Topographic modeling with GIS at Serra Gaúcha, Brazil: elements to study viticultural terroir

Modélisation topographique en SIG dans La Serra Gaúcha, Brésil : éléments pour l'étude du terroir viticole

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Abstract: Brazil is historically known at the international wine market as an importer, eventhough in the last decades there was an increase in quantity and quality of the internal production. Nowadays, about 40% of fine wines comsuption of the country are national ones. The main production region is called Serra Gaúcha, where the natural conditions are heterogeneous and viticulture is develloped in small properties, mainly done by the owners family. With the strong competition in internal and external market, there is a need to search distinct products in characteristic and typicality. In this context, the concept of terroir is important to drive an to match the grape variety and the cultural practices to the natural potential of each place. This work aim s to study the topographical components of the terroir at Serra Gaúcha using GIS. The study was based on a digital terrain model derived from 20 topographical map sheets in scale 1:50,000. The topographical variables analized were elevation, slope and aspect. Each variable was scores according to its suitability and integrated later on to generate topographical suitability map. The results show that 66% of the area has medium and 9% has high topographical suitability for grapes growth.

Key words: terroir, topography, GIS

INTRODUCTION

Brazil is historically known at the international wine market as an importer. In the last decades there was an increase in quantity and quality of the internal production, with expansion of the production regions and the development of new poles of production. Nowadays, about 40% of fine wines comsuption of the country are national ones. The State Rio Grande do Sul answers with 95% of the Brazilian production, with an area of about 5,000 ha cultivated with wine grapes.

The main production region is called Serra Gaúcha, located at the NE region of the State. The natural conditions are heterogeneous, with complex relief (elevation, slopes, aspect) and high soils variability. Viticulture at Serra Gaúcha is associated to the italian immigration and done at small properties with an average of 15 ha with 2.5 ha of grapes in steep and moderate slopes, low mechanization and mainly work done by owners family (Protas *et al*., 2004).

Facing a strong competition scenary on internal and external market, a great effort on organization and policies is needed driven to the search of new products, with a differential in characteristic and typicality in order to guarantee long-term profitability and maintenance of the wine activity at the region

The first initiative in this direction was the implementation of the geographic indication Vale dos Vinhedos (Tonietto and Mandelli, 2005). Aiming to offer additional subsidy for development policies of the sector, the Brazilian Institute of Wine (IBRAVIN) signed an agreement with different research institutions to develop a Wine Zoning Project for the State Rio Grande do Sul. The project aims to identify and spatialize the natural potential of climate, soil and relief of different regions of the State, and a zoom at Serra Gaúcha, traditional in wine grapes.

The concept of terroir is important to be used associated to the results of the wine zoning to support the wine sector to use the adequate grapes variety, the right practices, improving quality and typicality of wines and consequently its value.

Terroir is an holistic concept related to environmental and cultural factors which define influence both the quality of grapes and wines. It is known that the grape's quality is the result of the interaction of various factors like climate, site or topographical location, soil and geology, the selected grape and the cultural practices adopted. (Vaudour, 2002; Jones *et al*., 2004). But the discussion on the contribution of each component is far from consensus, since its interrelations are complex (Wilson, 1998 apud Jones *et al*., 2004).

Out of other factors, climate has a determinant effect on the possibility of quality grapes in a defined region. In a local scale, physical aspects of the terroir, especially the topographical factors (spatial location, elevation, slope and aspect) assume determinant importance since they influence the interaction of the climatic elements, affecting Sun light interception, air drainage, temperature and humidity fluctuation, and others.

The characteristic of topographical factors is, therefore, an essential step in the study of the terroir at one side, to evaluate the wine production of a give region at the other, to search for potential expansion regions. Recent technologies like the geographic information systems (GIS) are valuable tools to perform complex analysis, overlay of multiple layers, generating results on a spatial basis, being an important support for decision making (Aronof, 1989).

The present work aims to study the topographical components of the terroir in the Serra Gaúcha region, using GIS to evaluate the relief characteristics and to suggest a topographical suitability map for cultivation of wine grapes.

