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MODEL FOR INVESTIGATION, AMELIORATION AND ORGANIZATION OF TERRAINS WITH COMPLEX TOPOLOGY FOR PLANTING OF VINEYARDS

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Abstract

On the basis of areas with complex topography and soil diversity is proposed a stepwise model for reclamation of lands for planting of vineyards. The model includes climate, soil and hydromeliorative conditions. Limiting components are presented as being localized in different parts of the area limitations of the suitability. The strength of the constraints is evaluated depending on the area of their occurrence, the extent to which they limit the suitability of the terrain and the opportunities for ameliorative correction.
Soil sampling and mapping of soil is performed by applying of GIS for characterization of the spatial diversity. Obtained results are analyzed based on the expectations for constraints and non-differentiability of the function characterizing the properties of the soil at each point within the field. Through this approach is considered the minimum number of points required for investigation and are localized the areas for correction of limitations arising from the properties of the soil and terrain.

Key words: *GIS, soil properties, spatial diversity, vineyards.*

INTRODUCTION

Preparation of lands for vineyards puts the condition for formation of terroir. The concept of terroirs in viticulture is increasingly relieved from the context of descriptive and analytical characteristics of the areas, which traditionally are identified as vineyard terroirs and is directed towards the development of predictive models for the potential of lands to be converted into terroirs. In terms of its characteristics, each particular terrain, included in an area with suitable climatic conditions is a potential vineyard terroir, having its advantages and disadvantages. Regarding the requirements of grape wine varieties, the question for 'the most suitable growing conditions' is always controversial, as controversial are requirements to terrain able to provide a high quality of the grape in terms of very limited yield potential and from the other hand-terrains with very high yield potential, giving a mediocre production. In the conditions of increasing scarcity of land resources, will increase the advisability of utilization for vineyards of areas with limited suitability for agriculture. Somewhat, the limited fertility of the soil, and terrain conditions is a desirable quality in terms of vineyards, as for them, unduly intensive growth is undesirable. On the other hand, the suitability of the terrain for agriculture, mustn`t make it completely non-functional. In this context the field restrictions are divided into those which can be improved by ameliorative activities, and other on which such an effect is impossible or impractical.
The present work is an attempt to systematize the complex study of the suitability of a very complicated in terms of its topography and erosion conditions terrain, in respect of its suitability for becoming a vineyard terroir.

MATERIALS AND METHODS

This study was carried out on terrain, covered with eroded to different degrees Cinnamon forest soils, which is located at the foothills of the lower Eastern part of the Balkan Mountains and belongs to the administrative region of Sungurlare, which has old traditions as a wine-growing region and especially, growing of white wine varieties. The current terrain has not been used previously for viticulture, mainly due to its topographic conditions and high degree of erosion in a significant part of the area. Solving the problem with the suitability of this terrain, includes development of steps of the study, characterization and mapping of constraints and determining the meliorative practices. Figure 1shows an air-photo of the situation of the terrain. The exposition is in the direction north-northwest - south-southeast. The total area is 33.2 ha and is divided from the existing topographical conditions into two parts - a relatively high North-Northwest and lower - South-Southeast part. The land is used for agriculture in the Northwest part and as unregulated grassland in the southern part. In Figure 2 is shown a volumetric, three-dimensional image of the terrain, by which are characterized the topographical conditions of the area.

During our research we collect 31 soil samples from three depths 0-25, 25-50 and 50-75 cm. Soil sampling is coordinated with the topologic conditions of the terrain. After standard preparation soil samples were analyzed to establish the pH, potentiometrically in water (Arinushkina, 1970); easily mobile and exchangeable Al^{3+} and H^{+}, titrimetric by Sokolov (Sokolov, 1939); easy mobile exchangeable Mn^{2+}, in extract with 1m KCl, as the preparation of the extract was carried out under the Laboratory system for liming of Palaveev and Totev (LSVPT-64) (Palaveev and Totev, 1970) and the determination of Mn^{2+} is by AAS (Ganev, 1990); easily mobile and exchangeable Ca^{2+} and Mg^{2+}, complexometric (Arinushkina, 1970), organic carbon - ISO 14235:1998, total carbonates (Arinushkina, 1970), content of active calcium according to Gruinnot-Gallet (Hartikainen H., 1986)

