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ASPECTS REGARDING THE USE OF GIS FOR QUANTIFYING CLIMATIC FACTORS INFLUENCING VINEYARDS SUITABILITY

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Abstract : Our study presents some possibilities of quantifying climatic factors influencing vineyards suitability at fine scale. Because of the insufficient meteorological stations data, statistical models generally fail at local scale, being unable to take into account local terrain characteristics. This is especially the case of air temperature, for which we applied a correction based on global radiation, in order to take into account terrain slope and aspect. We further analysed the possibilities to derive spatial distributions for global radiation, sunshine duration, using SAGA-GIS software, mean annual precipitations, using a regression-kriging approach and more complex temperature parameters, such as the sum of daily temperatures above 10°C.

Keywords: *climatic factors, vineyards, GIS*

Introduction

The purpose of our study is to investigate the possibilities of modelling, at fine scale, the spatial distribution of climate variables influencing terrain suitability for vineyards. Working at fine scales (1:5000 or higher) triggers some problems related to the quality of the input data (DEM, climate data), the methods to be used etc. Regarding the latter aspect, we may generally recognize that statistical methods are not very suitable at fine scales because of the insufficient data. An alternative approach could be the use of some empirical methods or a combination of statistical and empirical methods which, on the other hand, are difficult to validate.

Study region and input data

The study area is represented by the region surrounding Huşi town, with a surface of about 76km^2 of which 21.4km^2 are covered by vineyards (fig. 1).

For this region, we explored the possibilities of computing spatial models for the following climatic parameters:

- Potential (clear-skies) and real (corrected according to sunshine fraction) *global radiation*;
- Astronomical (potential) and real *sunshine duration*;

• *Air temperature*: mean monthly, mean annual, mean growing period values, sum of mean daily temperatures above 10°C;

• Mean annual *precipitations*.

The **input data** consists in climate data recorded at Huşi meteorological station and the Digital Elevation Model (DEM). We tested several elevation models: SRTM model (80x80m), Aster model (30x30m) and the DEM (30x30m) derived from contour lines digitized from 1:50000 topographic maps, using both the settings from ArcGIS 9.3 and filtering techniques.

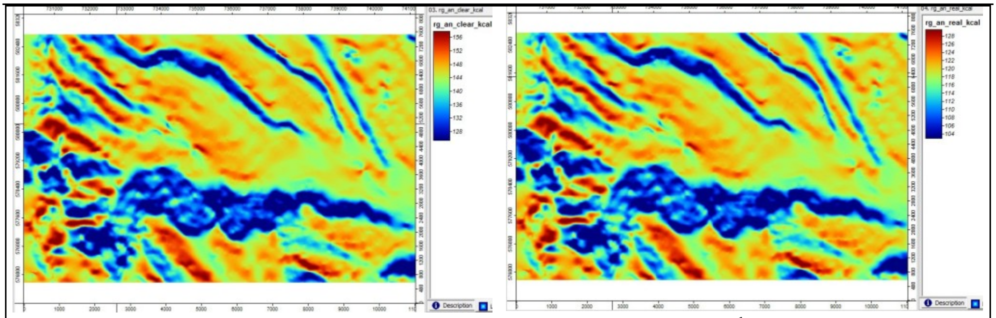
Figure 1. *Position of the study area*

Based on slopes configuration and the differences between real altitudes (along contour lines) and interpolated altitudes (from DEMs), we selected the DEM obtained using the implicit settings from ArcGIS 9.3 as the best elevation model.

Results and discussions

The potential (clear-skies) global radiation was computed using the Incoming Solar Radiation module from SAGA-GIS 2.0.4 software (fig. 2a). In order to obtain the *real global radiation* (fig. 2b), we multiplied the potential radiation with the factor: $(1 - 0.65xN^2)$, where N is the cloud cover fraction (Entekhabi D., 1997).

The potential (astronomical) sunshine duration was derived using the same SAGA-GIS module (fig. 3a). Such a computation has the advantage of taking into account the terrain configuration. Consequently, we shall encounter higher sunshine values on hilltops, because of the larger horizon, and lower values along valley bottoms, because of the narrower view of the sky. By multiplying the potential sunshine duration values with the insolation fraction, we obtained the spatial distribution of *the real sunshine duration* (fig. 3b).



