on the method developed by the National Agricultural Research Institute (Morlat and Bodin, 2006; Bodin and Morlat, 2006). The use of the maps makes it possible to:

1. **Spatialize** the potential and the various vine growing constraints of a vineyard at the plot scale using a detailed geo-pedological map and taking into account the mesoclimate
2. **Adapt** practices (grape variety, rootstock, soil management, etc.) to the vine growing potential as described in the consultative maps
3. **Promote and communicate** objectively on subjects such as vineyard diversity and potential
4. **Preserve and manage** the wine growing capital of a vineyard in the face of urbanisation, the need for renewal, etc.

1) Identification and mapping of the environmental factors of a terroir

For each terroir studies, a detailed map (1/10 000) of the environmental factors of each terroir unit is produced. Therefore, it is possible to spatialize the variables relative to the soil the geology and the landscape (mesoclimate). The cartographer uses a traditional hand-held auger of 120 cm and takes an average of 1 or 2 samples per hectare (Photo 1).



Photo 1. Sampling with a hand-held auger

The number and distribution of sampling points depends on the complexity of the terrain. Each one is pin-pointed on an aerial photograph; soil and landscape are described following a template. According to the soil characteristics and the landscape of each sampling point, the map contours are drawn onto the photograph, producing environmental zones, where each zone has its own geo-pedological and landscape characteristics (Fig. 1).



orthophotographics data from the French national geographical institute ©IGN-Paris-2005- Autorisation n° 40- 5001

Fig. 1. Map of soil sampling points

2) Description of operations on viticultural land

a. On site survey

Precise descriptions of the Basic Terroir Units are also done by means of pedological trenches (Photo 2): standard physical and chemical laboratory tests (texture, organic matter, mineral elements, etc), on site soil measurements (water content, resistance to penetration, etc.) (Photo 3) and analysis of the vine root profile.



Photo 2. Pedological trench



Photo 3. Measuring the bulk density of the soil

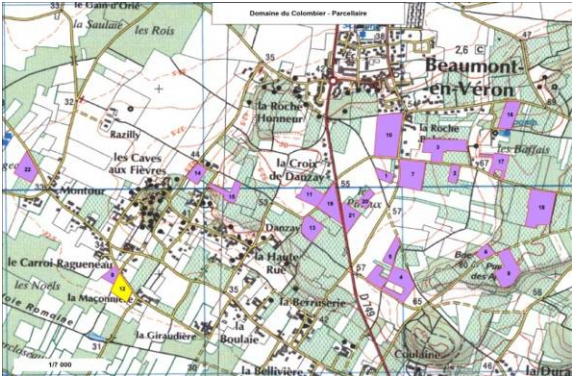
At this stage the geo-pedological and landscape characteristics of each plot have been established and spatialized: these are the Basic Terroir Units and their components (soil depth, soil texture, type of drainage, etc.).

The description of each Basic Terroir Unit is based essentially on the physical characteristics of the soil and topographical characteristics. These measurements give us an understanding of Useful soil Water Reserve and mesoclimatic conditions. These parameters have a direct influence on vine precocity and vigour, which largely determine the quality of the wine harvest.

The drawing up of an inventory and a geo referenced data-base for the variables of the environmental factors of a terroir allows to localise the various Basic Terroir Units precisely on a map. The description of the functioning variables of a Basic Terroir Unit, however, requires a survey and/or experimentation. Since experiments are very time-consuming and require significant human and financial resources, we propose an alternative method of enquiry. It is always possible for the local scientific and technical bodies to collaborate in using previous results of land studies.

b. Surveys at the plot scale

The empirical knowledge that the winegrowers have on the functioning of their own vineyards is taken into account in a survey at the plot scale (Fig. 2). The questionnaire used included questions such as grape varieties, rootstock and age. There were also other questions pertaining to vine vigour, yield, earliness of the growth cycle, intensity of water stress symptoms, quality of ripening or over-ripening of grapes, etc. It allowed us to obtain knowledge about the grape varieties and the agro-viticultural practices used in a vineyard (types of rootstock, soil management practices, fertilisation, pruning techniques, good practices for sustainable viticulture, etc). This knowledge can be rapidly obtained by surveys and is essential for the study of the adaptation of practices to the viticultural potential of the different Basic Terroir Units.



Topographical data from the French national geographical institute ©IGN-Paris-2005- Authorisation n° 40- 5001

Fig. 2. Example of vine plot localisation

The interview also included the localisation of each vine plot on a map in order to compare the responses of wine growers to the characterization of the BTUs in vineyards which was produced in atlases using a geographical information system (Fig 3). It is then possible to carry out statistical analyses on the answers of all the wine growers and thereby establish the main types of Basic Terroir Unit functioning.

