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Research Article

Terroir-Driven Viticultural Micro-Zoning In Bozcaada-Turkey

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Abstract

Bozcaada is renowned for its vineyards and wines. The island is located in the northeast of the Aegean Sea, in the southwest section of the Marmara region in Turkey. It is the third largest island in the Aegean Sea after Gökçeada and Marmara Islands. The dominant crops are grapevines, legumes, cereals, and fruits. The total vineyard area in Bozcaada is 11.850 ha, which covers 1/3 of the island and 80% of the agricultural lands. The two main factors that support viticulture and winemaking on the island are the unique soil types and the climate conditions, especially the north winds that determine the optimal diurnal temperature variation for viticulture. The island is unique for its viticulture and is characterised by its “terroir”. Terroir is a French word that describes how the interaction of the soil, terrain, and climate effect the vine, and how the combination of this effect with the human factor and viticulture management practices influence the quality of the grapes. In this study, qualitative and quantitative land evaluation tools were implemented to assess the lands and to suggest the most suitable rootstocks and varieties to winemakers. The land evaluation model uses climate, soil, and terrain indicators to evaluate the suitability of the soil-mapping units to the rootstocks and vine varieties. A detailed soil map was produced and has been implemented into the process together with other soil characteristics and climatic/topographic indicators. GIS and remote sensing tools have been used to create the soil map and input layers. Aspect, slope, and elevation layers were produced using the ArcGIS 3D Analyst tool from SRTM (Shuttle Radar Topographic Mission) data distributed by the Joint Research Centre together with the International Centre for Tropical Agriculture in Colombia. The SRTM digital elevation data, originally produced by NASA, is a major breakthrough in digital mapping and provides high quality elevation data for mapping and survey studies. Soil plays an important role in land evaluation and site selection, especially in site assessment for vineyards as the soil use to grow vines effects the fruit quality and flavours of wines. A detailed soil map of the island was produced to provide high quality soil data to be used in the land evaluation model. In this study, the components of the terroir concept and their complex relationships have been analysed to evaluate the land resources of the study area and several indices have been calculated for use in the land evaluation model, these are: Branas Heliothermic Index, Huglin Heliothermic Index, Cold Night Index, Winkler Index (IW), Jackson and Cherry Index, Riou's Drought Index, and Jones Index.

Keywords: Bozcaada, terroir, viticulture, viticultural zoning, land evaluation

Bozcaada’da (Türkiye) Terroir Odaklı Bağcılık Mikro Zonlaması

Öz

Bozcaada üzüm bağları ve şaraplarıyla ünlüdür. Ada, Ege Denizi'nin kuzeydoğusunda, Türkiye'de Marmara bölgesinin güneybatı kesiminde yer almaktadır.. Baskın ürünler asma, baklagiller, tahıllar ve meyvelerdir. Bozcaada'da toplam bağ alanı 11.850 ha olup adanın 1/3'ü ve tarım arazilerinin %80'i kaplamaktadır. Adada bağcılığı ve şarap yapımını destekleyen iki ana faktör, benzersiz toprak türleri ve iklim koşulları, özellikle de bağcılık için en uygun günlük sıcaklık değişimini belirleyen kuzey rüzgârlarıdır. Ada, bağcılık açısından benzersizdir ve “terroir” ile karakterize edilir. Terroir, toprak, arazi ve iklim etkileşiminin asmayı nasıl etkilediğini ve bu etkinin insan faktörü ve bağcılık yönetimi uygulamalarıyla birleşiminin üzümün kalitesini nasıl etkilediğini anlatan Fransızca bir kelimedir. Bu çalışmada arazilerin değerlendirilmesi ve şarap üreticilerine en uygun anaç ve çeşitlerin önerilmesi amacıyla niteliksel ve niceliksel arazi değerlendirme araçları

