PhD dissertation thesis

EXAMINATION OF THE AGRO-ECOLOGICAL POTENTIAL WITH GEOINFORMATICAL AND REMOTE SENSING METHODS IN VINE AND FRUIT PLANTATIONS

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1. BACKGROUND AND AIMS OF THE DISSERTATION

The intensive pomology and fruit production face to increasingly higher requirements. The standard of the production needs to be improved with modern agro-technical methods to achieve success both in the international and the inland market. However the precision production technology demands to be aware of the features of the production area accurately. To determine the agro-ecological potential of the production areas or plantations, as well as to maintain these resources in the long term, it is essential to reveal the spatial differences of the agro-ecological features.

The agro-ecological analysis means the survey of the spatial relationships of a complex ecosystem which can be associated with a certain sector of the agriculture. Of course in every case the researches always have a practical intention, the aim is to determine: the productivity referred to a certain area, the spectrum of the growable plant species and the conditions of the cultivability.

The agro-ecological potential survey of Hungary was carried out in the frame of a large scale research program led by *István Láng* (*Láng et al.,* 1983) in the end of the 1970's. During the ranking of the vegetation productivity they concentrated on the factors like the soil, the water management of the soil, the melioration and the climate. The Agro-ecological Research Program led by *György Várallyay* approached the production area qualification from the agro-ecosystems (*Várallyay*, 2004). During this program they also paid extra attention to the measurement of the pedological parameters. In the beginning of the 1980's, the agro-ecological regionalization program, led by *László Góczán*, was started which approached the subject from geography thus it paid attention evenly to the features of the relief and climate and the soil (*Góczán et al*., 1988).

The main aim of the cropland classification or qualification is to evaluate the production area in respect of the agricultural potential however most of the cases in practice this narrows down only to the soil evaluation. During the evaluation they determine the key "main" and the "minor" factors and a parametric or point system are established based on them. Considering the current situation of the market only the production of the quality fruits and special terroir wines have future, therefore the production area classification and qualification could have greater significance in the coming years.

The cultivated wine areas could be evaluated based on the Vineyard Classification System which scores the quality of the area based on its ecological features. 7 main components have been established by the 95/2004. (VI.3.) FVM regulation. The most significant and determining factors are the terrain (40.5%), the agro-meteorology (23.3%) and the soil (22.6%).

In pomology the ecological requirements of the fruit species vary considerably, consequently the production area evaluation must reflect these differences accordingly. Currently in the National Fruit Production Area Classification System the production area qualification point system is established for 17 fruit species. The system was planned for the slopes with 12% maximum. *Kállayné* (1993) highlights the soil, the water balance, insolation, the position and the height correlated to the environment as main environmental group of factors in the Fruit Production Area Classification System. The maximum score could be decreased by the limiting factors which are the erosion, the freezing during flowering and the water runoff.

Both the agriculture funding systems and the quality production demands the electronic registration of the cadastre system of the wine and fruit production areas. The VINGIS system opened new perspectives in the viticulture compared to the former paper based registration and also provides a basic database for carrying out the analyses. However unlike to the Regional Councils of Wine Communities the pomology sector do not have such centralized institution system which main task would be the geoinformatical data processing.

In the above mentioned examples the growing productivity of plants were investigated in a national or regional scale, however in the recent years the demand for the plantation level surveys increased, which phenomenon points towards the precision agriculture. In the precision wine-grape production and pomology the trend will be in the coming years to have more and more precise and high spatial resolution data, thus the demand could arise for the geoinformatic processing of the evaluation system. For this increasingly higher spatial resolution digital datasources are required to generate the map layers and to run the evaluation models for a production area.

The aim of the dissertation

Based on a few key factors (relief, soil, biomass, land use) I aimed to study the ecological suitability of the vineyards and fruit production areas using geoinformatical methods in the case of the chosen sample sites.

To reach this general goal I defined the following detailed aims:

- To develop geoinformatical models for assessing the vineyards and fruit production areas as well as to analyze the vineyard classification system with geoinformatics modeling.
- To represent the applicability of the digital elevation models (DEM) in the evaluation of the vineyards and fruit production areas with the modeling of the natural terrain and the phenomenon closely associated with it.
- To study the artificial terrain elements (supporting walls) with the condition assessment of the vine terrace - dry stone wall system.
- To analyze the aerial hyperspectral images for assessing the condition of the biomass.
- To reveal the temporal and spatial fluctuation of land use as well as to analyze the connection (system) between the land use variation and the natural conditions, applying geoinformatical methods.