A b

Figure 2. *Potential (a) and real (b) annual sums for global radiation (kcal/cm^2)*

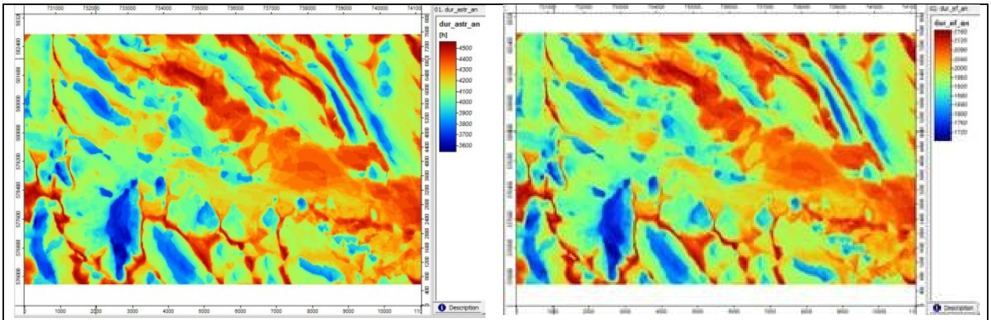


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Figure 3. *Potential (a) and real (b) mean annual sunshine duration (hours)*

For modelling the spatial distribution of *temperature variables*, there are several possible approaches:

- Application at fine scale of statistical models obtained at regional scale;
- Use of *Worldclim* data (Hijmans R et al., 2005) and refinement of spatial distribution (requires validation with meteorological stations' data);
- Application of some empirical models, such as altitudinal gradients plus corrections for solar radiation, land use etc.

Using a statistical temperature spatial model derived at regional scale, has the disadvantage of being more or less generalized. The insufficient number of meteorological stations usually does not allow the taking into account of local terrain characteristics such as slope or exposition, which induce important local variations (*Patriche C.V.*, 2009). As stated before, Worldclim data need to be validated using stations data and its resolution is too coarse for a fine scale approach.

Consequently, we focused on the third approach, using altitudinal temperature gradients to create the altitudinal spatial model for temperature variables and corrections in order to account for local variations induced by slope angle and orientation. The altitudinal gradients for mean monthly and annual temperatures (table 1) were obtained using the available meteorological stations from eastern Romania implemented in NewLocClim software (FAO/SDRN).

Table 1. Mean monthly and annual altitudinal temperature gradients for eastern Romania

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
-0.35	-0.41	-0.47	-0.57	-0.62	-0.67	-0.67	-0.64	-0.58	-0.49	-0.44	-0.4	**-0.53**