uygulanmıştır. Arazi değerlendirme modeli, toprak haritalama birimlerinin anaçlara ve asma çeşitlerine uygunluğunu değerlendirmek için iklim, toprak ve arazi göstergelerini kullanır. Ayrıntılı bir toprak haritası oluşturulmuş ve diğer toprak özellikleri ve iklimsel/topografik göstergelerle birlikte sürece uygulanmıştır. Toprak haritası ve girdi katmanlarının oluşturulmasında CBS ve uzaktan algılama araçları kullanılmıştır. Bakı, eğim ve yükseklik katmanları, Kolombiya'daki Uluslararası Tropikal Tarım Merkezi ile birlikte Ortak Araştırma Merkezi tarafından dağıtılan SRTM (Shuttle Radar Topographic Mission) verilerinden ArcGIS 3D Analyst aracı kullanılarak üretilmiştir. Orijinal olarak NASA tarafından üretilen SRTM dijital yükseklik verileri, dijital haritalamada büyük bir atılımdır ve haritalama ve araştırma çalışmaları için yüksek kaliteli yükseklik verileri sağlar. Toprak, arazi değerlendirmesinde ve yer seçiminde, özellikle üzüm bağları için yer değerlendirmesinde önemli bir rol oynar. Çünkü asma yetiştirmek için toprak kullanımı meyve kalitesini ve şarapların lezzetini etkilemektedir. Arazi değerlendirme modelinde kullanılmak üzere yüksek kaliteli toprak verileri sağlamak amacıyla, adanın detaylı toprak haritası üretilmiştir. Bu çalışmada, çalışma alanının arazi kaynaklarının değerlendirilmesi amacıyla bölgesel kavramının bileşenleri ve bunların karmaşık ilişkileri analiz edilmiş ve arazi değerlendirme modelinde kullanılmak üzere çeşitli endeksler hesaplanmıştır. Bunlar; Branas Heliothermic Index, Huglin Heliothermic Index , Soğuk Gece Endeksi, Winkler Endeksi (IW), Jackson ve Cherry Endeksi, Riou Kuraklık Endeksi ve Jones Endeksidir.

Anahtar Kelimeler: Bozcaada, Terroir, Bağcılık, Bağcılık zonlaması, Arazi değerlendirme

Introduction

Successful viticulture begins with land selection. For commercial purposes, land selection is the most important decision in the overall process, as this decision influences profitability and production for the next 30 to 40 years (Kurtural et al., 2008). The basic components to be taken into account when making this decision are climate, soil, and topography. In this study, the components of the terroir and the complex relationships between those components and how the soil, climate, and topography are used in the selection of the vineyards were examined in many aspects. By studying these relationships and using scientific data, the lands of Bozcaada, which have a long history of winemaking and a high potential for the future, were evaluated within the concept of terroir.

According to Robert White (2009), unlike all other products, the taste and flavor of wine is directly related to the soil. In his study "Terroir: At the Heart of Geography", Unwin says that the French term “terroir”, which is defined as “land” in most language dictionaries, is actually a much more complex and comprehensive term that refers specifically to the complex relationship between land and geology, soil, climate, geomorphology, and vegetation (Unwin T., 2012).

Climate is crucial for vines as it is for all agricultural plants. Extreme temperatures during summer and winter months limit vegetative growth and shorten the lifespan of vines to a significant extent. Climate can also positively or negatively affect the yield and quality of fruits (IAGT, 2014). When considering the climatic parameters according to IAGT 2014, sufficient length of vegetation period, sunshine and temperature, plant nutrients, sufficient water sources, and drainage factors come into prominence for viticulture. In terms of viticulture, climate is based on three indicators: macroclimate (at the district level), mezoklima (at the parcel level), and microclimate (at the vine level) (Carbonneau, 2001). Taking into account the bio-ecological potential of the vine, the relationship between climate demands and biological reactions has been transformed into numerical indicators and expressions called indexes. Using these indicators, the numerical limits on the quality of viticulture, and whether or not viticulture could be performed in a geographical region, are obtained (Bahar et al., 2010).

The main components of viticulture activity are geographic and topographic components, which are comprised of geographical location, aspect, elevation, and slope. Considering that viticulture is generally performed in the northern hemisphere between the latitudes of 11 and 55 (primarily between the latitudes of 30 and 50) (Çelik et al., 1998), it is feasible to say that Bozcaada is a suitable location for wine and table wine production. The latitude is important since this aspect determines the arrival angle of the sunlight over the vineyard area and directly affects the total temperature budget. Even if the area where the vineyard is built is in a temperate zone, the vineyard should receive direct sunlight for at least part of the day. In viticulture, the regions with all the right aspects provide optimum benefit. The morning sun provides the necessary light for photosynthesis at the right time, while quickly condensing moisture from the fruit and leaves. Areas having their aspects to the south and west orientations become hot during the spring and budding occurs earlier than in vineyards with aspects to the north. Height is one of the most important topographic components for

viniculture. When talking about height, the height above sea level and the relative height are both significant. The relative height refers to the height of the vine area relative to its circumference, and is one of the important parameters that determine the degree of cold damage in winter months. On the other hand, slope is an important feature for viticulture, as it determines the effect of other important terroir components, such as soil and climate characteristics, on the vine. While mild to moderate gradients (5-10%) are preferred for rapid removal of cold air in viticulture, higher gradients than these values are not desirable as they can lead to erosion (Kurtural et al., 2008).

