IDENTIFICATION OF NATURAL TERROIR UNITS FOR VITICULTURE: STELLENBOSCH, SOUTH AFRICA

IDENTIFICATION DES UNITÉS DE TERROIRS NATURELS POUR LA VITICULTURE: STELLENBOSCH, AFRIQUE DU SUD

VA CAREY[1, 2]; E ARCHER[2] & D SAAYMAN[3].

[1] ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa.

[2] Department of Viticulture and Oenology, Stellenbosch University, Private Bag X1, 7602 Matieland, South Africa.

[3] Distell, P.O. Box 184, 7599 Stellenbosch, South Africa.

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ABSTRACT

A natural terroir unit (NTU) can be defined as a unit of land that is characterised by relatively homogenous topography, climate, geological substrate and soil. Such units are invaluable for better understanding of the terroir/vine/wine system. The aim of this study was to characterise the Bottelaryberg-Simonsberg-Helderberg wine growing area using existing digital information and to identify NTU using a Geographic Information System.

The study area was situated to the south west of Stellenbosch and covered an area of approximately 25 000 ha. It is bordered by mountains, situated close to the Atlantic Ocean and bisected by a river valley resulting in notable spatial variation of all climatic parameters. The geology is complex due to the high degree of tectonic movement and mixing of parent material. Despite a high degree of soil variation that is difficult to represent in soil associations, a pattern of soil distribution could be noticed in relation to landscape position.

Terrain morphological units, altitude and aspect were used as primary keys for the identification of NTU. Broad soil categories and geological attributes for residual soils were included at a secondary level resulting in 203 units. These units must be characterised with respect to the extent to which proximity to the sea has an influence on climatic characteristics as well as the associated viticultural and oenological potential.

RESUME

Une unité de terroir naturel (UTN) peut être définie comme une unité de terre qui est caractérisée par une relative homogénéité topographique, climatique, géologique et pédologique. De telles unités sont de grande valeur pour mieux comprendre le système terroir/vigne/vin. Le but de cette étude est de caractériser la région viticole du Bottelaryberg.-Simonsberg-Helderberg en utilisant une information digitale existante et d'identifier des UTN en utilisant un Système d'Information Géographique.

Cette région d'étude est située au sud-ouest de Stellenbosch et couvre approximativement 25 000 ha. Elle est située près de l'Océan Atlantique, bordée par des montagnes et découpée par une vallée produisant une variation spatiale notable de tous les paramètres climatiques. La géologie est complexe en raison de nombreux mouvements tectoniques et mélange de la roche-mère. Malgré un fort degré de variation du sol qui est difficile à représenter dans les associations pédologiques, un schéma de la distribution des sols a pu être noté en relation avec la position du paysage.

Les unités morphologiques de terrain, l'altitude et l'exposition ont été utilisées comme premières clés pour l'identification des UTN. De larges catégories de sols et attributs géologiques pour les sols résiduels ont été inclus à un niveau secondaire aboutissant à 203 unités. Ces unités doivent aussi être caractérisées en fonction de l'étendue à laquelle la proximité de la mer a une influence sur les caractères climatiques ainsi que du potentiel vitivinicole qui leur est associées.

INTRODUCTION

Natural terroir units have been defined by LAVILLE (1993) as being a volume of the earth's biosphere that is characterised by a stable group of values relating to the topography, climate, substrate and soil. The grouping of such units in relation to the characteristics of the product obtained constitutes a terroir i.e. the terroir cannot be defined in isolation from its product. Because the concept of the terroir relies on the intrinsic agronomic potential of the environment and is thus inseparable from the characteristics and "identity" of the final agricultural product, all studies to delimit terroirs will include two stages; firstly the mapping of pertinent environmental features in order to obtain relatively homogenous environmental units and secondly a study of the reaction of the crop to these delimited units. This paper describes the first step of such a study in the Bottelaryberg-Simonsberg-Helderberg wine producing area in South Africa, the aims of which were to characterise the study area using existing digital environmental data and to identify natural terroir units using a geographic information system.