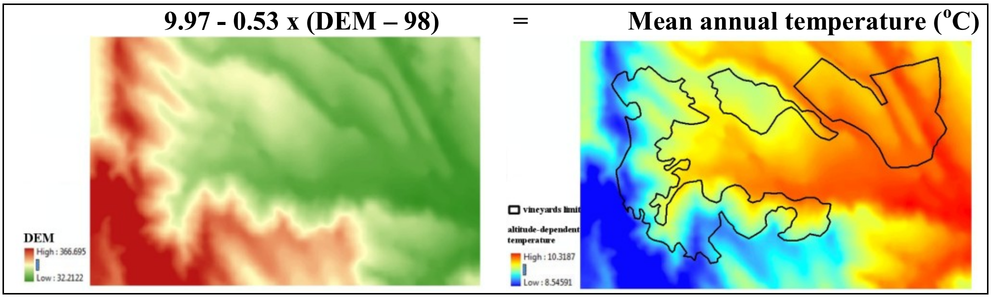

Figure 4. *Computation of altitude-dependent mean annual temperature*

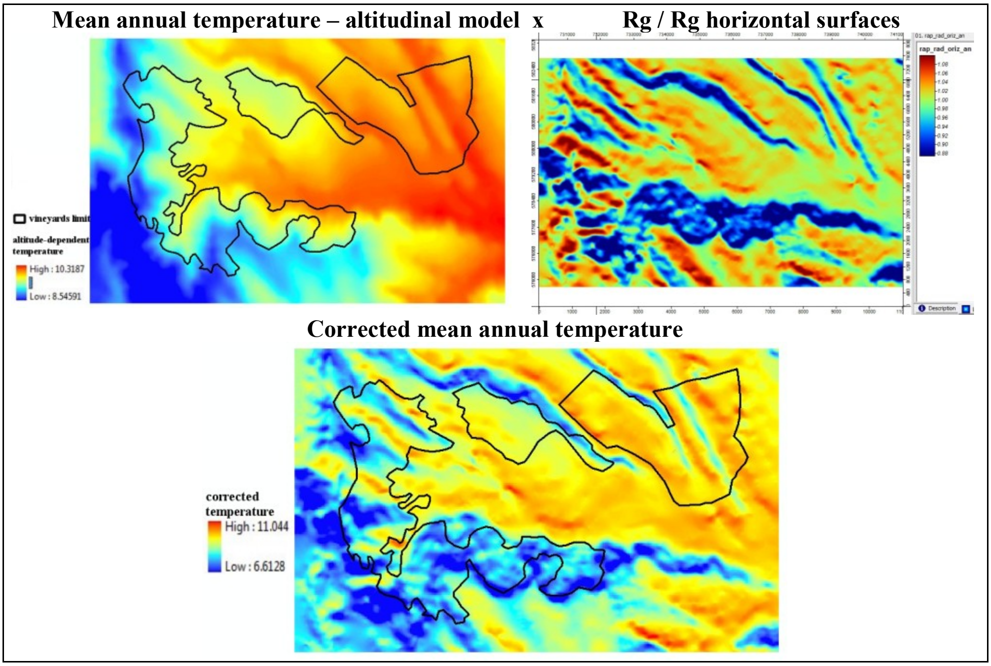

Figure 5. *Correction of altitude-dependent temperature to account for slope and aspect influence*

Based on these gradients, we can estimate in any point the altitude-dependent temperature (T_H), using the respective temperature recorded at Huşi meteorological station (T_{Husi}) and the point's altitude (H):

$$T_H = T_{Husi} + \text{gradient x } (H - H_{Husi}) / 100$$

An example is given in *figure 4* for mean annual temperature.

In order to account for slope and aspect influence, we further applied a correction to the altitude-dependent temperature models, multiplying these models with the ration between real global radiation and the global radiation computed for horizontal surfaces only (Patriche C.V., 2004). An example is given in figure 5 for mean annual temperatures.

For agroclimatic purposes, it is very useful to quantify more complex temperature parameters, such as the *sum of daily temperatures above 10°C*. Though the computation is quite easy for punctual data, its application in GIS is far more complex. Figure 6 shows how the interval with temperatures higher than 10°C is delimited based on mean monthly temperature values. The difficulties consist in deriving continuous raster layers representing the number of days with daily temperatures above the specified threshold (green lines) and the mean temperatures (red lines) for the two intervals corresponding to the months when the 10°C threshold is reached.

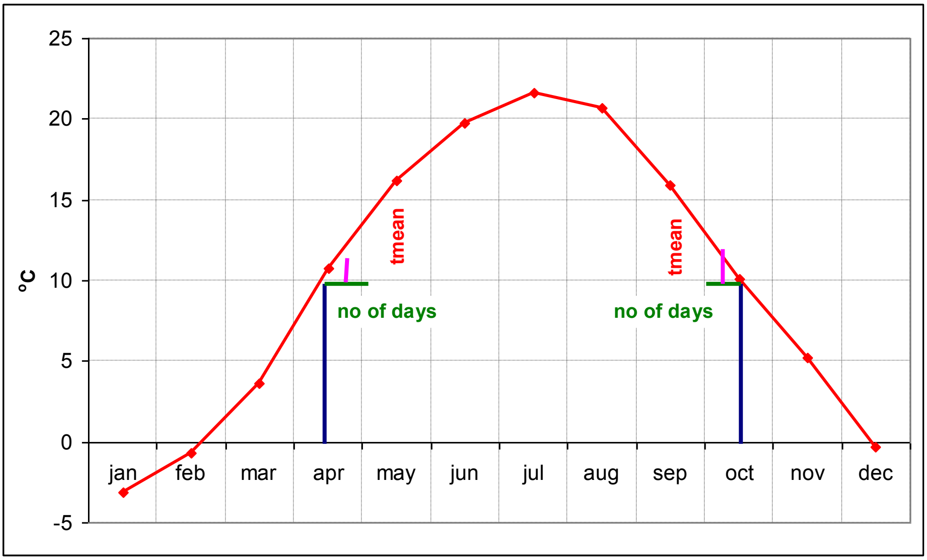

Figure 6. *Delimitation of the interval with daily temperatures above 10°C at Huşi meteorological station*

The following steps were necessary for the above mentioned computations:

• Computation of the diurnal temperature gradient between March and April (September and October respectively): $g = (T_{April} - T_{March}) / 30$

• Computation of the number of days from 15[th] of March (September) to 10^{o}C threshold: $N_{15.03\text{-}10oC} = (10 - T_{March}) / g$

• Computation of the number of days from April (October) with temperatures higher than 10^{o}C: $N_{April>10oC} = 30 - (N_{15.03\text{-}10oC} - 15)$

• Computation of temperature for the 1[st] of May (October): $T_{1stMay} = (T_{April} + T_{May}) / 2$

• Computation of mean temperature for the interval in April (October) with temperatures higher than 10^{o}C: $T_{April>10oC} = (10 + T_{1stMay}) / 2$