Figure 1. Air-photo of the situation of the investigated terrain

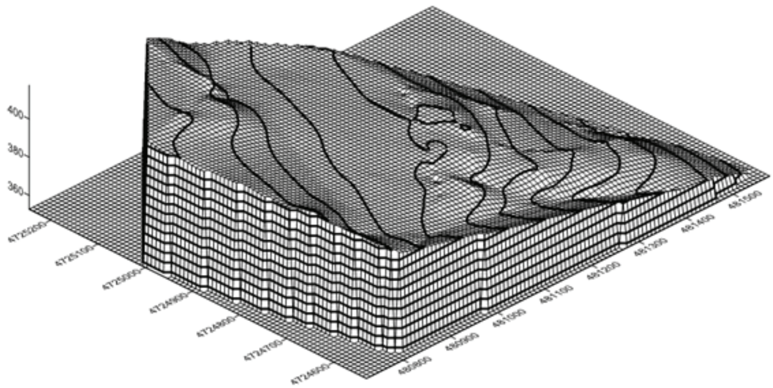

Figure 2. Volumetric topographic image of the terrain

RESULTS AND DISCUSSIONS

Characteristic of the topographic conditions

Topographical conditions are characterized by the altitude, gradient, exposure and the ruggedness of the terrain. Based on these features is formulated in a first approximation the separation of terrain into topographic areas. Reason for the topographic subdivision into individual sections is only the gradient magnitude. Altitude of the terrain changes monotone and the exhibition is uniform along the line of the main catena. Based on this are summarized three topographical areas: with gradient inclination 6-9^o (sections A and C) and with 3-6^o in section B. In section C are established active erosion forms, which are indicated in Figure 3.

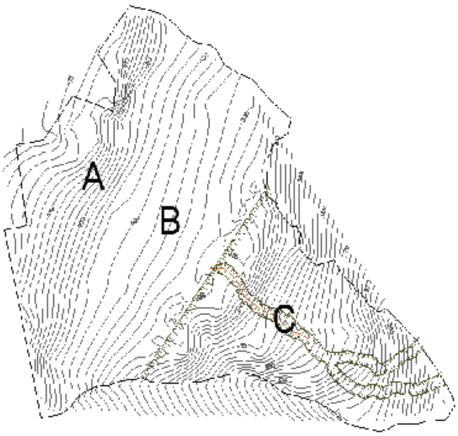

Figure 3. Topographic sketch of the terrain with separated topographical areas

Soil conditions

Taxonomic affiliation of soils and soil depth

Within the boundaries of terrain are established Cambisols, which in some parts passed into shallow Regosols, as a result of the erosion (it is used the Taxonomic list of soils in Bulgaria developed by Ninov in 2005).

There have been determined similar in origin but reduced to different degrees profiles, as a result of active contemporary erosion or by older erosion processes. Both deep and shallow soil profiles in terrain are formed on gneiss. Weathering crust is common for the whole area of our survey. In the southern parts of terrain is established contemporary process of waterlogging, which did not affect the morphology of the soil profile. Based on data from 11 exploration wells have been identified boundaries of the two main soil types. The distribution of soil differences within the terrain is shown in the soil map in Figure 4. The differentiation of soil profiles on deep Cambisols and shallow Regosols basically copies the data for gradient. This gives reason as a second approximation, the sections separating the terrain by topographic feature to be identified with the sections dividing the terrain in respect of profile depth. The parameter 'profile depth' may absolutely limit the suitability of soil for growing grapes, in cases where the depth of all soil horizons down to the weathering crust does not exceed 1m. In the researched field such limits have not been established and therefore the need for sufficient depth of soil is available.

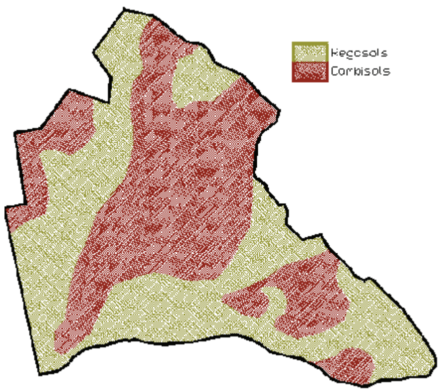

Figure 4. Soil map

Particle size distribution

Particle size distribution is an absolute limitation if the content of physical clay (particles < 0.01mm) is less than 10%, or more than 70%. Data from the field study showed that the probability to establishing such values is small, and actually they are not determined for any of the soil layers throughout the whole studied area.