The Bottelaryberg-Simonsberg-Helderberg wine growing area is characterised by a combination of plains with straight slopes and low relief, undulating plains with moderate relief and free standing and undulating hills with high relief (Schultz, 1997) resulting in a complex landscape. Topography is a static feature of the landscape and is described by altitude as well as the rate of change of altitude over distance (Schultz, 1997) and has thus components of slope form, slope inclination, slope aspect, altitude and relief. Topography of a region is determined to a large extent by the geological formations present, with their inherent resistance to weathering shaping the landscape (WOOLRIDGE, 2001). Topography also determines the local climate either directly as a result of the change in the incidence of the sun's rays on the earth's surface or indirectly as a result of altered soil drainage patterns, exposure to wind and ventilation (Crowe, 1971). Climate is one of the dominant soil forming factors (de BLIJ, 1983) and is inseparable from pedogenetic studies as climate and climate-dependant organisms are some of the most important factors affecting the formation of soil. Soil distribution can therefore often be related to landscape positions. This is represented in the concept of a "catena", "a sequence of soils of similar age, derived from similar parent material, and occurring under similar macroclimatic conditions, but having different characteristics due to variation in relief and drainage" (Soil Classification Working Group, 1991). Variation in drainage characteristics of the landscape can be defined with the aid of terrain morphology with each terrain morphological unit (crest, scarp, midslope, footslope, valley bottom) having associated slope inclinations and slope shape (KRUGER, 1973).

Viticultural management practices are not standard between vineyards but are usually adapted by the producer to best suite their conditions. Management practices of particular significance are deep soil preparation, supplementary irrigation, drainage and possibly ridging and liming during soil preparation, weed management, numerous methods of training and trellising vines and summer canopy management practices (Carey, 2001). The high degree of topographic variation in the Bottelaryberg-Simonsberg-Helderberg wine growing area, however, provides many diverse environments for viticulture. Better understanding of the associated natural terroir units is necessary in order to better understand the terroir/vine/wine system, leading to optimal choice of cultivar and technology (in vineyard and cellar) in order to produce outstanding and unique wines and improve sustainability of viticultural practices.

MATERIALS AND METHODS

The study area of approximately 25 000 ha falls within the Stellenbosch wine producing district, to the west and south west of the town of Stellenbosch and includes the footslopes of the Simonsberg, midslopes and footslopes of Stellenboschberg and Helderberg, the Eerste river valley and the Bottelaryberg hills (Fig. 1). A network of automatic weather stations has been established in the Bottelaryberg-Simonsberg-Helderberg study area since 1994 (Fig. 1). These weather stations are either situated in the vineyard row (in the case of T04, T05 and T06) or on open ground, representing various landscape positions. The parameters of temperature, dry and wet bulb temperature, rainfall, radiation, sun duration, wind speed and wind direction are recorded every 6 min. These values are averaged or summed, depending on whether or not the parameter is cumulative in nature, for the period of an hour. The temperature sensors are housed in a Stevenson screen 1.2 m above ground level.

Digital topographic data were obtained by manipulating a 50 m digital elevation model. A map of terrain morphological units was compiled with the aid of Spatial Analyst in ArcView® based on the theoretical movement of water and slope inclination to determine crests and valley bottoms and distance between crest and valley bottom to distinguish between midslope and footslope (compiled by M. Wallace, Department of Agriculture: Western Cape, 2000). These terrain morphological units formed the basis for the identification of natural terroir units in the Bottelaryberg-Simonsberg-Helderberg study area. They were divided with the aid of altitude (100 m intervals) and aspect classes. The aspect categories were selected in order to represent the slope interception of sunlight and dominant winds and were divided into east (45° to 135°), south west (135° to 270°) and north west (270° to 45°, passing through 0°).

