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THE USE OF GIS IN VITICULTURE MICROREGIONING IN THE AREA OF SUHINDOL, BULGARIA

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Abstract

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Microregioning (zoning) in viticulture is used to identify the natural habitat of each variety, one that complies with all its biological requirements to cultivation, optimal growth, development, productivity and high grape quality. The study took place on the land of Kramolin village. A database of soil parameters was created and the climatic characteristics, necessary for GIS, were processed statistically for the establishment of viticulture microregions in the area of Suhindol. Triangulated Irregular Networks (TIN) were developed for the terrain surface of the relief and distribution of the total vegetation temperature.

Key words: Geographical Information System, regioning, microregioning, soil, climate, vine varieties, vine rootstocks

Introduction

The production of good quality grapes requires competent accounting of ambient characteristics and their coordination with the biological requirements of vine varieties for their optimal development. Having to account for the elements of the specific natural environment as well as the biological characteristics of each variety makes this kind of study complex, difficult and time-consuming (Popov, 1998).

The microclimatic and soil study of farm land in a number of areas in Bulgaria as well as the microregioning of viticulture within their boundaries was an attempt to solve this complex issue (Popov, 1997). Several models were developed for microregioning of the viticulture potential in major viticultural and winery areas such as Suhindol, Perushtitsa, Karlovo, Sungurlare and Veliki Preslav, famous for growing domestic varieties like Gamza, Mavrud and Misket Cherven (Muscat Red).

The present study took place on the land of Kramolin village, Suhindol area. In order to establish the viticultural microregions, a database was created to be used with GIS that accounted for the complex effect of all important factors on the development of vine varieties as well as cut down and facilitated the process of viticulture microregioning.

The study required the coordination of the data on geographical location and microclimatic characteristics of the studied area, their visualization with numerical models (TIN) and the use of adequate mathematical methods and relational languages for deriving and processing the necessary information (Arnaudova, 2008).

Objective and tasks

To update and supplement the existing database of climate, soil and viticultural potential of the land in Kramolin village, Suhindol area to be used by GIS for the establishment of viticultural microregions.

Material and Methods

The material and methods of data processing were described in detail in previous publications (Arnaudova, 2008; Arnaudova and Popov, 2010) and comprise the following:

Preparation of materials and data for GIS

- *Graphic information*

- digital cadastre map and map of reclaimed property in the studied area. The digital model format is ZEM, CAD. Information source: the Geodesy, Cartography and Cadastre Agency;

- digital large-scale soil map of the area 1:10 000. Soil maps reflect in detail the boundaries between the separate soil types within the frames of a single study. Information sources: The Soil Resources Agency and the Institute of Soil Science “Nikola Pushkarov”;

- topographical maps in a scale 1:25 000 and digital elevation models (DEM);

- *Attributable information*

- soil type– physical and chemical parameters;

- relief – slope, exposure, slope length;

- biological requirements of grape varieties grown for different purposes to climate and soil;

Mathematical processing of data:

- regression analysis was used to derive mathematical models of polynomial type I and II. The insignificant coefficients were evaluated by Student’s criterion (Mitkov and Minkov, 1993);

- the evaluation of total vegetation air temperature in °C allowed for deriving the regression correlation between exposure and the calculated total vegetation air temperature in °C (Arnaudova, 2008).

Solving an optimization assignment

The mathematical formalization of the assignment to select a site for vine varieties was made under the following prerequisites:

- Identification of microclimate parameters of the studied land in compliance with the conditions for yield formation and grape quality, depending on the relief and landscape characteristics;
- Complete evaluation of the effect of accompanying factors on site selection for the specific variety and identification of the direction of grape production: *average annual temperature, minimum and maximum temperatures by month and other factors, affecting grape growing and quality*;
- The identification of land boundaries with the suitable climate for a certain grape variety was followed by a study of the opportunity to ensure the optimum conditions for vineyard development with the existing soil map and an analysis of suitable soils and microrelief in view of the limitations. This stage allowed for flexibility in site selection for a specific variety.

Application of GIS

- *Development of Triangulated Irregular Networks* (TIN) for relief surface, temperature distribution, slopes and exposure;
- *Combining layers* with different information allows for applications, necessary for vine varieties’ microregioning – map of reclaimed property, soil map and topographic map, etc.;
- Development of *thematic maps* that rep-

resent cross-sections of the common map by a certain type of graphic or attributable information.

- Relational languages.

Results

The territory of Suhindol area is on the Pre-Balkan physical and geographic region, characterized with low hilly formations. The relief of the area is complex, diverse and rugged – plain, hilly and medium-mountainous but hilly terrains prevail. The surrounding elevations consist of limestone of different composition: compact, coquinoid to marlstone known as the Urgonian-Barremian type. The region is open to the north-east along the waterlogged basin of Rossitsa river.