Data for the physical clay can be approximated to the Gaussian frequency distribution and are suitable for further mathematical analysis. Mean content of physical clay distributed in soil depth – 0-25, 25-50 and 50-75 cm is shown in Table 1, and the distribution of the clay content between the soil types is shown in Table 2.

The data shows that the probability to establish clay content, higher than 60% is negligible. However, within the boundaries of the terrain is determined one of all 33 cases with clay content exceeding the critical value, but this result is not confirmed in any of the other samples.
Therefore, the accumulation of clay is possible to be identified in individual plots, which is not relevant to the suitability of the terrain. Therefore the particle size distribution, expressed by the physical clay content is not a restriction for vineyards. The most frequently observed value for the physical clay is about 36%, which is close to the optimal values of this parameter for vineyards.
In sections where it is established low clay content, naturally increases the skeletal fraction. The relationship between the skeletal and clay fraction in the observed terrain is shown in Figure 6. The power of the dependence is greater in shallow and relatively light Regosols.

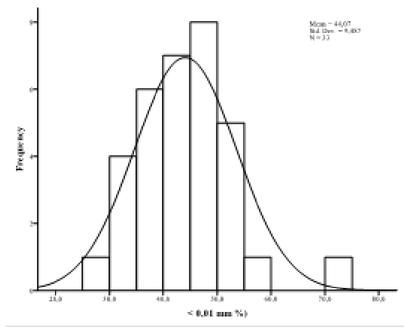

Figure 5. Histogram of the frequency distribution of physical clay content in the total sample

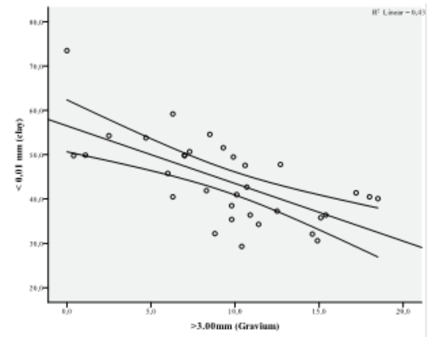

Figure 6. Relationship (correlation) between the content of gravel and physical clay in the observed terrain

Table 1. Distribution of physical clay content down to soil profile

Depth (cm)	Mean	N	Std. Error of Mean	Std. Deviation	Minimum	Maximum	Median
25	45.318	11	2.2504	7.4638	32.1	54.6	49.500
50	42.764	11	3.5464	11.7621	30.6	73.5	40.500
75	44.118	11	2.8661	9.5059	29.3	59.2	41.900
Total	44,067	33	1.6515	9.4870	29.3	73.5	41.900

Table 2. Distribution of physical clay content in different soil types

Soil type	Mean	N	Std. Error of Mean	Std. Deviation	Minimum	Maximum	Median
Cambisols	42.750	18	1.7677	7.4997	29.3	53.8	42.300
Regosols	45.647	15	2.9723	11.5117	32.1	73.5	40.500
Total	44.067	33	1.6515	9.4870	29.3	73.5	41.900

Soil chemical composition

In our study we determined the pH and content of the main macro and micronutrients in the soil, as the results are presented in Table 3. They show that studied soils are characterized by slight acid reaction, contain no carbonates, relatively poorly stocked with essential macronutrients and the content of micronutrients (Ca, Mg, Fe, Mn, Cu and Zn) is sufficient for normal mineral nutrition of plants but in non-toxic concentrations.

Analyzing the data, we do not find reason to formulate limitation of the suitability of soil for growing grapes, based on data on the soil chemical composition. The results, however, indicate a need for carefully considered and balanced mineral fertilization throughout the whole growing period of the vineyard.
The lack of carbonates down the profile and low content of Ca in all studied forms of this element may not be considered as a disadvantage in this object. That is because the

terrain is in the composition of a large area, proved as terroir based on non-carbonate soils, with a slightly acid reaction and pronounced deficiency of Ca, as we found in our study.

Model of differentiated fertilization

The rates for stockpiling fertilization with phosphorus and potassium, and rates for ammonium nitrate in the individual parcels are shown in Table 4. The borders of each outlined sub-parcel can be seen in Figure 8.