2. METHOD AND MATERIALS

In the dissertation especially the vine and fruit production areas are examined, therefore the geoinformatical analysis of the agro-ecological factors were also processed in this view. The study was carried out on 3-3 different vineyards and fruit plantation.

Vineyards

All three vine hill has strong viticulture traditions where the landscape transformation looks back to more than 1000 years.

- ***Csobánc Hill***: It is situated in the Tapolca Basin next to the village of Gyulakeszi (46º 52’ 08”N, 17º 28’ 55”E) which is the part of the and the Badacsony Historical Wine Region. The 375 m alt basaltic circumdenudated butte covers an area of approximately 300 ha. Till 200-240 m the bedrocks of the hill consist of mainly Sarmatian limestone, Pannonian gravels (greyish-white and yellowish-brown sand, sandy-clay, clayey-marl) and Pliocene basalt. Up to approximately 270 m altitude the foothill area consisting of the Pannonian sediments, characterized by mainly slopes less steeper than 40% is the main area for the viniculture. The 39% of the total surface represents the best area for the vine cultivation (southern, 5-25% gradient). The Csobánc Hill is characterized by calcareous soil with a clay-loamy or loamy-silt texture.
- ***Sátor Hill***: The Sátor Hill is the part of the world heritage site the Tokaj foothills (Tokaj-Hegyalja) Historical Wine-producing Region next to the city of Abaújszántó (48º 16’ 30”N, 21º 11’ 01”E) in the NW border of the wine region. In 2002 UNESCO incorporated it into its World Cultural Heritage list as a region of outstanding cultural significance thanks to the untouched, original form of viticulture traditions which were developed over the last thousand years, the characteristic vineyards, wine cellars, architecturally traditional villages and towns. It occupies an area of 140 ha. The parent material consist of Sarmatian - Pannonian acid rocks, rhyolitic tuff and rhyolite lava composing several hundred meters wide strata. More than 50% of its whole area is characterized by steep slopes (17-25%, 25-40%), in addition the slopes with more than 40% occupy further 11.42%. On the hill vineyards have been cultivated up to nearly 300 m above sea level according to the placement of the terrace-dry stone wall system. Ramann brown forest soil and chernozjem brown soils were developed on the volcanic bedrock and loess slopes.

- ***Nagy-Eged Hill***: Nagy-Eged Hill is located on the southern part of the Bükk Mountains, next to the town of Eger (47°55'27.44"N, 20°24'55.25"E). The Nagy-Eged Hill is the one of the highest grapevine cultivating area in Hungary. The 537 m high hill covers 280 ha. The hill’s major part consists of Upper Triassic (Nori) light grey limestone on which Upper Eocene yellowish-white, fine calcareous marl and white nummulitic limestone settled. The steep (17-25%) slopes represents the 30.3% of the cultivated area and further 28.6% of its area is covered by the 12-17% slopes. The vineyards are situated on the southern steep slopes. Modern plantations on the Nagy-Eged Hill consist of trained vines, usually planted perpendicular to the contour lines and without terraces and irrigation system. The original soil type was humus-rich carbonate rendzina, which can be eroded very easily and bare limestone remains on the surface. The erosion is very characteristic for its cultivated area due to the very high slope angle and the cultivation methods of the grape parcels.

Fruit plantations

- ***Újfehértó***: The investigation was carried out in the area of Fruit growing Research and Consultant non-profit company, near Újfehértó (47° 49’ 30” N; 21° 40’ 27” E) in the Nyírség. The total cultivated area (fruit plantations and arable land) of the research company is approximately 300 ha large. The pear gene bank studied in detail is 2,74 ha large with 1660 tree spaces (row pace is 8 m and the space between the trees is 2 m). It was established in 1982. The investigated genetic collection consists of 673 apple, 480 pear, 57 quince and 28 naseberry species, varieties and hybrids, from these 389 are for genome preservation. The relief was shaped by the surface forming processes, specifically the shifting sand movement, during the Pleistocene. 92.06% of the area has 0-5% slopes. The physical characteristic of the soil is sandy.

- ***Siófok***: The plantation is situated in the South East shore line of Lake Balaton, next to town of Siófok (46°52'33.05"N, 18° 1'2.92"E). The examination area (property of the Siófok Fruit Growing Co.) occupies 300 ha. Cherry, peach, apricot, pear and quince plantation were planted. The bedrock’s components are Pliocene fluvial sand and gravel sediments. The area is characterized by relatively gently slopes and bordered by steep valleys. The percentage of the southern slopes is very low within the sample site. The highest point is at the southern part of the plantation and the altitude is decreasing from this point northwards and towards Lake Balaton. The physical characteristic of the soil is sandy loam and loam.

