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The vineyard of Camel Valley (above) and (left) Chilford Hall.

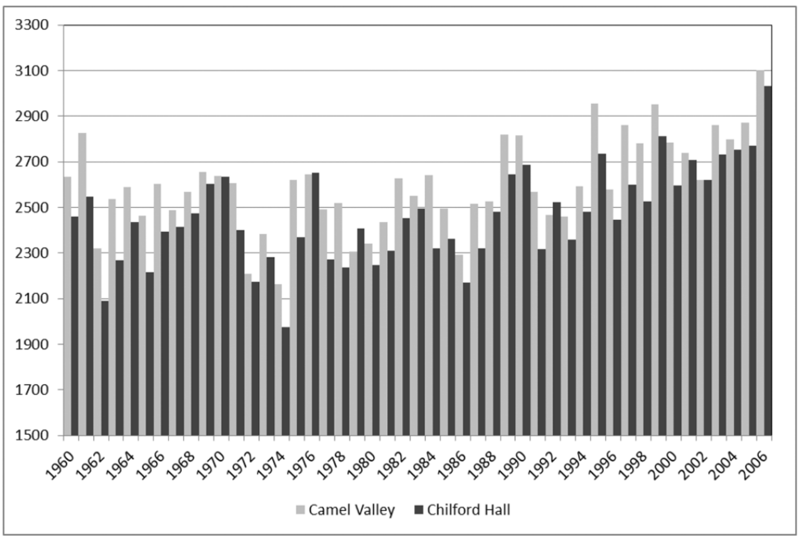
THE AVAILABILITY OF LOW-COST microprocessor technology and GIS software have made the acquisition and processing of spatial data more affordable and practical for the small-scale vineyard.

Grape Expectations: 'Terroir' explained

– collecting, characterising and analysing spatio-temporal data in a small vineyard

Continuing on from his first article in June issue in which he explained how GIS guided by satellite navigation is helping vineyard owners, **David Green** now explains how the processing of spatial data in to information can provide new insight into where different grape varieties will grow most successfully.

Publicly accessible meteorological and climatological data can be processed relatively easily and combined with data collected in the vineyard. Climate analysis is enhanced using basic agroclimatological indices (e.g. Sum of Active Temperature, Growing Degree Days) from the closest weather stations to recommend vine varieties for different sites. Discrete measurements, such as soil samples (pH and moisture), and continuous 'surfaces' such as terrain models (DTMs) with their derivative slope, aspect, and curvature surfaces can then provide Topographic Position & Wetness Indices (TPI & TWI), as well as measures of potential irradiation. Further analyses of attributes can then classify different types of Terroir using aspatial cluster analysis, and indicator Kriging with sample points.



Sum of Active Temperatures (SAT) in the period 1960-2006

Cambs v Cornwall As an example, calculations based on gridded data acquired from the UK Climate Projections programme (UKCIP09) were made for two vineyard sites – Chilford Hall in Cambridgeshire, and Camel Valley in Cornwall.

Temperature statistics for the growing season (April-October)

Table 1 shows the mean temperature for the growing season in both vineyards, which limits the choice of vine varieties (see Amerine & Winkler 1944). Comparison with the grape varieties grown at Chilford Hall and Camel Valley shows them to be suited to cooler climates.

The Latitude-Temperature Index (LTI)

The Latitude Temperature Index (LTI) is often used to determine areas suitable for viticulture and to compare regions located at different latitudes. It is based on the latitude and mean temperature of the warmest month (TWM) and is a proxy indicator of the amount of solar energy that areas are likely to receive during the growing season. For the study sites, the mean temperature for July, usually the warmest month, has been used for the calculation of the LTI (Table 2):

$$LTI = T_{WM} * (60\text{–latitude})$$

Four climatic zones can be distinguished for grape cultivation. The two study vineyards fall into zone A with an LTI of less than 190.

Sum of Active Temperatures (SAT)

SAT is calculated as:

$$SAT = \sum_{1.04}^{31.10} \frac{T_{max} + T_{min}}{2} \quad \text{for} \quad \frac{T_{max} + T_{min}}{2} \geq 10°C$$

and is the sum of mean daily temperatures equal to or higher than 10°C for the period 1st Apr – 31st Oct. SAT is considered to be one of the most important thermal parameters in agroclimatology in general, as well as in viticulture. It should be equal to or higher than 2500°C for a vineyard. Each grape variety has its own minimum average SAT value required during the growing season. Chilford Hall falls into the early ripening category and the Camel Valley into the moderately early ripening category (Table 3).