For stockpiling fertilization are used phosphorus and potassium fertilizers. It is recommended introduction of triple superphosphate (TPS) and potassium sulfate in rates listed in Table 4. Phosphorus and potassium fertilizers are applied separately, after cleaning the terrain from weeds. After the fertilization, the area is harrowed in 15 cm in order to achieve the best possible homogenization of fertilizers with the soil. During the first three years of the vegetation phosphorus and potassium fertilizers are not applied.

Nitrogen fertilizers are applied at the beginning of the vegetation in each growing season. It is proposed the use of ammonium nitrate in listed above rates. During the vegetation is recommended performing of three-four foliar application of suitable fertilizers containing micronutrients and amino acids. Application of fertilizers can be combined with the system for crop protection of the vineyard.

Table 3. Soil chemical composition

Sample	Depth (cm)	Soil type	pH (H_2O)	$CaCO_3$ (%)	Ca (%)	C (%)	N	P_2O_5	K_2O	Ca	Mg	Fe	Mn
				(%)			mg/100 g			mg/kg			
1	25	Regosols	5.62			1.18	0.98	13.00	24.49	455	819	2367	281
1	50	Regosols	5.77			0.71							
1	75	Regosols	6.82			0.19							
5	25	Regosols	6.50			1.31	0.87	12.50	19.75	594	1161	2813	
5	50	Regosols	6.78			0.77							
5	75	Regosols	6.90			0.25							
9	25	Cambisols	6.06			0.99	0.76	17.00	17.31	563	1335	2744	
9	50	Cambisols	6.92			0.59							
9	75	Cambisols	7.36		0.61	0.23							
10	25	Cambisols	6.03			0.98	0.53	15.00	17.31	531	1279	2744	
10	50	Cambisols	6.94			0.60							
10	75	Cambisols	6.62			0.33							
13	25	Cambisols	6.12			1.06	0.37	24.10	12.00	485	1301	4213	189
13	50	Cambisols	6.39			0.56							
13	75	Cambisols	6.79			0.27							
19	25	Cambisols	6.79			1.04	1.04	25.00	19.75	938	1526	2761	
19	50	Cambisols	7.60		0.50	0.69							
19	75	Cambisols	7.31			0.33							
22	25	Cambisols	6.84			0.99	1.04	34.00	19.94	1333	1400	2519	281
22	50	Cambisols	7.08		0.60	0.62							
22	75	Cambisols	7.18		0.43	0.31							
23	25	Regosols	6.31			1.56	0.29	18.00	16.54	667	1417	3149	174
23	50	Regosols	6.53			0.80							
23	75	Regosols	6.38			0.23							
27	25	Cambisols	6.06			1.69	0.31	26.00	21.37	483	943	1982	
27	50	Cambisols	6.25			0.96							
27	75	Cambisols	6.45			0.33							
30	25	Regosols	5.97			1.89	0.64	29.75	15.37	451	1032	1853	
30	50	Regosols	6.59			1.00							
30	75	Regosols	6.42			0.30							
31	25	Regosols	5.92			1.58	0.39	23.00	16.54	515	1240	2917	188
31	50	Regosols	6.18			0.96							
31	75	Regosols	6.70			0.42							

Table 4. Fertilization rates in parcels, kg/ha

Parcel №	Sub-parcel №	Sub-parcel area, ha	Stockpiling fertilization rate P_2O_5, kg/ha	Fertilizer rate, TPS, kg/ha	Stockpiling fertilization rate K_2O, kg/ha	Fertilizer rate Potassium sulfate, kg/ha	Fertilization rate, N, kg/ha	Fertilizer rate Ammonium nitrate, kg/ha
198	198-1	8.6318	566	1230	143	290	87	250
	198-2	11.746	406	880	220	440	93	270
199	199-1	0.9457	553	1200	240	480	106	310
	199-2	3.7758	353	770	250	500	94	270
	199-3	4.1389	558	1210	164	330	105	300
	199-4	0.6957	540	1170	240	480	103	300
	199-5	1.1433	540	1170	240	480	103	300

Erosion conditions

The studied area is with active erosion process. Topographical conditions described in previous section define an intensive surface runoff in conditions of low filtration capacity of the soil, especially in lower southeastern parts of the field. Erosion activity in them is the main reason they are not used for agriculture. Areas with relatively high potential concentration of the erosive flow are established also in the northern areas of terrain.