- ***Nagykanizsa***: We investigated 3 larger fruit plantation of Gyümölcskert Zrt. next to the settlements of Surd (46°21'36.18"N, 16°57'34.00"E), Szepetnek (46°25'41.01"N, 16°52'0.51"E), and Zalasárszeg (46°29'31.58"N, 17° 5'22.53"E). The plantations mainly consist of Bosc, Williams, Packhams, Triumph, Conference and Clapp pear breeds grafted on wild and Farold-87 under stocks. The plantations were established on the ridges between meridional valleys having slopes less than 17%. Most of the slopes' direction is westward. The main physical assortments of the soil are sandy loam and loam with loamy clay spots.

Examination of the artificial and natural surface

With the digitalization of the 1:10000 scale topographical maps based on the elevation points and contour lines I created digital elevation models for all the sample sites. Uniformly 5x5 m raster pixel resolution was applied in case of every parameters and variables.

In case of the slope category maps I used both the accepted classes by the international agriculture (0-5%, 5-12%, 12-17%, 17-25%, 25-40% and >40%) and the vineyard classification system's categories. 8 and 16 class were applied to describe the directions of the slopes. The relative relief maps (differences between the lowest and highest point in meter /1km^2) and "valley" density maps (length of the runoff in meter /1km^2) were created based on the DEM (Digital Elevation Model) for the wider area of the fruit plantations. Furthermore I calculated TWI (Topographic Wetness Index) based on the DEM.

Based on the digital elevation model I created the direct soil surface radiation map for each of the sample sites assuming a clear sky and the maximum radiation which belongs to the given latitude. The maps display the full radiation in a certain cell given in Wh/m^2. The maps were used during the geoinformatical adaptation of the vineyard classification system as well as during the geostatistical analyses.

I created a terrain model about the area of the genetic pear orchard of Újfehértó based on the hyperspectral images and field measurements to be able to calculate the radiation values more precisely. This model takes into consideration the spatial coverage of the foliage besides the natural surface. I defined the trees' foliage parameters (width, height) based on the results of the field measurements and the NDVI (Normalized Difference Vegetation Index) maps derived from the hyperspectral images. These parameters were used during the interpolation. The NDVI image were reclassified to 4 categories: bare soil surface, grassland between rows, weak foliage and healthy - dense foliage. With the help of the completed parametrical model I defined the height value of every ‘unknown’ cell in the area of the pear gene bank using univocal assignment. I used the terrain model, created with this method, to calculate the average evaporation value.

We sized up the actual condition of the supporting walls, their length, height and the extent and frequency of the different types of wall damages (wall belly, destruction and soil flow). The dry stone walls examined on the Sátor Hill (271 pieces) were 2.33-205.05 m long and 48-300 cm high in average 149.3 cm. The 86 dry stone walls, examined in detail on the Csobánc Hill, were 6.29-146.18 m long and 50-250 cm high. Furthermore the thickness of the soil layer accumulated on the crown and base of the dry stone walls were measured. I determined the frequency of phenomenon depending on the height of the dry stone wall. I studied the relationship between the dry stone walls ruination and the characteristic land use on the neighbouring vine terraces. I differentiated four basic types: cultivated terraces, abandoned terraces for a short time (<5 years), abandoned terraces in the recent past with grassy vegetation (5-25 years) and the long-time abandoned terraces with dense shrub and tree vegetation (>25 year).

The examination of soil parameters

To reveal the relationship between the soil parameters and the dilapidation processes of the dry stone walls we carried out soil samplings. On the Sátor Hill and the Csobánc Hill we have taken soil samples from the accumulated terrace material sections from behind the already ruined down dry stone walls from 2006 till 2010. 7-7 different sample sites on the sections of the crashed down dry stone walls have been sampled at every 10 cm (161 soil samples altogether). The soil analysis was taken place in the laboratories of the Geosciences Departments and Institute of Water and Environmental Management. The analysis of pH (H_2O, KCl), humus (Tyurin method), $CaCO_3$ (Scheibler calcimeter) and grain size distribution (dry separation and wet deposition) was performed on the soil samples. Before analysing the soil physical composition the fine fraction of the samples has been separated from the rough rock detritus using boiling distilled water. The proportion of grains, larger than 10 mm, was not taken into consideration during the analysis. The grain fraction (<0,2 mm) was defined in volume percent.

The macro element content of the soil was measured with a mobile NITON XL-700 X-ray fluorescence spectrometer in the lab of Institute of Water and Environmental Management. The prepared 50g fraction (<0,2 mm) was measured for 60 sec repeated for three times in foil sacks. Soil erosion calculation was carried out on the basis of 1:5000 scale soil map at Újfehértó. In the course of geoinformatical processing the Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) equation was used.