Available digital soil data (ELLIS & SCHLOMS, 1975, ELLIS *et al.*, 1976) was classified into four broad soil groups and used to refine the determined slope-aspect-altitude units. These soil categories were based on the water holding and drainage characteristics as well as characteristics affecting root growth (CAREY, 2001). The data layers for terrain morphological units, aspect, altitude (increments of 100 m) and simplified soil map were overlaid and intersected.

It is particularly difficult to associate geology with derived soils in the Stellenbosch wine growing area due to the high degree of tectonic movement and mixing of parent material (Van SCHOOR, 2001) and as such the only soil group for which the geology of the parent material was considered to be of obvious importance was that of residual soils. Available digital geological data (THERON, 1990) was overlaid on the identified soil-landscape units and each of the units was characterised according to the associated dominant geological formation using five broad groups (Carey, 2001).

All land unsuitable for viticulture was grouped, regardless of landscape position, aspect or altitude, i.e. valley bottoms, poorly drained alluvial soils, rocky outcrops and urban areas and removed from the determination of natural terroir units.

For the analysis of climatic data, automatic weather stations were used as plots and years were used as replicates for a single factor ANOVA for each climatic variable. Student's t test for lowest significant difference was used to compare the means for each variable at the automatic weather stations.

RESULTS AND DISCUSSION

No scarps were identified in the study area, which consisted predominately of midslopes (44.7%) and footslopes (42%) (Fig. 2a). Approximately 90% of the study area is situated between 0 m and 300 m above sea level. Soils in the study area could be classified into four main groups. **Residual soils (A)** have parent material in various stages of weathering (lithocutanic or saprolite horizons) and a leached E-horizon as a limit to root growth. Weathered granite **(GR)** has a high percentage of quarts particles, resulting in a higher proportion of sand and/or grit together with the clay, while weathered shale **(SH)** generally has a higher clay content. Weathered sandstone **(QS)** is sandy in texture and is poor in mineral elements. Ferricrete **(F)** and the alternating conglomerate and grit layers of the Franschoek formation **(CG)** result in high levels of gravel. The potential of the soil for viticulture will depend on the nature of the decayed parent material with shales being considered excellent for quality (D. SAAYMAN, Distillers, 2000. Personal communication). **Red and yellow neocutanic and apedal soils (B)** can have limits to root growth due to a high bulk density in the subsoil and/or a low pH. They have excellent drainage as well as generally good water retention properties. **Duplex soils (D)** have a relatively sandy topsoil above a subsoil with a markedly higher clay content. The change in texture results in a limit to root growth and often in a perched water table resulting in an E-horizon. These soils have excellent drainage in the topsoil and good soil water retention in the subsoil, a combination resulting in restricted but sustained growing conditions. **Sandy soils (S)** have limits to root growth of stratification, if present, and low levels of organic material and nutrients. These soils have a low water retention capability and require irrigation. The distribution of these soil types was very closely linked to height above sea level (Table 1). Duplex soils were found mostly below 200 m. Between 100 m and 200 m, the position on the landscape unit is shared with red and yellow apedal (and neocutanic) soils. Between 200 m and 300 m, red and yellow apedal (and neocutanic) soils dominate while above 300 m residual soils are dominant. This concurs with the observations of SAAYMAN (1981) that vineyards in this coastal area are found predominately between 60 m and 300 m above sea level, on granite foothills and protuberances associated with the mountains of the Table Mountain sandstone group with mainly duplex and apedal and neocutanic red and yellow, intensively weathered granite soils.

Climatic variables differed significantly between automatic weather stations (Table 2) as a result of topographic differences, proximity to the ocean and soil effects. The east facing slopes warm earlier in the morning and cool earlier in the afternoon, while the south western slopes are cooler due to interception of the sea breeze in the early afternoon and reduced interception of sunlight. The north western slopes are the warmest due to being protected to a certain extent from the moderating influence of the sea and receiving the most direct radiation in the Southern Hemisphere. Man-made masking features such as windbreaks and walls (T14) and exposed reflective rock surfaces (T12) can, however, result in temperatures being warmer than expected.