One of the most basic and irreversible decisions in viticulture is the selection of a location. The selection of rootstocks and types to be planted should be based on topographic, climatic variables and the results of a physico-chemical analysis of the soil. Therefore, it is necessary that the rootstock and type should be in harmony with climatic conditions, physiographic structure, soil fertility, and structure of the region. This study has been carried out in Bozcaada, where the non-purpose use of land, under the name of vineyard house, has increased rapidly in recent years and the fertile agricultural land has been rapidly destroyed. In this study, Bozcaada lands were surveyed and a detailed basic soil map was prepared at a scale of 1:10.000. By using climatic and topographic characteristics, land evaluation for viticulture has been developed. In recent years, the concept of "viticultural zoning" has been mentioned frequently when evaluating sites for vineyards. Vaudour describes it in his book "Les Terroirs Viticoles - Définitions, Caractérisation et Protection" as a separation of regions according to their characteristics for the production of grapes and wines (Vaudour, 2003). As a result of this study, the basic components used in the study and separated into zones, were determined as soil, topography, and climate.

Material and Method

Bozcaada is an Aegean island with an area of approximately 36 km^2 and a population of 2,465 (2012), according to the census made by the Turkish Statistical Institute (TUIK) with the "Address Based Population Registration System" (ADNKS). Bozcaada, a district of Çanakkale province, is located in the Marmara Region, in the south-western Marmara sub-region, to the northeast of the Aegean Sea (Figure 1).

Figure 1. Geographical location of work area

Bozcaada is famous for its wine grapes and wines. Most of the island is covered with vineyards. A small amount of cereals, legumes, and fruit are also grown. The island is an important place when it comes to growing wine grapes. What makes Bozcaada so special for wine can be described as “terroir”. Bozcaada is a natural extension of the Biga Peninsula and shares both geological aspects and topographical features of that region. The main geological units of the island are Palaeozoic schist and marble, ophiolites formed by submarine volcanism, the red coloured basal conglomerates of Eocene (which uncomfortably overlie these basic units), limestone, sandstone, marl and clay stones in the

flysch facies, the conglomerate, sandstone, and macrotric limestone of the Miocene, and red and pink coloured andesite.

The climate of Bozcaada is affected by its location in the northeast Aegean Sea, where it is influenced by the Mediterranean and Thrace. For this reason, the winter months are mild and the summer months are generally dry and hot. According to data obtained from the island's meteorological station belonging to the General Directorate of State Meteorological Services, from the 32-year period from 1975 to 2006, the annual average temperature of the island was calculated at 16.8 ^{0}C and annual precipitation at 497 mm. The altitude of the Bozcaada meteorology station is 28 meters, whereas the average altitude on the island is 39 meters. The station's geographical coordinates are 39.50 latitude and 26.04 longitude. The basic temperature and annual precipitation parameters calculated from the data obtained by the General Directorate of State Meteorological Services are presented in Table 1.

Table 1. Basic meteorological data for the study area

		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Monthly Average Temperature	°C	**8.3**	**8.2**	**9.8**	**13.6**	**17.3**	**21.5**	**23**	**23**	**20.7**	**16.9**	**12.7**	**9.8**
Monthly Average High Temperature	°C	10.6	10.7	12.5	16.6	20.6	25.1	26.4	26.2	23.9	19.6	15.2	12
Monthly High Temperature	°C	19.6	20.9	25.9	26.3	31.5	35.3	35.4	36.3	32.4	31.2	26	21.5
Monthly Average Low Temperature	°C	5.9	5.8	7.1	10.7	14.2	18.1	19.8	20	17.9	14.4	10.4	7.5
Monthly Low Temp.	°C	-5	-7	-4.7	2	6.1	9.1	14.3	15	12	4.6	-1.4	-4
Monthly Average Precipitation	mm	67.8	57.9	53.4	39.1	23.2	10.8	5.8	5.4	19.3	26.2	70.8	86.1
Monthly Avarege Sunshine	hours	2.46	3.54	4.59	7.25	10.47	10.53	10.57	10.4	7.49	4.3	4.46	3.56

The elevation, aspect, and slope data (Figure 2a, b, c, d) of the island were generated using SRTM's 90m (Shuttle Radar Topographic Mission) data from the European Commission Joint Research Centre (EU-JRC) and International Tropical Agriculture Centre (Jarvis and Ark, 2008). SRTM digital elevation data is produced by NASA and is widely used in digital mapping projects. The elevation model's resolution, which was originally 90 meters, has been reduced to 100 meters for convenience in calculation by using ArcGIS Spatial Analyst Aggregate tool. SAGA GIS, ArcGIS 10.2 and Spatial Analyst, 3D Analyst, and Geostatistical Analyst extensions were used to create layers for topographical elements (ESRI, 2014 and SAGA GIS, 2014).