Analysis of the hyperspectral images

The hyperspectral images were made with two hyperspectral sensors of the AISA DUAL airborne hyperspectral cam system which were installed and operated in cooperation by the University of Debrecen, Institute of Water and Environmental Management and by the Mechanization Institute of Agricultural Ministry in Gödöllő. The Eagle camera takes images in the visible and near infrared range (400- 970 nm), while Hawk operates in the middle infrared range (970-2500 nm). The two cameras were installed into a common mount which is able to take pictures in 498 spectral channels altogether.

For the spectral analysis of the Újfehértó sample site I used the hyperspectral images with radiometric and geometric corrections. The spatial resolution of the images taken on 29th July 2009 was 1.5 m. During the fieldwork we collected data for the spatial and spectral analysis. ENVI 4.7 software was applied for the analysis of hyperspectral images.

The pigment of the plant leaves, chlorophyll, intensely absorbs in the visible spectrum (in red from 630 to 690 nm) on the other hand it strongly reflects the near-infrared (NIR) light (from 700 to 1100 nm). Utilizing these numerous vegetation indices were established, with the definition of the spectral profiles and the jumping out values, which are used for assessing the spatial differences in the green vegetation. Therefore I calculated several vegetation indices related to health state, and water stress (Table 1).

To define the spectral similarity between two spectrums the Spectral Angle Mapper (SAM) method was used (Kruse et al., 1993). I reclassified the hyperspectral images into 4 vegetation types (fruit plantation, grassland, arable land, bare soil surface). I made spatial correlation measurements for each of the four land cover types during which I compared the values of the vegetation indices with the soil and terrain data.

Table 1. Calculated vegetation indices

Normalizált Differencia Vegetációs Index - **Normalized Difference Vegetation Index** (*Tucker*, 1979)	$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}$
Vörös él Normalizált Differencia Vegetációs Index - **Red Edge Normalized Difference Vegetation Index** (*Sims és Gamon*, 2002)	$NDVI_{705} = \frac{\rho_{750} - \rho_{705}}{\rho_{750} + \rho_{705}}$
Módosított Vörös él Normalizált Differencia Vegetációs Index - **Modified Red Edge Normalized Difference Vegetation Index** (*Sims és Gamon*, 2002)	$mNDVI_{705} = \frac{\rho_{750} - \rho_{705}}{\rho_{750} + \rho_{705} - 2\rho_{445}}$
Módosított Vörös él Index - **Modified Red Edge Simple Ratio** (*Sims és Gamon*, 2002)	$mSR_{705} = \frac{\rho_{750} - \rho_{445}}{\rho_{705} + \rho_{445}}$
Nedvesség Stressz Index - **Moisture Stress Index** (*Hunt és Rock*, 1989)	$MSI = \frac{\rho_{1599}}{\rho_{819}}$

Land use change examination

The airborne images with 0.5 m resolution, the cadastral maps (1:4000 and 1:2000) and the topographic maps (1:10000) served as suitable reference data for Sátor Hill and Csobánc. After digitalized I processed maps from 10 times (1784-2007) at Sátor Hill and maps from 8 times (1858-2008) at Csobánc Hill. To compare the different land use categories I defined 8 main classes: Vineyards-1, Fruit plantations and small gardens-2, Grasslands-3, Arable lands-4, Abandoned area-5, Forest-6, Other-7, Pathways-8. The other class also includes the abandoned pathways and gullies.

I determined the strength of the relationship between the land use and the factors derived from the digital elevation model. The examined factors were as follows: elevation zone maps, slope degree, slope direction, solar radiation, distance from pathways and the forest, slope values and the vineyard values based on the vineyard classification system (5.1. factor).

Modelling the Vineyard Classification System with geoinformatical methods

For two sample areas (Csobánc Hill and Sátor Hill) I generated the layers determining the availability of the complex production area according to the point system presented in the 95/2004. (VI.3.) FVM regulation. In order to determine the appropriate pixel resolution for the geoinformatical processing of the point system and for evaluating the relief conditions I included an additional sample site (Nagy-Eged Hill). I prepared map layers among 7 main parameters - soil (2), terrain (5), land use (6), roads (7) - in the point system with processing multistep. However, I assigned equal point values in the total area of the hills for the agro-meteorology (1), water management (3), and erosion (4) main parameters. For producing the main component maps, describing the land use and terrain, I processed topographic maps (1:10000) together with 0.5 m aerial ortophotos. I defined the soil value layers according to the soil maps of Kreybig and Géczy (1:25000) and the geographic maps (1:100000).