The average height above sea level is 300-400 m. The relief inclination is within 1 - 6° with diverse exposure, most often southern, northern and eastern.

The continental climate is softened by "Alexander Stamboliiski" Dam, the semi-mountainous terrain, the rugged relief and forest nature of the land.

The climate in this area is favorable for the development of viticulture and growing high quality grapes.

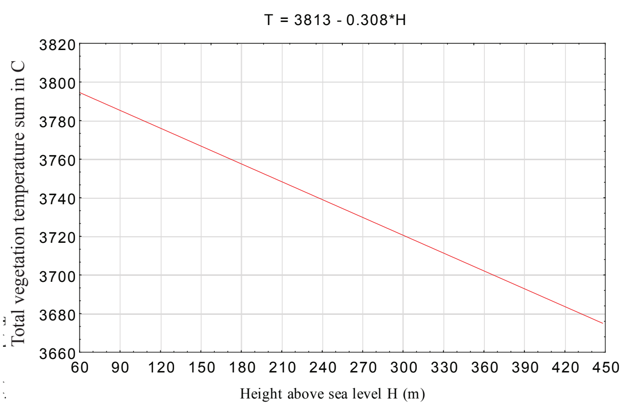

Fig. 1. Correlation between the total air temperature sum during the vegetation period and height above sea level within the interval of 120-450 m

Climatic conditions

According to the climate, this area belongs to the Middle or Hillock region of the Danube undulating valley, which is part of the moderately continental European climatic area. It is characterized with a hot and comparatively dry summer and cold winter. The average annual temperature in this area is 11°C. The coldest month is January with an average monthly temperature of +1.2°C and the warmest – July with an average of +21.8°C. The total air temperature during vegetation, measured by the Suhindol Meteorological Station was 3700.3° and the length of the vegetation period – 218 days.

The annual precipitation is within 530 - 650 mm.

Tables 1 and 2 show the agro-climatic parameters, including temperature and humidity at 80% availability that influence vine development in this area. The data present the average for a 30-year period (Stoychev, 2006).

The temperature zones in the area of Kramolin village were specified on the basis of the climatic data. A regression model of the temperature sum was developed for this purpose by means of statistical processing (Mitkov and Minkov, 1993). The height above sea level was adopted as an independent variable – H (m) and the total vegetation temperature sum in °C – $T_{sum.}$ – as dependent.

$$T_{сум} = 3813 - 0.308*H \quad (1.1)$$

$R^2 = 0.94$ at a level of significance $\alpha = 0.95$
validity limits $60<H<450$

The correlation obtained was the linear function of the total air temperature sum depending on the height above sea level within the valid interval (H – 60-450 m). The temperature sum was observed to decrease with height increase (Figure 1).

The following correlations of the effect of height above sea level (**H,** m) on the sum of annual precipitation (W_{sum}) (1.2) and

Table 1
Agro-climatic parameters of the area by temperature conditions (80% availability)

Station	H, m	1	2	3	4	5	6	7	8	9	10	11
Troyan	422	17.IV	13.X	3017.2	179	28.IV	5.X	160	-22.4	-21.0	23.4	19.2
Lovech	197	15.IV	1.XI	3420.5	200	20.IV	23.X	186	-24.6	-19.3	25.1	20.9
Pleven	163	28.III	2.XI	3756.4	219	7.IV	22.X	198	-23.0	-19.0	26.9	22.3
D. Mitropolia	62	29.III	1.XI	3715.2	217	17.IV	22.X	188	-26.7	-23.0	26.0	22.3
Somovit	28	27.III	4.XI	3952.5	222	26.III	24.X	182	-25.2	-17.2	25.8	22.7
Vabel	41	30.III	1.XI	3501.6	216	11.IV	25.X	197	-20.4	-17.0	24.9	21.1
Novachene	50	29.III	31.X	3687.1	215	18.IV	17.X	182	-25.3	-21.3	25.9	22.1
Svishtov	235	27.III	4.XI	4024.3	222	23.III	27.X	218	-20.4	-15.8	26.3	23.0
Suhindol	235	29.III	2.XI	3700.3	218	5.IV	26.X	204	-19.0	-17.6	27.3	21.9
Elena	329	17.IV	14.X	3063.8	180	17.IV	22.X	188	-24.5	-21.8	22.4	19.5
Veliko Tarnovo	198	30.III	16.X	3476.2	200	22.IV	5.X	166	-22.6	-19.1	24.6	21.1
Pavlikeni	136	29.III	2.XI	3660.4	218	19.IV	21.X	185	-24.8	-20.0	26.1	22.0
Sevlievo	197	24.III	13.X	3264.5	203	28.IV	6.X	161	-27.2	-23.6	23.8	20.6