Material and methods

The State Rio Grande do Sul located between latitudes 27º00'S and 33º45'S and longitudes 57º40'S and 49º35'W, it shares borders with Argentina and Uruguay (figure 1). The Serra Gaúcha region is located in the NE portion of the State, between latitudes 28 30'S and 29 30'S and longitudes 50 45'W e 52 W (figure 1). Based on Bento Gonçalves, located at Serra Gaúcha, the viticultural climate is IH+1 IF-1 IS-2 (humid, warm temperate, temperate nights) (Tonietto et Carbonneau, 1999).

Figure 1 - Location of the State Rio Grande do Sul.

The study area corresponds to a set of 20 topographical map sheets in scale 1:50,000, in UTM Projection, Zone 22. They were generated by the Brazilian Army (*Diretoria de Serviço Geográfico, DSG*) and are the largest scale available as continuous mapping for the whole region. Even being a small scale, there is no study, they represent a material of great relevance since there are no previous studies nor surveys in larger scale on the regional topography

The surface covered by the 20 map sheets (figure 2) corresponds to 1,348,961 ha (13,490 km^2). The area covers 86 municipalities, 44 of them integrally covered and 42 partially (20 of them with more than 50% of its territory and 22 in lower proportion).

For the spatial analysis of the topographical data GIS software Idrisi was used (Clarklabs©).

First step was the organization of a digital cartographic basis in a GIS environment, in order to make analysis information extraction easier. The data were structured based on the vectorization of the map sheets in 1:50,000 available only as paper.

The originals were rasterized with a resolution of 400 dpi, georeferenced and vectorized manually on screen to extract the features corresponding to the layers of interest, especially the ones related to altimetry (contour lines and height points). At the end, the map sheets were concatenated to generate one single digital archive for each of the layers.

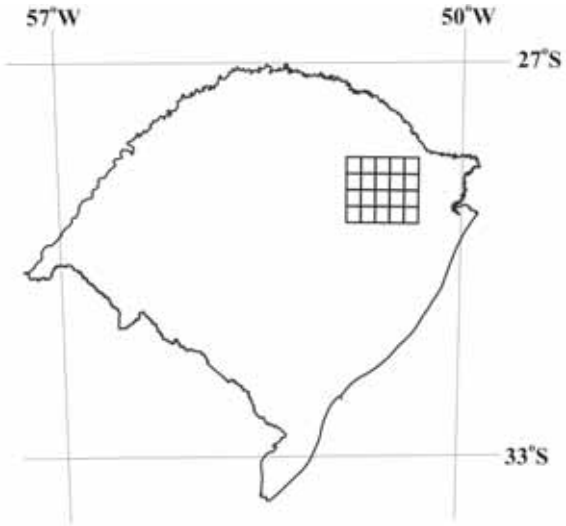

Figure 2 - Location of the 20 map sheets 1:50,000 of the Wine Zoning Project of Rio Grande do Sul.

Based on the structured elements of the altimetry a DTM was generated, using a linear interpolation based on a triangular irregular network (TIN). A parabolic function was used to accommodate the topographic brakes and to remove the bridge and tunnel effects.

The result was a raster file with 30 m resolution in which each cell contains the estimated elevation. Figure 3 shows hill shading and figure 4 a 3D view of the region.

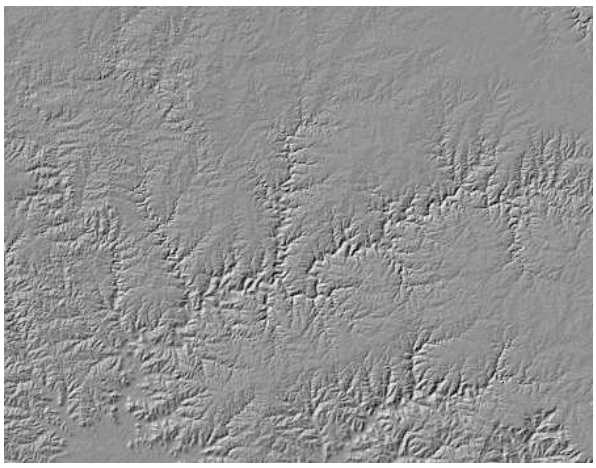

Figure 3 - DTM Hillshading of the 20 map sheets.