Applied geoinformatical and statistical methods

I georectified the paper based airborne pictures and maps, having different reference system, with the Erdas 9.1 software environment applying quadratic and tertiary polynomial Nearest Neighbour method (margin of error: 0.03 RMS). I corrected the spatial accuracy in case of the occasional distortions in ArcGIS 9.1 software environment using the Spline method. To create the terrain-, pedological-, land use factors and for the qualitative characterization of the map layers I worked out parametric models using ArcGIS 9.2 and Idrisi Tajga software. Correlation analyses were made with SPSS 17 software and geostatistical applications of ArcGIS. I used Kolmogorov-Smirnov test to determine the data distribution type and to determine the strength of the relationship I applied principle component analysis as well as linear and partial correlation in SPSS environment.

3. MAIN STATEMENTS OF THE DISSERTATION

Natural relief

The terrain play an important role in the Vineyard Classification System, it represents the 40.5% of complete score, while it only represents maximum 6-20% of score of Fruit Plantation Classification System. I created the maps of the variables, describing the surface, using indices derived from Digital Elevation Model. I characterized the spatial distribution of the factors representing the relief and determined the main differences between the sample sites. My results indicated that the reason behind the illness and weak yield of the Surd plantation is in connection with the relief features which can be moderated with the suitable land forming. Using airborne hyperspectral images I worked out a new geoinformatical method for modelling the surface of the orchards which is able to display the natural relief and the foliage of the trees together in one model. The developed terrain model is suitable for calculating solar radiation values for a certain plantation as well as it can be used indirectly during the irrigation planning.

Anthropogenous forms

Terrace-supporting wall system was developed on the vineyards to decrease the slope gradient and the effect of the erosion. The state of the traditionally terraced agricultural areas has been worsened significantly throughout Europe in the past hundred years. The ruination process of the terrace - dry stone wall system is a characteristic problem both for the Sátor Hill and the Csobánc which can thwart the cultivation as well as it indirectly reduces the agroecological potential. *Carl and Richter* (1989) pointed out, according to their research in the area of Cinque Terre, that the direct cause of the ruination of the dry stone walls is mainly the water movement after the heavy rainfalls in spring. Along the compaction horizon, at around 40cm deep, the strong sideward infiltration through the leaks of the wall accumulates fine particle sized material which facilitates the dilapidation of the dry stone walls. The rate and extent of the structural damages of the dry stone wall system increased progressively after the cultivation has been finished in Cinque Terre.

I verified with measurements that the landscape degradation phenomenon affects large parts in my study areas too. Similarly to the observations in Cinque Terre the farmers at Sátor Hill and Csobánc Hill reported the damage of the supporting walls in the springtime (April – May) too. On the average the total length of the wall breaks is 1.7 times larger than the total length of the wall-bellies however the number of wall-bellies is 1.9 times more than the number of the breaks. The value of correlation between the total height of the walls and the phenomenon’s distance from the crown of the walls is 0.5 in case of the wall-bellies and 0.8 in case of the wall breaks in ($p<0,05$) significance level. So the higher is the wall the lower the wall breaks appear.

Table 2. The frequency of the wall breaks in different vegetation stage at Sátor Hill

	Cultivated	**Abandoned (<5 év)**	**Abandoned (5-25 év)**	**Abandoned (>25 év)**	**Sum**
Height of walls (cm)	70-250	110-160	72-300	48-300	**48-300**
Number of walls	10	6	13	7	**36**
Length of walls (m)	556,9	223,8	491,8	301,7	**1574,2**
Number of breaks (db)	197	101	155	98	**551**
Length of breaks (m)	65,3	38,2	109,9	75,7	**289,1**
Number of breaks /100 m	35,37	45,13	31,52	32,48	**144,5**
Relative differences	35,37	9,76	-13,61	0,96	-
Length of breaks /100 m	11,72	17,07	22,34	25,09	**76,22**
Relative differences	11,72	5,35	5,27	2,09	-

The extent of the wall breaks in case of the Sátor Hill’s dry stone walls is shown in the summarizing data series of Table 2. The ruination process and its main features of the dry stone wall system on the 2 study area differ notably from the ones experienced in Cinque Terre. On the observed vineyards I recognized that the wall degradation is more significant on the cultivated parcels than in Terre. Both the number of the structural damages and the spatial extent of the damages, correlated to the whole length of the wall, were large in case of the cultivated terraces, while this ration were slightly higher in the phases abandoned.