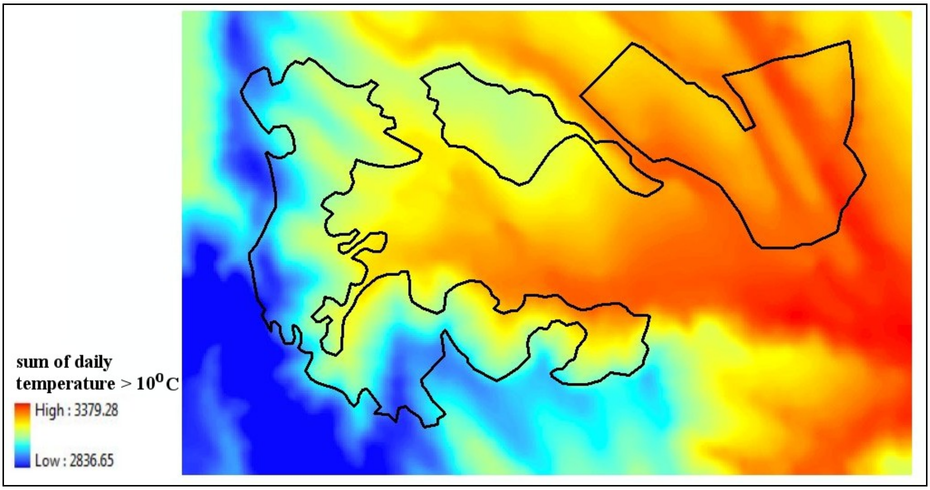

Figure 7. *Sum of daily temperatures above 10°C*

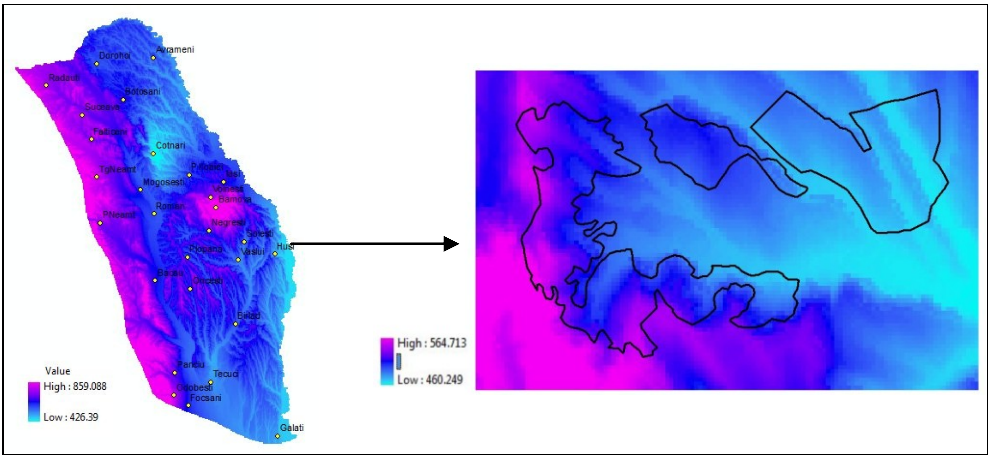

Figure 8. *Mean annual precipitations extracted from a regional regression-kriging model*

Having assessed these parameters, we can further calculate the sum of daily temperatures above 10^{o}C for the entire interval (*fig. 7*):

$$\sum{>}10^{o}C = T_{April>10oC} \cdot N_{April>10oC} + T_{May} \cdot 31 + T_{June} \cdot 30 + T_{July} \cdot 31 + T_{August} \cdot 31 + T_{September} \cdot 30 + T_{October>10oC} \cdot N_{October>10oC}$$

The last parameter we have taken into account, namely *the mean annual precipitations*, was approached by means of regression-kriging, using the available precipitations data from the larger area of the Moldavian Plateau.

In this case, we were not able to find any deterministic approach. However, considering the fact that precipitations are generally less dependent on local morphometry, the regional statistical model should produce results well enough for agroclimatic purposes. The spatial distribution of mean annual precipitations for Moldavia, obtained by regression-kriging (Patriche C.V., 2009) and the extracted distribution for our study region are displayed in figure 8.

Conclusions

Our study shows that a fine scale approach for modelling the spatial distribution of climatic variables influencing vineyards suitability is hampered by the insufficient meteorological stations' data. While the solar radiation can be accurately modelled because of its deterministic nature, in the case of air temperature we need to apply a certain empirical model in order to take into account local variations induced especially by terrain slope and aspect. These empirical models are however difficult to validate. On the other hand, the spatial distribution of precipitations can be extracted from a more general, regional scale, regression-kriging model, as these parameters is not strongly related to local terrain characteristics.

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