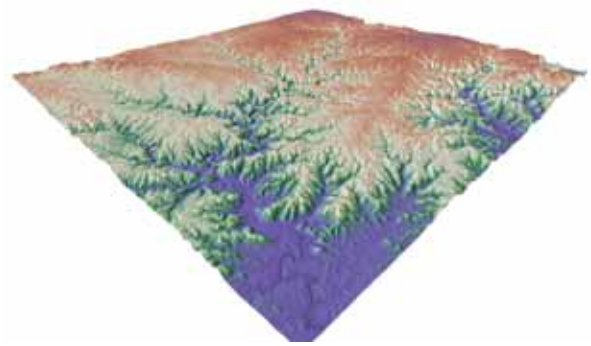

Figure 4 - 3D view of the region (SW to NE)

Based on the DTM, three topographic variables were analyzed: elevation, the DTM itself, slope and aspect (both basic to derive the Sun light interception). The original values of each map were reclassified to generated three new grids containing ranking values corresponding to suitability classes for viticulture (table 1).

Table 1 - Suitability classes and ranking values.

Suitability class	Ranking
Not suitable	0
Low	1
Medium	2
High	3

Tables 2 to 4 show the class intervals used to define the adopted ranking values associated to each of the variables elevation, slope and aspect. The reclassification of the aspect raster was based on a division in eight classes corresponding to the compass main directions (figure 5) plus a 9th one associated to flat areas. Since the region is located at the southern hemisphere, slopes faced N, NE and NW have higher ranking,

followed by slopes facing E and W, of medium ranking. Slopes facing S, SE and SW have lower ranking. Medium ranking was assigned to flat areas.

Table 2 - Ranking values for elevation.

Elevation (m)	Ranking
0 - 100	0
100 - 200	1
200 - 300	2
300 - 600	3
600 - 800	2
800 - 900	1
> 900	0

Table 3 - Ranking values for slope.

Slope (%)	Ranking
< 5	2
5 - 15	3
15 - 30	2
30 - 45	1
> 45	0

Table 4 - Ranking values for aspect.

Aspect (degrees)	Ranking
0º - 22.5º (N)	3
22.5º - 67.5º (NE)	3
67.5º - 112.5º (E)	2
112.5º - 157.5º (SE)	1
157.5º - 202.5º (S)	1
202.5º - 247.5º (SW)	1
247.5º - 292.5º (W)	2
292.5º - 337.5º (NW)	3
337.5º - 360º (N)	3
Flat	2

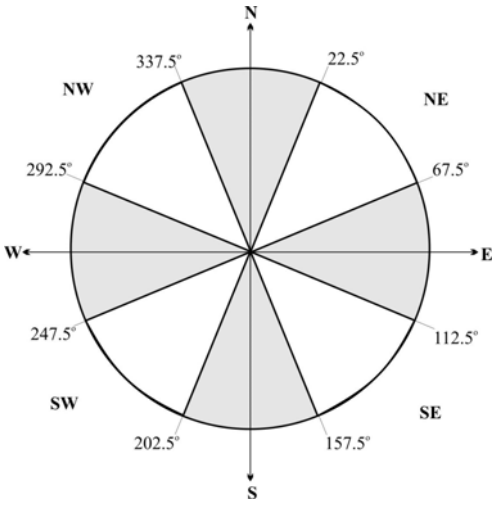

Figure 5 - Octants partition for the aspect grid.

The reclassification intervals used for each of the grid are a proposal to assess topographic suitability based on the natural and cultural characteristics of the region. Since it is a proposal it can be discussed and if necessary changed to better describe the desired landscape. The main objective is that once defined a specific classification for the topographical variables, it can be applied to a whole region using the same criteria.
After the generation of the suitability of each of the three topographical variables, the grids were combined to generate an integrated suitability map that shows potential and limitation of the local topographic conditions aiming a higher quality for viticulture. The overlay method was based on a weighted combination in which the final ranking assigned to each cell is the average of the three variables.

RÉSULTS AND DISCUSSION

Figures 6 to 8 spatialize the ranking classes of each variable, tables 5 and 6 show the absolute and proportional surface related to each suitability class.
Figure 9 illustrates the result of the integration of the variables. Table 7 shows the absolute and proportional surface associated to the topographical suitability for viticulture at Serra Gaúcha. Colors and classes used in figures 7 to 9 adopt same legend shown in figure 6.