Soil features

After processing of the 161 soil samples I defined the relationship between the soil parameters and the dilapidation process. I assessed the effect of grain size distribution, pH values, $CaCO_3$ content and some nutrient elements to the dilapidation process of dry stone walls. Based on the results of the cluster analysis I defined what parameters are altering collectively this phenomenon the most. The distance of the dilapidation from the crown of the wall in explained in 35% by the factors in the first component together (grain size:<0.2, <0.02, <0.002 mm; pH: H2O, KCl; Rb, K) while the dilapidation zone is represented only with 27%. Studying only the effect of the 3 grain fractions I received a value around 10%, when the significance level dropped significantly. Thus my hypothesis, that the grain size distribution has a role in the dilapidation process, was only partly verified.

The examination of the soil factors has an outstanding role in the vine and fruit production area classification. The sustainable usage of the plantations should be secured for a long term as the average life span of a plantation is more than 10 years. I studied the changes in the spatial extension of the area endangered by the erosion in the Újfehértó plantation with modelling different rainfall intensity events. The Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) equation was used. The results increased by the R factor (250, 500, 750 $MJ*mm*ha^{-1}*h^{-1}*y^{-1}$) is shown in Table 3. Increasing the R factor the extension of the non-eroded areas halved (1) while the erosion risky areas (3) more than doubled in all the three surface cover categories (Fruit, Grassland, Arable Land).

Table 3. Estimated erosion in rate of area (%) according to R factor (erosion level 1:0-2t/ha/y, 2:2-11t/ha/y, 3:>11t/ha/y; land use: F-fruit, G-grassland, A- arable land)

R	**250**			**500**			**750**		
	F.	**G.**	**A.**	**F.**	**G.**	**A.**	**F.**	**G.**	**A.**
1	28.0	76.5	39.5	15.2	63.3	21.8	10.4	48.6	15.1
2	55.9	22.0	51.7	47.3	26.5	53.4	34.0	36.1	43.5
3	16.1	1.5	8.7	**37.4**	10.2	**24.8**	**55.6**	15.3	**41.4**
	100%	100%	100%	100%	100%	100%	100%	100%	100%

Fruit orchards

The health state of a plant represents the best the changes in the natural conditions and production circumstances. When the unfavourable influences are getting stronger in one of the agroecological factor it will manifest in the vegetation too: water stress, lack of nutrition and yield decrease. In order to define in which extent terrain and soil parameters are explaining vegetation state I used vegetation indexes derived from hyperspectral images. In case of arable lands I revealed weak statistical relationship ($r<0.4$; <0.01) between some terrain, pedological indicators and vegetation indices. However in case of the grasslands and fruit plantations this kind of weak relationship wasn't revealed. Further studies are needed to reveal the relationship system more precisely in case of fruit plantations and grasslands. According to stepwise regression analysis the soil parameters have higher influence on the vegetation indices than the relief factors. The cause could be among others that inside the chosen sample site the elevation difference is very small scale.

Land use change

Examining the two vineyards (Sátor Hill and Csobánc Hill) I defined the land use categories' spatial extension changes and their extent using historical maps. I determined the terrain factors and their intensity with cross tabulation process and timeline trend analysis. Most of the cases I revealed significant linear trends between the vineyard area and slope features, the direction of the changes were similar in case of both hills. I pointed out that the 95% of the cultivated vineyards are located between 90 m from the hill roads and the rate of the abandoned areas and forests is quite high even near to the roads. This emphasises further the degradation of the landscape in the vineyards.

I examined the shift in the vineyard area from the view of the slope point values (5.1 factor) of the vineyard classification system as well as the total score of the production area. A strong correlation can be experienced between the extent of the historical grape covered areas and the slope point value which derives from the vineyard classification system Fig 1. Thus the slopes having excellent slope degree and direction will remain in cultivation in the future more likely.