Vineyard	Average	Max	Min
Chilford Hall	13.1	15.1	11.8
Camel Valley	13.4	15.1	12.2

Table 1. Mean temperature of vegetation season in the period 1960-2006

Vineyard	Average	Max	Min
Chilford Hall	130.3	162.4	130.3
Camel Valley	155.3	184.7	138.3

Table 2 Latitude-Temperature Index (LTI) in the period 1960-2006

Vineyard	Average	Max	Min
Chilford Hall	2464.1	3033.1	1974.8
Camel Valley	2602.6	3101.7	2165.2

Table 3. Sum of Active Temperatures (SAT) in the period 1960-2006

Vineyard	Average	Max	Min
Chilford Hall	784.7	1143.1	534.8
Camel Valley	797.3	1111.7	530.3

Table 4. Growing Degree Days s (GDD) in the period 1960-2006

Growing Degree-Days (GDD)

GDD is defined by:

$$GDD = \sum_{1.04}^{31.10} \frac{T_{max} + T_{min}}{2} - 10°C$$

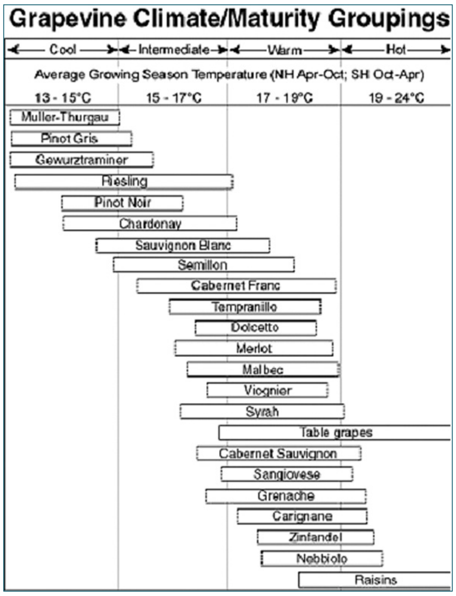
is the summation of daily temperatures in the growing season (using a 10°C base) to predict the vine's ability to produce a high quality crop in the northern hemisphere. Suitability models measure

Varieties	SAT
very early ripening	2000-2200
early ripening	2200-2500
moderately early ripening	2500-2700
late ripening	2700-2900
very late ripening	>2900

***Left:** Average Sum of Active Temperatures (SAT) [°C] and ripening ability of groups of varieties (Szymanowski et al., 2007).*

Group	LTI	Varieties
A	< 190	Bacchus, Chardonnay, Pinot Blanc, Pinot Gris, Perle, Riesling and others
B	190-270	Pinot Noir and Riesling
C	270-380	Cabernet Sauvignon, Cabernet Franc, Malbec, Merlot, Sauvignon Blanc and Semillon
D	>380	Carignan, Cinsaut, Grenache, Shiraz, Zinfandel

***Above:** Suggested groups of Vitis vinifera varieties according to Latitude-Temperature Index (LTI) and ripening ability in different climates* (adapted from Gustafsson and Martensson, 2005).



***Right:** Mean temperature of vegetation season (April-October)* (Jones, 2006).
Length of rectangle indicates the estimated span of ripening for that varietal.

Region	GDD [°F] [°C]	Suggested varieties	Type	Similar region to:
I	= 2500=1371	Early ripening varieties to achieve high quality	Very Cool	the coolest European districts such as Champagne in France and the Rhine in Germany
II	2501-30001372-1648	Early and mid-season table wine varieties	Cool	Bordeaux in France
III	3001-35001649-1927	High yield of standard to good quality wines	Warm	the Rhone in France or Tuscany in Italy
IV	3501-40001928-2204	High yield, but wine quality is only acceptable	Hot	the San Joaquin Valley
V	= 4000= 2204	High production of late season wine and table varieties for bulk production	Very Hot	only table grapes are usually grown commercially in this region

Above: Grape growing regions based on Growing Degree Days (Amerine and Winkler, 1944).

heat unit accumulation to ensure sufficient vine ripening. On this basis viticultural areas are divided into five regions based on the GDD value. Using this classification, both vineyards would be classified into the very cool grape growing regions. Notably, whilst cool climate growing regions like the German Rhine area have a GDD equal to 944 considered the lowest cumulative degree-day acceptable for commercial wine grapes, both UK vineyards fall well below this value and yet successfully produce high quality crops (Table 4).