These results emphasized the validity of using topography as a starting point for delimitation of natural terroir units in the Bottelaryberg-Simonsberg-Helderberg study area. A total of 203 units were identified, each described by a four-component key (e.g. 1SW3B). The first number represents the terrain morphological units (e.g. 1 = crest), the following letter(s) represent(s) the slope aspect (e.g. SW = south west), followed by a number representing the altitude category (e.g. 3 = 200 - 300 m) and finally letters representing the soil group (e.g. B = red and yellow apedal and neocutanic soils) and, in the case of residual soils, the associated geology.

The number of natural terroir units delimited in the Bottelaryberg-Simonsberg-Helderberg study area is approximately 8 per 1000 ha. If soil depth and degree of drainage are included, the total number of natural terroir units increases to approximately 12 per 1000 ha of study area. However, in view of the scale of the data (1:50 000 soil map and 50 m DEM), and the general practices of deep soil preparation and supplementary irrigation in the region, the broad soil categories should be sufficient for a medium scale identification of natural terroir units. More detailed studies would be needed per production unit (estate or cooperative) at a later stage but would be performed at the level of private consultants.

In order to evaluate the grouping, the actual positions of the weather stations in the landscape were compared to the determined natural terroir units. Only T14 appeared to be misrepresented by the delimited natural terroir units with the actual slope of the site being too flat to represent a midslope position.

CONCLUSION

The Bottelaryberg-Simonsberg-Helderberg study area is complex with many factors affecting the mesoclimate and root environment, compounded by management practices that affect the vigour and microclimate of the vine. This should result in diverse wines of different characters, each representative of their own unique environment. Characterisation of the study area by means of existing digital data and data gathered by automatic agroclimatic weather stations emphasized the important role that the diverse topography plays in this region. It is important to remember the scale of the original data and not to apply the results at a level more detailed than the said data. In this case, the natural terroir units can only be applied at a medium scale and for general, regional planning purposes.

Temperature in the study area is not only affected by sunlight interception and radiation from the soil, but also by the occurrence and efficacy of the sea breeze. The Regional Atmospheric Modelling System is a powerful tool for modelling the movement of sea breeze as well as the occurrence and interplay of slope and land breezes. Further numerical simulations of the sea breeze on a detailed grid (=200 m) must be performed for various synoptic situations during the ripening period in order to determine the spatial limit of the effectiveness of the sea breeze. This “front” would form an important basis for further division of the study area as well as being a tool for extrapolation of temperature and relative humidity data from the automatic weather station network within the Bottelaryberg-Simonsberg-Helderberg study area.

The use of terroirs to understand and manage vineyards requires diverse information, which this topographically based method organises into homogenous units. Such a study can be performed at various scales, depending on the end use of the product, to identify natural terroir units. It is an invaluable decision-making tool from farm to regional level.