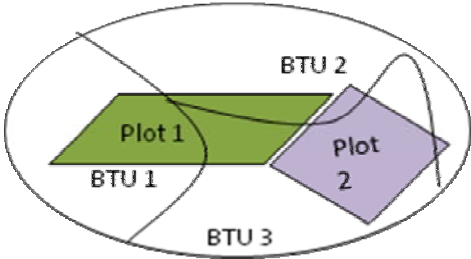


Fig. 3. Layered map between plots and Basic Terroir Units (BTU)

The results obtained through the surveys are then compared to the potentials obtained by the use of expert algorithms which enable us to take the map data and calculate certain potentials such as the Useful soil Water Reserve, rooting constraints, precocity, vigour, etc.).

c. Estimating potential and agronomic constraints and the associated risks

The estimate of these potentials and constraints is based on calculations that take into account certain variables observed in the mapping phase (Guilbault et al., 1998). The choice of criteria and their weight were validated on experimental plots (Morlat, 2001). For example, the potential for early vine growth (PEG) algorithm includes the following nine variables: soil depth, soil stoniness, rock hardness, soil water percentage at field capacity, soil drainage, soil colour, depth of the maximum rooting zone, altitude and landscape opening, and intensity and aspect of the slope. PEG is calculated using the following formula:

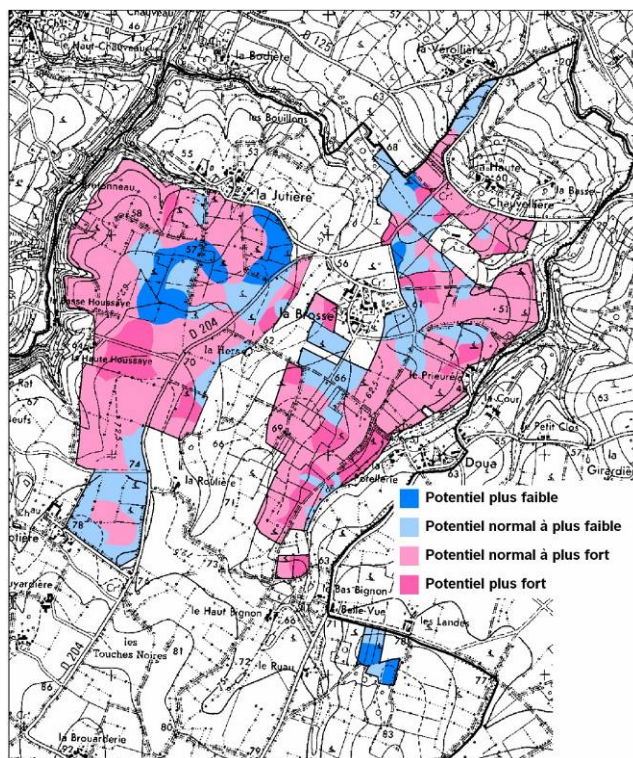
$$PEG = \sum_{v=1}^9 [(v_{mi}) \cdot (v_i)]$$

where v is the variable, v_{mi} is the modality of the variable i , and v_i is the weight of the variable i which was determined using measurements on experimental plots (Morlat, 2001) Range of PEG values are from 20 to 60.

Other potentials are also calculated such as the Useful soil Water Reserve (Goulet et al., 2004) and vigour. The agronomic constraints (depth of rooting, etc.) and the associated risks (iron chlorosis, erosion, etc.) derive from a systematic analysis of the variables observed and the calculated potentials and are worked out for each point of measurement.

This method, where surveys and calculations are combined, makes it possible to estimate the potential of a BTU using the empirical knowledge of the winegrowers and the knowledge of local technicians. Spatialization of these potentials and constraints is done by converting the survey results into calculations using the map data: the potentials are calculated automatically and identically for each sampling point and they are then checked manually.

This procedure enables us to recognise and spatialize the potentials and agronomic constraints for each land parcel (Fig. 4).



Topographical data from the French national geographical institute ©IGN-Paris-2005- Autorisation n° 40- 5001

Fig. 4. Map of PEG

3) Adapting practices to the environment

Once the first objective has been attained (mapping and characterisation of the vine growing terroirs), we can turn to the second objective, which is to adapt practices to the environment. Depending on the characteristics of a BTU (geo-pedology, landscape, potential, constraints), the characteristics of the planting material in each vineyard in the survey (grape varieties, rootstocks) and the sensorial characteristics desired for the final products, it is possible to suggest various technical approaches.