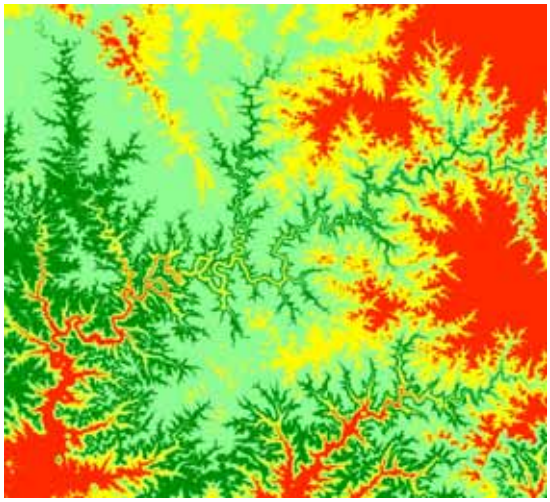

Figure 6 - Suitability based on elevation.

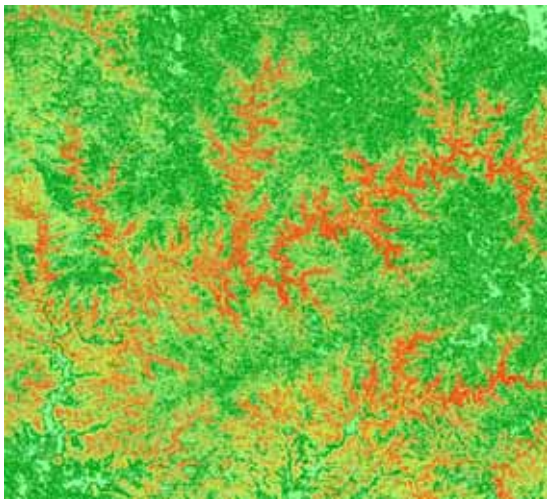

Figure 7 - Suitability based on slope.

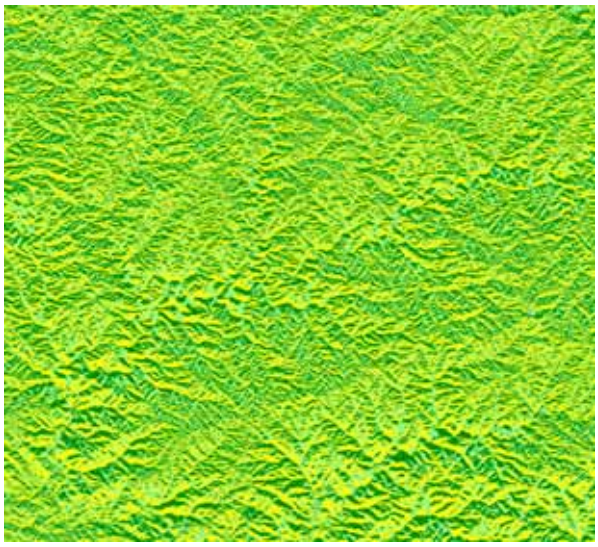

Figure 8 - Suitability based on aspect.

Table 5 - Surface (hectares) related to the suitability of each variable.

Suitability	Elevation	Slope	Aspect
Not suitable	275,388.0	167,922.8	0.0
Low	299,379.6	188,386.6	520,609.8
Medium	539,650.7	519,755.8	328,401.3
High	246,792.1	485,145.3	512,199.4
Total	1,361,210.4	1,361,210.4	1,361,210.4

Table 6 - Surface proportion (%) related to the suitability of each variable.

Suitability	Elevation	Slope	Aspect
Not suitable	20.23	12.34	0.00
Low	21.99	13.84	38.25
Medium	39.64	38.18	24.13
High	18.13	35.64	37.63
Total	100.00	100.00	100.00

Table 7 - Surface related to the final suitability classes.

Suitability	Area (ha)	%
Not suitable	5,713.7	0.42
Low	335,645.4	24.66
Medium	896,797.8	65.88
High	123,053.5	9.04
Total	1,361,210.4	100.00

Suitability based on elevation (figure 6) shows large continuous surfaces, presenting low fragmentation. About 58% of the region has elevation in acceptable intervals (high and medium suitability) for viticulture (tables 5 and 6). Suitability based on slope generates a higher fragmentation of the landscape (figure 7), evidence that areas at the same height may have different steepness. Comparing figures 6 and 7 high suitable areas for elevation may have medium or even low suitability considering slope. About 70% of the region presents high and medium suitability (tables 5 and 6). Only a small portion is considered not suitable.