Figure 7 presents vector graphic of the intensity of runoff, where it is visible its predicted direction and intensity, with a leveling of surface resistance of water movement after preparation and use of land for vineyard.

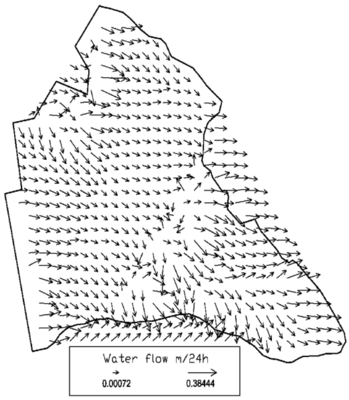

Figure 7. Direction and intensity of the surface runoff

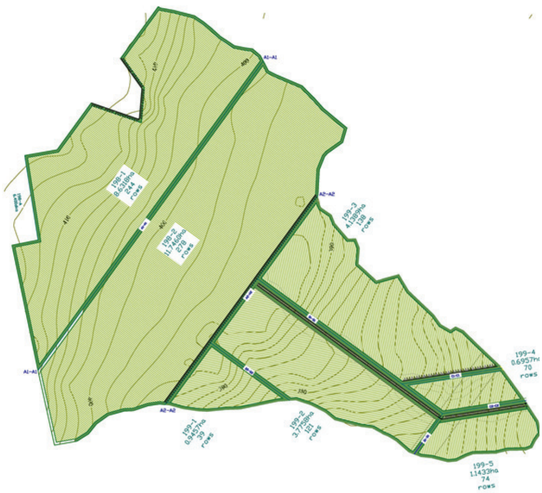

Figure 8. Plan of the vineyard in a conceptual stage

The vector diagram outlines two zones: a zone of potential waterlogging in areas of dispersion of erosion runoff and in areas where there is an abrupt change in its direction, and area with very active erosion runoff in parts where there are topographic conditions for its concentration in torrential beds.

Such characteristics require the need for catching of surface runoff in the direction coinciding with that of the main slope.

In the southern part of the field are formed active erosion gullies that are in an active phase of their development. Routes of erosion gullies are shown in Figure 3.

Plan of the vineyard

Described field conditions require the need vineyard plan to be complied with the described limitations. This can be achieved by the orientation of rows, density of planting, and mainly – by the direction, position and stabilization of the farm roads longitudinal and transverse to the flow and the direction of the rows. Plan of the terrain, accompanied by appropriate amelioration and communication infrastructure is presented in Figure 8.

The catchment of runoff is carried out approximately along the main erosion layout by building of anti-erosion canal that plays a role also in regulating of the subsurface flow in waterlogged areas of the terrain. This canal is discharged into the adjoining to the terrain natural gullies, as in the places of discharge banks are stabilized by building of a permanent barrage. The direction of rows in the southeastern erosively risky part of the terrain concludes a large angle with the vector of surface runoff. Anti-erosion and drainage canal crosses the flow and prevents its concentration in long layouts, especially in erosively risky areas and for that in southeastern parts are provided additional farm roads. General layout of the vineyard in conceptual stage is presented in Figure 8.

CONCLUSIONS

The described sequence of investigative and ameliorative works for creating of vineyards in the terrain, objected in this article represents a model for amelioration and utilization of complex in terms of topographic and soil conditions terrains for growing grapes. The experience from the work show us the relevance of implementation of terrain investigations and analyzes, which to a large extent can be considered as universally applicable for lands, with limited suitability for agriculture.

The main stages in our opinion, which are universally applicable to such kind of ameliorative surveys in order establishing vineyards, are:

1. Topographic conditions – exposure, slope and sections within the terrain, which can be differentiated based on these two main topographic features;
2. Soil cover – soil sampling and mapping of the representativeness of sampling points into uniform conditions within the terrain;
3. Erosion characteristics of the terrain;
4. Characterization of soil water regime.

The conclusions that are imposed by the analysis of the conditions stages 1 and 2 are not reason for ameliorative intervention in the terrain conditions, but they are limiting conditions in respect of its suitability for agriculture in the direction which it is being studied.

Conclusions from 3 and 4 have a meliorative importance. The analysis of the erosion conditions and conditions for waterlogging require construction of relevant to the degree of erosion risk, anti-erosion facilities and systems for regulation of water balance in the soil root zone. These events in the stage of design and construction of the plantation should be taken into account in the conceptual and technical design of vineyards.

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