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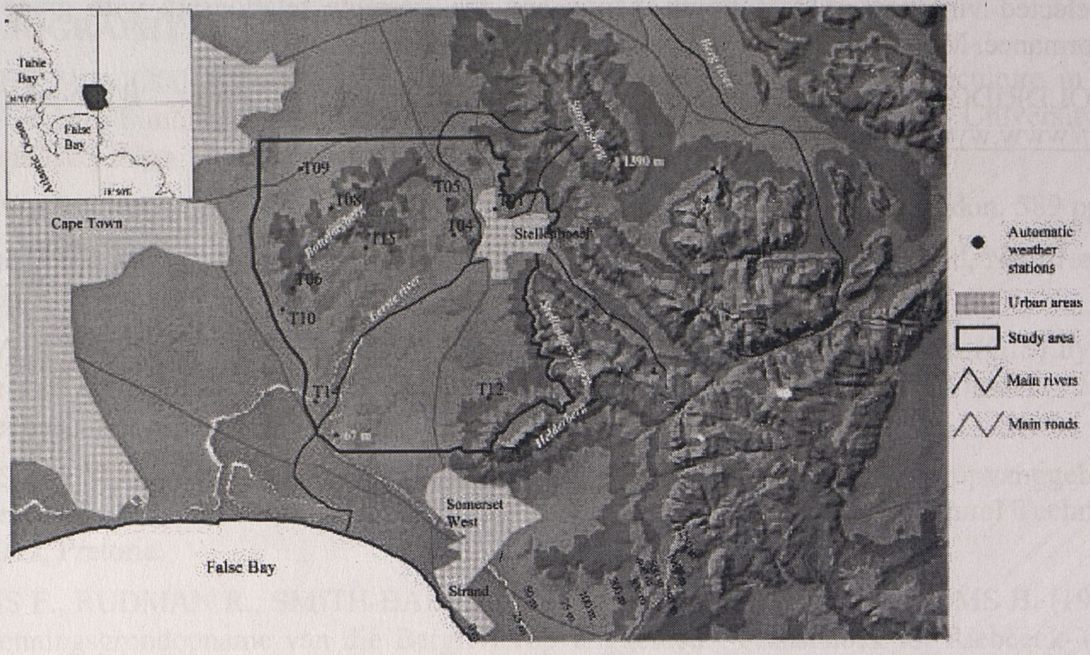

Figure 1. Position of the Bottelaryberg-Simonsberg-Helderberg study area in relation to the coastline and other geographic features. Insert shows position of study area in relation to False Bay and Table Bay.

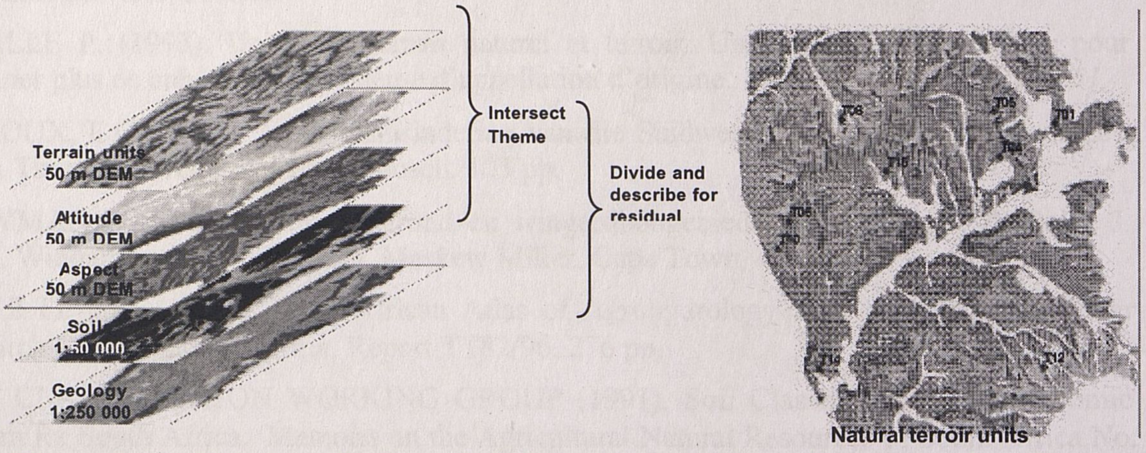

Figure 2. Manipulation of a 50 m digital elevation model provided maps of terrain morphological units, slope aspect and altitude categories for the Bottelaryberg-Simonsberg-Helderberg study area. Intersection of these data layers with the digital soil data and further description by overlaying these units with the digital geological data resulted in a map of natural terroir units

Table 1. Distribution of broad soil groups according to altitude in the Bottelaryberg-Simonsberg-Helderberg study area (Values are given as percentages of soils suitable for viticulture in that particular altitude category).