It is essential that this stage is carried out in collaboration with the local partners (wine growers and technicians) who are thoroughly familiar with the behaviour of their grape varieties in the particular conditions of their own vineyard. After recommendations have been made on adapting practice (choice of grape variety, choice of rootstock, soil management, etc.), CTV spatializes the recommendations and offers a series of consultative maps, depending on the environmental location (Fig. 5).

Adaptation of practices is therefore based on the type of product desired (consumer surveys, etc.), on controlling the cost of production and on consideration for the environment (adaptation of practices to the environment in order to reduce the incidence of plant disease).

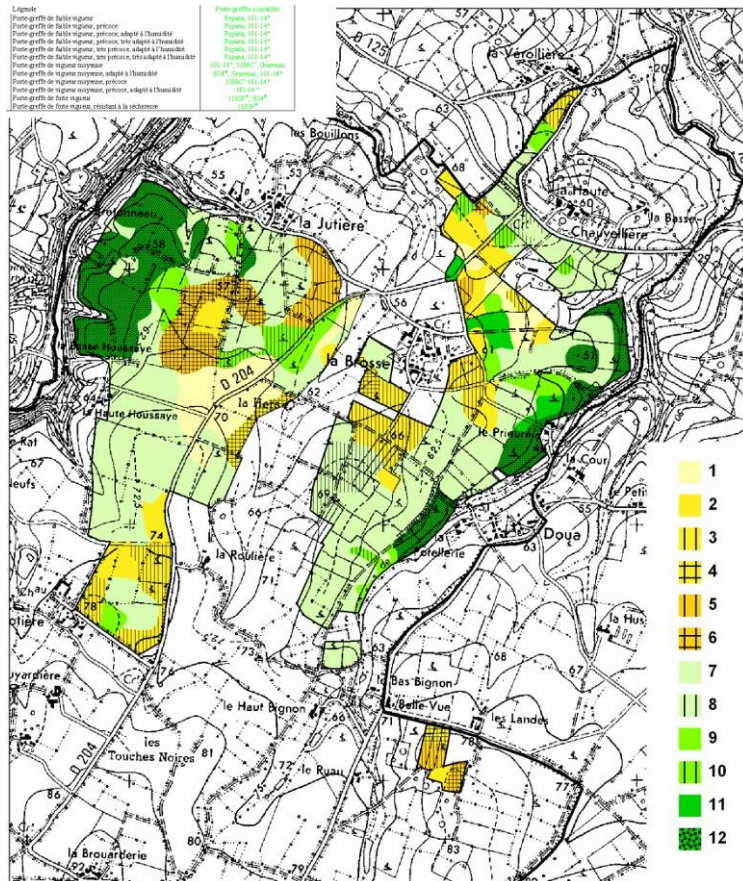


Fig. 5. Consultative Map on the choice of rootstock

By this stage, the recommendations for adapting practices for each plot have been made and spatialized.

4) Technical and commercial exploitation

The maps are not an aim in themselves but a tool offered to all the professionals. The transfer of knowledge is therefore just as important as acquiring it. In reality, although **knowledge** of the terroirs is important, the **technical adaptation** of wine growing practice to the nature of the terroirs is fundamental if you wish to produce quality wines. The economic aspect is also essential when it comes to sustainable wine growing; and the **commercial exploitation** of the terroirs by producing specific cuvees or through suitable publicity may contribute to improving the financial health of a vineyard.

In order to facilitate the transfer of results and exploit the research on the terroirs, there are various formats on offer to winegrowers and viticultural organisations (Goulet et al, 2004).

a. Paper terroirs atlas

The thematic maps obtained during the study of a vineyard are published in A3 format, arranged in files for each commune. Each atlas contains, in addition to all the thematic maps, a presentation of the methodology used and an explanation of the calculations done to define the various potentials. The maps include:

- Maps of environmental variables observed (BTU, soil texture, soil depth, natural drainage, etc.)
- Maps of viticultural potentials (Useful soil Water Reserve, vigour, precocity, etc.) and agronomic constraints (water constraint, rooting constraint, erosion, etc.)
- Generic consultative maps on adaptation of the technical approach (rootstock selection, agro viticultural practices, etc.) for each zone.

b. Digital terroirs atlas

The wine atlas is also available in digital form for easy reading of the results and to customise the maps for each vineyard. Using our software, the wine grower is able to consult the thematic maps from the comfort of his own computer: he can zoom in, change theme with a simple click or go directly to a particular land parcel. There is also a popup function, displayed when the user hovers over the map, showing a list of all the themes in the selected item. In order to access a detailed map for any one of these themes, you just click on the 'View' button and select one of the themes. It is also possible to select a precise geographical zone and click to see all the themes without losing the general view.