Legend: 1 – average initial date of the average 24-h air temperature of 10°C in spring; 2 – average final date of the average 24-h air temperature of 10°C in autumn; 3 – total temperature of the vegetation period with air temperature above 10°C; 4 – duration of the vegetation period (days); 5 – average date of the last spring frost; 6 – average date of the first autumn frost; 7 – duration of the frost-free period (days); 8 – absolute annual air temperature minimum (°C); 9 – average absolute air temperature minimum (°C); 10 – highest average temperature of the warmest month (July) in °C; 11 – average temperature of the warmest month (July) in °C.

precipitation for the months of September and October (IX and X) – W_{IX-X} (1.3) were received as a result of the statistical data processing:

$$W_{sum} = 401.9517 + 0.5874*H \quad (1.2)$$

$R^2 = 0.883$ at significance level α =0.95 validity limits 60<H<450

$$W_{IX-X} = 33.481 - 0.0157*H \quad (1.3)$$

$R^2 = 0.833$ at significance level α = 0.95

Validity limits 60<H<450

The correlations obtained (1.2 and 1.3) were linear and showed that the sum of annual precipitation increased with the increase of above-sea level, while the correlation for the precipitation sum in September and October was vice versa. The validity limits in both cases were within the studied interval (60-450 m).

Development of Triangulated Irregular Networks (TIN) for the area

- *Relief characteristics of the terrain (TIN).*

The terrain in the area of Kramolin is diverse and complex with a transition from plain to undulating at 250-450 m.a.s.l. and inclinations within 1 - 12° (Figure 2).

- *Distribution of the total vegetation air temperature in °C.*

The distribution of the total vegetation air temperature sum in the studied area was within 3650-3740°.

The complexity of the relief affected the de-

Table 2
Agro-climatic parameters of vine by humidity conditions (80% availability)

Station	Annual humidity sum, mm	Humidity sum, mm за IX и X
Troyan	649.7	62.0
Lovech	569.1	41.4
Pleven	482.1	37.0
D. Mitropolia	422.6	28.4
Somovit	403.6	33.6
Vabel	441.4	38.1
Novachene	417.9	35.6
Svishtov	447.3	30.3
Suhindol	515.3	37.1
Elena	651.2	49.2
Veliko Tarnovo	582.3	41.4
Pavlikeni	472.3	37.2
Sevlievo	538.4	43.2

veloped model (Figure 3) and gave us the picture of the distribution of the total vegetation temperature sum during the vegetation period in the separate relief sectors of the terrain. Due to the small difference in temperature sums (less than 100°C) that wouldn't affect the development of vine varieties, it is recommended to outline just a single temperature zone.

- *Distribution of the annual precipitation sum and the precipitation for the months of September and October (IX and X) in mm.*

- the annual precipitation sum in the studied area was within 537-700 mm.

- the precipitation sum for September-October (IX and X) was 25.7-29.9 mm.

Geology and geomorphology

The high parts of the area were built upon karst limestone rocks while river deposits (alluvium) prevail in the terrace of Rossitsa river.

Soil diversity

Part of the territory of Suhindol area is within the North Bulgarian forest steppe zone and part – in the semi-mountainous zone. Due to this location, the prevailing soil diversity is as follows: medium-leached Chernozems (Haplic Chernozems) (6362 da), low-clay Rendzins (Rendzic Leptosols) (3200 da), alluvial-deluvial and deluvial soils (Eutric Fluvisols) (1314 da), dark-grey forest soils (Luvic Faeozems) and light-grey forest soils (Leptic Leptosols) that occupy large areas but are not suitable for viticulture.

Content of physical clay in the plough and sub-plough soil layers

The content of clay in the soils of this area varies within 43 – 64%, the prevailing soils being as follows: heavy sandy-clay and low-clay with physical clay content within 45 – 64%.

There is a higher content of physical clay in the sub-plough soil layer, except for shallow soils (Figure 4).

Soil reaction (pH)

Soils are characterized as low-acid, neutral and alkaline, depending on their reaction (pH in H_2O).

Organic matter content of soil (humus %) and depth of the humus horizon (cm)

The soils are characterized with good humus storage (2-4%). The depth of the humus horizon is 30-40 cm. This horizon occasionally reaches up to 120 cm in alluvial-deluvial soils.

Strength of soil profile cm

The soils in the area of Kramolin are characterized with profile strength of 60 – 180 cm.

Discussion

The complex accounting of the climatic and soil conditions and factors in the land of Kramolin – Suhindol area resulted in the identification of a single climatic zone with a total temperature sum of 3650-3740°, which is suitable for growing early and medium-ripening wine and table vine varieties.