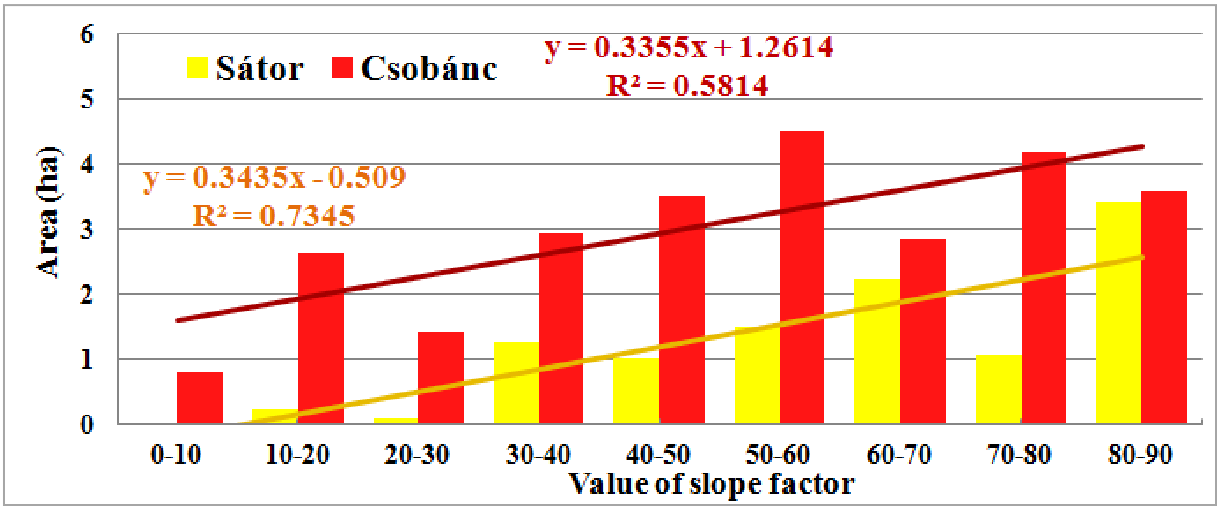

Figure 1. Relationship of the cultivated vineyards all the time and the values of the slope factor

The vineyards remained for a long time in the areas with generally higher total cadastre score which is also represented by the strong linear relationship (Fig 2). However, there are also premium quality areas among the parcels which became grassland or forest, consequently we cannot declare that just the parcels, having less score, have been abandoned. I established that the production area point value - as one of the measuring factor of the natural features – can be used for assessing the root cause of the land use changes. However in summary I came to the conclusion that the land use changes in the examined two vineyards were affected less than 55% by the production area's conditions.

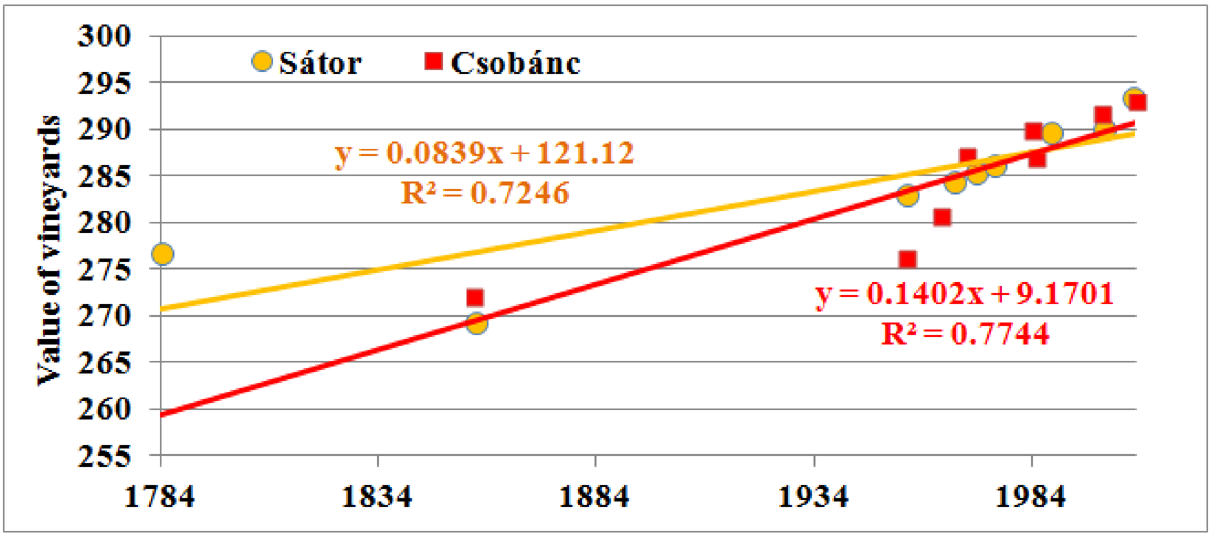

Figure 2. The mean values of the cultivated vineyards according to the vineyard classification system during the years

Geoinformatical modelling of the vineyard classification system

In the course of my research I produced the digital maps of factors using parametric geoinformatical models according to the scoring system of the vineyard classification system. Figure 3. shows some of the map layers of the production of terrain (5) as one of the main factors. The ideal spatial resolution is 5 or 10 m for the geoinformatical processing of the vineyard classification system, which was defined by the terrain main factor weighted with 40% in the evaluation system. I concluded that the usage of the 80 classes (16 slope direction x5 slope gradient) are not justified from the aspect of the terrain scoring. Applying the 8 slope direction the loss information wasn't significant and the rate of the mosaic patterns also decreased.