It is possible to customise a map so as to see, for example, all the parcels owned by one wine grower or one wine-producing cooperative. To do this all the parcels need to be digitalised; it is then possible to customise them and add information on the attributes of each wine-growing parcel (name of the parcel, grape variety, rootstock, year of planting, etc.). The parcel layout can be layered with the BTU plan and you can then see the components of a local terroir in the parcel, as shown in Fig. 6.

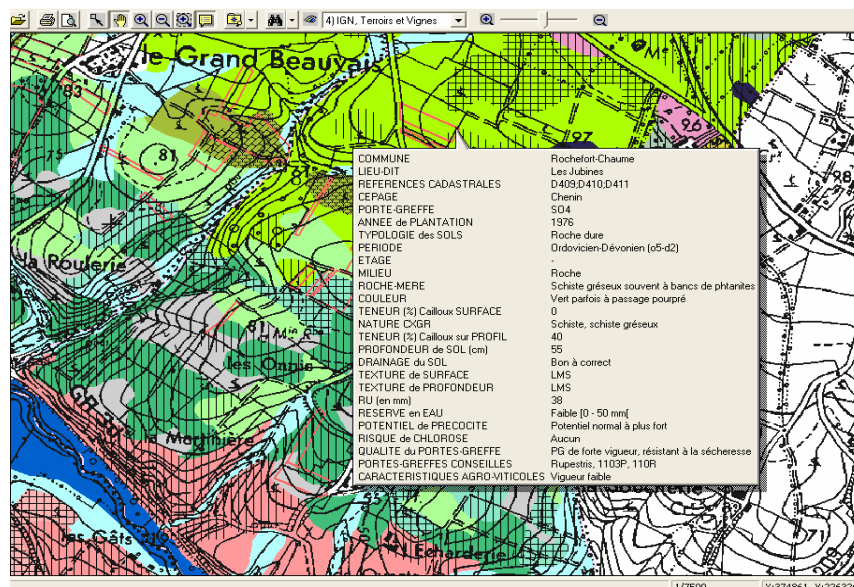


Fig. 6. Digital terroirs map and popup

These tools allow us to transmit knowledge in a sophisticated way and to adapt techniques so as to achieve the sustainable production of quality wines. This digital information may be helpful for controlling wine quality; it is not however intended to be used directly for publicity on the products.

We offer other software that can be used by wine growers to communicate the knowledge derived from the terroir surveys to their customers.

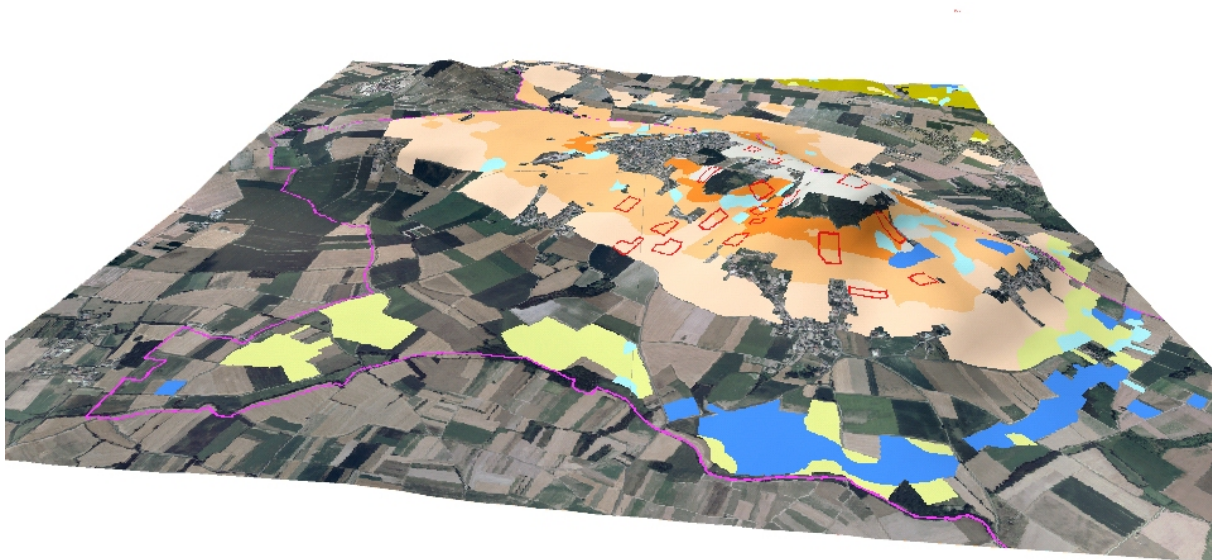
c. Commercial application of the terroir surveys