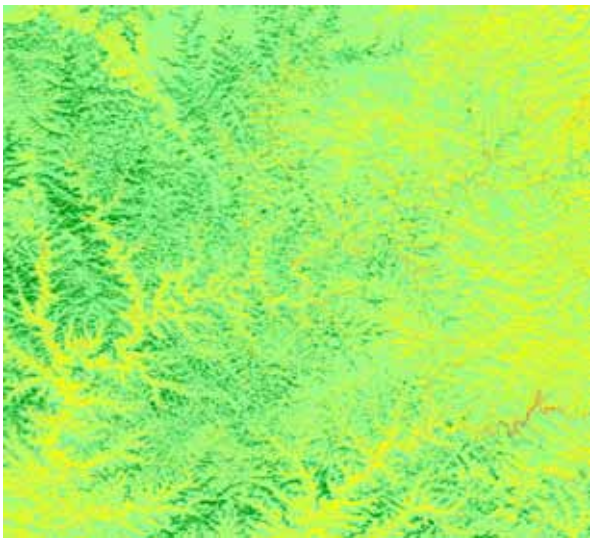

Figure 9 - Final suitability classification, result of the integration of the three topographic variables.

Suitability related to aspect generates even a higher fragmentation than the one observed with slope (figure 8). Even being fragmented, more than 60% of the region presents aspect in acceptable intervals (high and medium) for viticulture (tables 5 and 6).
The final result based on the variables integration allows to identify suitable sites for viticulture, on a topographic point of view as well as to compare different sites based on the same criteria. The method allows also that sites less suitable for one variable can be compensated by a higher score in another variable evaluating the topographic effect as a whole.
Based on the criteria used in this study, most of the Serra Gaúcha region (about 66%) has medium suitability associated to topography. Only about 9% has high suitability (figure 9 and table 7).
These data are an important contribution to the definition of terroir. In addition, topographic information georeferenced and structured in GIS makes new topographic analysis and integration to other information like climate and soil easier.
The results can help to build up policies to improve the value of viticulture at Serra Gaúcha, which involves more than 12,000 families.

Conclusion

The topographic studies are of great importance to understand the viticultural terroir. The results obtained for the Serra Gaúcha region show a potential to improve quality and typicality of wines produced there, contributing also to the definition of geographical indication. The use of GIS may be of help not only to integrate topographic variables but also other criteria related to geographical indication making the analysis and interpretation easier.

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References

ARONOFF S., 1991. *Geographic information systems: a management perspective*. WDL publications. Otawa. 294p.
JONES G., SNEAD N. and NELSON P., 2004. *Geology and wine 8. Modeling Viticultural Landscapes: A GIS Analysis of the Terroir Potential in the Umpqua Valley of Oregon. Geoscience Canada*, 31, 167-178.
PROTAS J.F.S, CAMARGO U.A. and MELLO L.M.R., 2004. *A vitivinicultura brasileira: realidade e perspectivas. Embrapa Uva e Vinho* (http://www.embrapa.cnpuv.embrapa.br/publica/artigos/vitivinicultura/).
TONIETTO J. and CARBONNEAU A., 1999. Análise mundial do clima das regiões vitícolas e de sua influência sobre a tipicidade dos vinhos: a posição da viticultura brasileira comparada a 100 regiões em 30 países. *In: 9th Congresso Brasileiro de viticultura e enologia*, Bento Gonçalves. Embrapa Uva e Vinho, Bento Gonçalves, p.75-90.

TONIETTO J. and MANDELLI F., 2005. Como organizar, promover y reconocer regiones de excelencia de producción de vinos: Una experiencia de Brasil en Indicadores Geográficos. *In: 2nd Seminario Internacional de Vitivinicultura*. Ensenada, Mexico. Inifap, Mexico, P. 7-19.

VAUDOUR E., 2002. The quality of grapes and wine in relation to geography: Notions of terroir at various scales. *Journal of Wine Research*, 13, 2, p. 117-141.

WILSON, J.E., 1998. *Terroir: the Role of Geology, Climate, and Culture in the Making of French Wines*: Mitchell Beazley, London, UK, 336 p.