The adequate soil diversity was identified

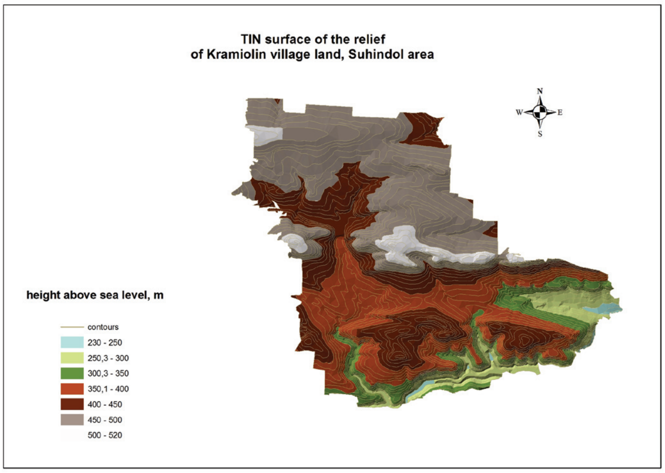

Fig. 2. TIN surface of the relief

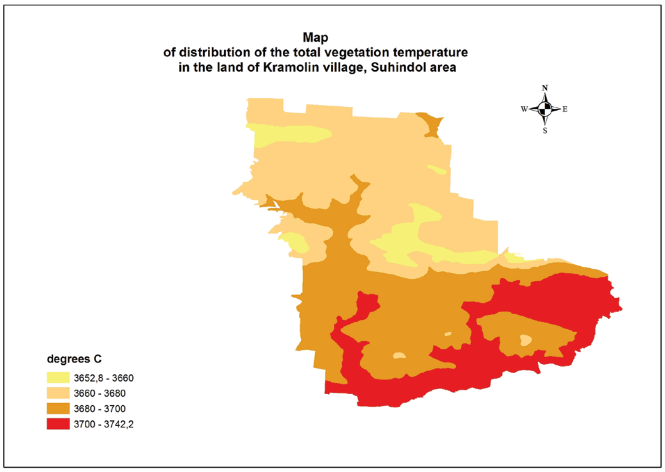

Fig. 3. Distribution of the total air temperature sum in °C

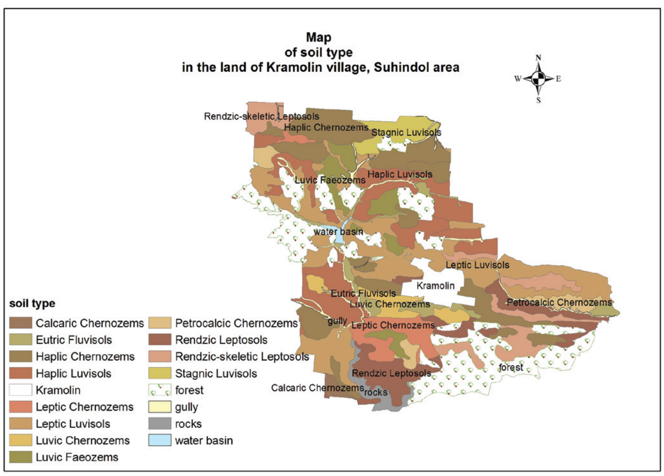

Fig. 4. Soil map

(medium leached Chernozems – Haplic Chernozems, low-clay Rendzins – Rendzic Leptosols, alluvial-deluvial and deluvial soils – Eutric Fluvisols) for grape growing for three purposes – white wine varieties for manufacturing good quality dry white wines, red wine varieties for manufacturing good quality dry red wines and table varieties for high quality table grapes for fresh consumption.

The following parameters were established: total air temperature sum during the vegetation period (3700.3°) for the Suhindol area, duration of the vegetation period (218 days) and average monthly temperature of the warmest month – July (+21.8°) that are completely suitable for growing early and medium-early ripening vine varieties.

The annual precipitation sum was within 530 - 650 mm, which satisfied vines' requirements for humidity, hence, no necessity for additional irrigation.

The obtained thematic maps of the distribution of air temperature and precipitation enabled the evaluation of the climate for the specific area studied. Suitable soil diversity was also mapped.

The developed models for the Suhindol area gave a full characteristic of the soil and climatic parameters and an opportunity to outline the boundaries of viticulture microregions in the land of Kramolin village.

The models that were developed will help farmers to make decisions on the use of their land as well as to select suitable vine varieties.

Conclusion

Based on the climatic characteristics of the Suhindol area, mathematical models were developed for the total vegetation air temperature with reference to the above-sea level and exposure.

The obtained Triangulated Irregular Network *(TIN)* model for the distribution of the air temperature and the regression correlations between the height above sea level and the annual sum of precipitation for September and October gave the opportunity to evaluate the climate for the specific area studied.

An analysis of soil characteristics was made such as characteristics of soil diversity, content of physical clay in the plough layer, organic matter content in percentage and soil reaction.

The data on climate and soil diversity in the area are useful for the identification of microregions for vineyards with red and white wine varieties as well as table grape varieties.

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