One of the difficulties wine growers experience with presenting their product at a wine fair or in their own cellar is the preconception that consumers have of their vineyard and their product. If a winegrower can make a good presentation of his domain and demonstrate how he adapts his practices according to the characteristics of his plots, he achieves extra credibility and will be able to present his audience with a concrete idea of the complexity of wine-making. Such a presentation may be enhanced by the use of computer applications such as 3D interactive views or a specific slide show.

It is possible to have interactive 3-dimensional views of a vineyard, produced from a digital terrain model, in order to take an easy and enjoyable tour of an entire wine growing property.

To be able to see these 3D images the user needs a browser plug-in. He can then use extra functionalities and different tracking modes: Walk, Fly or Study. You can move around in the 3D image using commands such as Forward / Back, Right / Left, Up / Down, Rotate / Flip, etc.

With this 3D navigator you can fly over or walk around a particular wine growing parcel and explore the different layers (aerial photographs, BTU, etc.). The software allows you to replay a saved itinerary with one click and project it in 3D onto a screen at a fair or at a wine tasting – this is an animation visitors always enjoy, because they can see what a particular vineyard or a parcel actually looks like (Fig. 7).



orthophotographics data from the French national geographical institute ©IGN-Paris-2005- Authorisation n° 40- 5001

Fig. 7. Interactive 3D animations

For presentation purposes or wine tastings we also offer slides and film clips. These contain information in the form of video or photographs on the environmental characteristics of the parcels where the wines are produced; you can also use them to present the various wine making processes or to explain organoleptic differences between several products. The slides can also be e-mailed to customers, particularly in other countries, to present your domain and your products to agents with a view to future exports.

The maps therefore constitute a permanent technical reference for good practice in adapting wine production to the environment; they also provide a database of scientific knowledge which can be drawn on for marketing purposes using modern communication media.

5) Conservation and management of wine growing land

Apart from the use that an individual wine grower may make of the technical information, it is possible to make collective use of the maps and descriptions of an appellation terroir to manage the natural environment. The CTV maps may therefore usefully serve as the basis for objective discussions around peri urban development and the protection of wine growing territory. They also provide a valuable tool in the joint management and renewal of vineyards in an appellation since it becomes much easier to make objective technical decisions (which sectors to renew, plant selection, etc.).

Acknowledgements: The authors thank Gerard BARBEAU (INRA UEVV, UMT VINITERA) for valuable comments on this manuscript.

References

BODIN, F., MORLAT R. 2006. Characterization of viticultural terroirs using a simple field model based on soil depth. I. Validation of the water supply regime, phenology, and vine vigour, in the Anjou vineyard (France). *Plant and Soil* 281, 37-54.

GOULET E., RIOUX D., BARBEAU G., 2004. Cartographie des terroirs viticoles : Valorisation des résultats par un logiciel de consultation dynamique de cartes. Congrès viticultural Terroir Zoning, Cape Town (Afrique du Sud), 15-19 Novembre 2004.

GOULET E., MORLAT R., RIOUX D., CESBRON S., 2004. Méthode de calcul de la réserve utile en eau des sols : application à la cartographie des terroirs viticoles en Val de Loire. *Journal International des Sciences de la Vigne et du Vin*, 2004, 38, n°4, p 231-235.

GUILBAULT, P., MORLAT, R., and RIOUX, D., 1998. Elaboration de cartes conseil pour une gestion du terroir à l'échelle parcellaire. Utilisation d'algorithmes basés sur des paramètres physiques du milieu naturel. Actes du 2ème Colloque International sur les Terroirs viticoles, Sienna, Italie, 741-751.

MORLAT R. 2001. Terroirs viticoles : Etude et valorisation. Editions Oenoplurimédia, 118p.

MORLAT, R., BODIN, F. 2006. Characterization of viticultural terroirs using a simple field model based on soil depth. II. Validation of the grape yield and berry quality in the Anjou vineyard (France). *Plant and Soil* 281: 55-69.