	0 m-100 m	100m-200 m	200 m-300 m	300 m-400 m	400 m-550 m
A_GR	1.4	3.6	11.6	40.7	23.5
A_SH	0.5	0.8	3.1	14.4	26.2
A_QS	0	0.2	1.2	1.1	24.4
A_F	0.2	0.1	0	0	0
A_CG	0	0	0	0	0
B	11.2	37.3	75.3	41.9	20.9
D	84.6	55.3	8.5	0	0
S	2.1	2.7	0.3	2.0	4.9

A represents residual soils with the following origins: GR being granites of various plutons as well as weathered products of granite, SH being greywacke and weathered material formed on Malmesbury rocks, QS being Cenozoic deposits of sedimentary rocks and sand, F being loose nodules or zones cemented with iron and CG being the Franschoek formation consisting of conglomerate and grit horizons. B represents red and yellow apedal and neocutanic soils. D represents duplex soils. S represents sandy soils.

Table 2. Mean values for some climatic parameters and indices for the period 08/1995-03/2001 for the automatic weather station (AWS) network in the Bottelaryberg-Simonsberg-Helderberg study area.

AWS	GDD(1) (Sep-Mar) (°C)	MFT(2) (°C)	Max temp. (Feb) (°C)	IH(3) (Oct-Mar) (°C)	IS(4) (Oct-Mar) (mm)	TVI[6] (Jan) (°C)	TVI(5) (Feb) (°C)	TVI[6] (Mar) (°C)	Rainfall (Apr-Aug) (mm)	Rainfall (Dec-Feb) (mm)	RH(6) (15:00) (Feb) (%)	Wind(7) S/SW/W (Feb) (%)	Wind(8) >4m.s^{-1} (Dec-Mar) (hrs)	Mean max. wind speed (Feb) (m.s^{-1})
T01	1884	22.0	28.3	2313	-224	39.8	37.7	37.1	437	56	46.6	65.8	833	5.5
T04	1946	22.2	29.8	2416	-201	42.8	41.4	40.5	465	57	53.2	54.0	60	3.1
T05	1858	21.8	29	2322	-191	40.7	39.0	38.2	366	54	56.6	44.1	364	4.3
T06	1750	21.0	27.5	2159	-152	36.7	34.5	32.1	462	65	55.1	60.7	358	4.2
T08	1791	21.3	27.3	2156	-152	34.4	33.9	32.7	413	60	55.0	60.9	1152	6.5
T10	1754	21.0	27.1	2153	-201	38.3	35.0	34.0	336	52	55.1	59.8	824	5.4
T12	1988	22.6	29.4	2404	-161	37.7	36.6	34.5	459	80	55.5	56.7	241	3.9
T14	1972	22.2	28.3	2348	-208	38.4	37.0	37.6	332	56	55.5	57.2	335	4.5
T15	1952	22.1	28.4	2322	-205	37.6	37.6	34.1	547	63	54.5	56.0	601	5.0
AVG	1877	21.8	28.3	2288	-188	38.5	38.5	35.7	424	60	54.1	57.2	531	4.7
?	0.0001	0.0001.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001.	0.0001.	0.001	0.0001	0.0001
LSD	56	0.3	0.4	63	-25	1.6	1.2	0.9	65	14	4.8	9.4	72	0.2

(1) GDD=Summation of temperatures above 10°C for the Sep-March (Le Roux, 1974).

(2) Mean February temperature (De Villiers, 1996).

(3) Heliothermic index (Huglin, 1986).

(4) Aridity Index (Riou *et al,* as reported in Tonietto, 1999).

(5) Temperature variability index (Gladstones, 1992). Mean for period 1995 to 2000.

(6) Average percentage relative humidity at 15:00.

(7) Percentage of wind occurring from the south, south west and west during February.

(8) Number of hours with a wind speed greater than 4m.s^{-1} for the period December to March.