Cluster Analysis Another example shows the use of Terrain and Surface Model derivatives combined with field soil measurements such as pH and moisture to account for local microclimatic conditions observed in the vineyard. The derivatives include:

- **Aspect**
- **Curvature**
- **Altitude above channel network**
- **Topographic position index (TPI)**
- **Topographic Wetness Index (TWI)**
- **Sums of potential global solar irradiation in the vegetation period (Apr-Oct) [Wh^{2}m^{-1}]**
- **Duration of incoming potential direct solar radiation [h]**
- **Slope**

Derivative	Cluster 1 - n=72 (AVG)	Cluster 2 - n=16 (AVG)	Cluster 3 - n=7 (AVG)
pH	8.8	9	9
Soil moisture	6.4	7.2	5.5
Altitude above channel	1.3	0.6	0.7
Curvature	0.1	0	-0.1
DTM	67.8	65.5	66.7
Duration of radiation DSM	2586.9	1693.2	874.5
Duration of radiation DTM	2907.6	2896.3	2894.3
Global radiation DSM	799175.1	620081.8	281606.1
Global radiation DTM	828112.4	822776	829406.3
TPI	0.1	0	0
TWI	6.9	7	6.9
Slope	3.1	3.7	3.5

Table 5 - Averages of the variables a-h

Heights and derivative values were assigned to soil moisture data collected in the summer of 2011 for the two study sites. A K-function cluster analysis was performed to divide the entire dataset into three groups of points. Averages of the variables are shown in Table 5.

Indicator Kriging was used to determine the probability of occurrence of each cluster type in each part of vineyard. A local raster function was used to determine sub-regions of vineyard.

For Chilford Hall, the results of these analyses reveal that the vineyards are too small and not subject to considerable variation or significant differences in conditions; and that most diversifying factors are deemed to be of radiation origin e.g. differences of incoming solar energy and duration of insolation caused by the lines of trees planted around the vineyard.

Conclusions These case studies demonstrate that multiple sources of spatial information can provide new insight into where different grape varieties will grow successfully. However, a single piece of information is not sufficient and the location and success of a vineyard is clearly dependent upon many factors. Whether or not we have explained 'terroir' we will leave the reader to judge!

Editor: Perhaps c'est magnifique, mais ce n'est pas la vintage.

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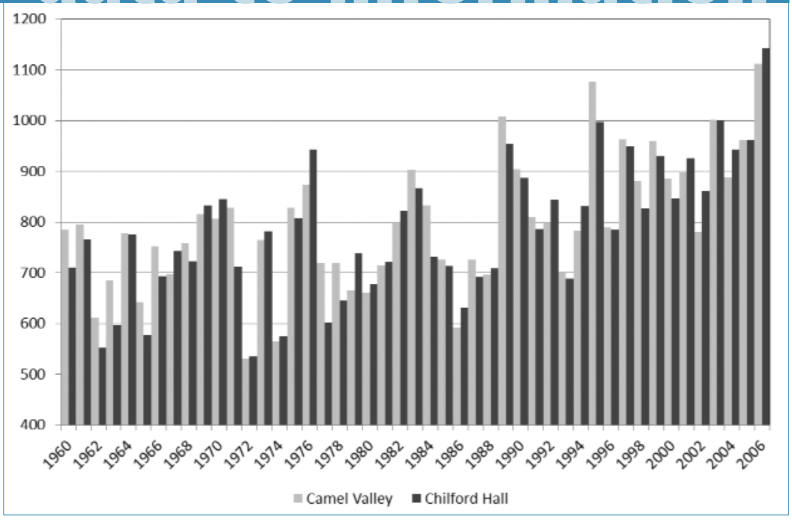
About the author:
David R. Green of University of Aberdeen, Scotland, UK has been working with Chilford Hall Vineyard, Cambridgeshire and the Camel Valley Vineyard, in Cornwall to explore the potential role of Precision Viticulture in UK vineyards.



Class	GDD	Suitability
1	> 1389	Most suitable
2	1165-1389	Good suitability
3	945-1164	Fair suitability
4	< 945	Questionable suitability

Above Top: *Growing Degree Days s (GDD) in the period 1960-2006.*
Above Bottom: *Growing Degree-Days' suitability classes for cool climate growing regions (after Szymanowski et al., 2007)*