I proved during the verification process using linear regression analysis that the influence role of the 16 slope direction classes is inferior. I also concluded that the solar radiation represents itself within the slope score with a maximum of 50% which depends on the variability of the terrain elements in a sample site. I came to the conclusion that the evaluation based on digital maps provides much more detailed results compared to the "ecotop" (production area input unit) map used in the wine community level. Within the production area total score the terrain factor is significantly overrepresented compared to the other main factors. In case of digital processing the total score value of the production area is yet determined in more than 50% by the slope feature scores. This value is significantly higher than the maximum rate (22,1%) of the score values according to the regulation. This overrepresentation is caused by the other factors' great homogeneity and the small variation of the score values. The difference is traceable even through the map layers describing the terrain features Figure 3.

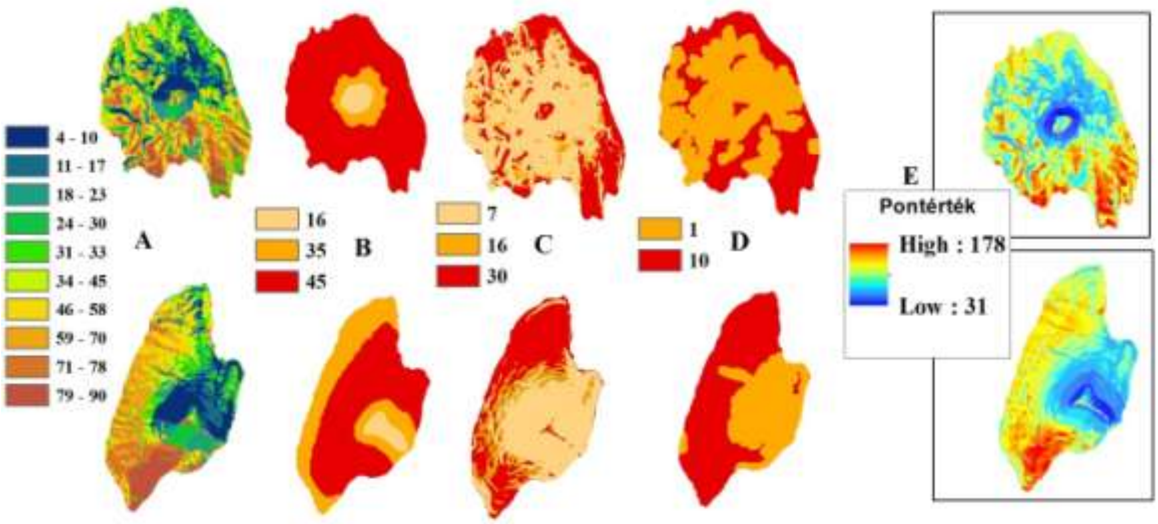

Figure 1. Determination of the terrain factor on the Csobánc Hill and the Sátor Hill (A) slope direction and slope gradient altogether, (B)elevation zones, (C) landscaping, (D)distance from forests

4. NEW AND NOVEL SCIENTIFIC RESULTS OF THE DISSERTATION

Scientific results:

1. I demonstrated numerous aspects of the production area evaluation applying geoinformatical methods; I developed a mapping method to spatially determine the factors of the vineyard production area classification system for which I used information derived from different data sources together.
2. I defined the conditions of the applicability of the vineyard production area classification system in a geoinformatical system along with the ideal spatial resolution. I made a suggestion to decrease the slope factors weighting with nearly 50%, applied in the traditional vineyard production area classification system’s scoring system. The reliability of the geoinformatical evaluation doesn’t decreases in this way.
3. I proved the importance of the geoinformatical mapping in the assessment of the agroecological parameters of the fruit plantations.
4. Based on the NDVI values derived from the airborne hyperspectral images I developed a new terrain modeling method for calculating the tree level evaporation values.
5. I mapped the state of the dry stone walls in the sample sites which affects the agroecological potential as well as I introduced the features of the degradation process.
6. I defined the relief factors involved in the land use change; also evaluated the process in comparison with the point values of the vineyard production area classification system.

Practical results:

1. The parametric models, developed during the research, allow the faster evaluation of the production areas using appropriately prepared data. They also help to identify problematic places and to plan investments.
2. The geoinformatical evaluation system of the vineyard production area classification system is applicable within the Vineyard Geographic Information System (VINGIS) and it allows a more detailed assessment also in a wine community level.

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