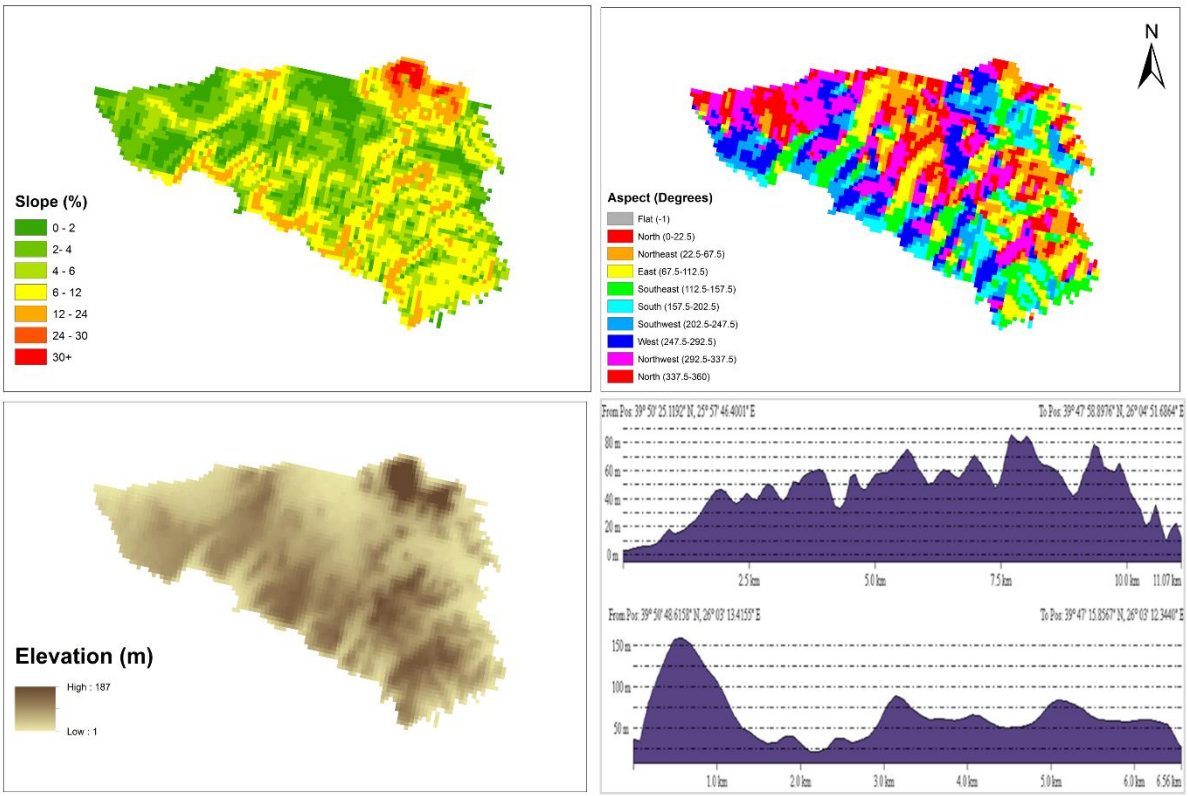

Figure 2. Slope (a), Aspect (b), Elevation (c) maps and Elevation profiles of the study area - East-West, North-South (d)

The soil layer, which is the most basic aspect of land evaluation studies for viniculture, directly affects many properties from site selection to healthy development of grapevines to fruit quality to the taste of the wine. For these reasons, the soil characteristics of the existing vineyards, and the vineyards yet to be planted, need to be known in detail. Soil map was also produced in this study, which is one of the main components of the Bozcaada's terroir and the part of the land evaluation model. The detailed soil map, which determines the soil attributes and soil zones used in the model. The detailed soil map defines the boundaries and zones of the soil series. The physical and chemical results of the soils, topography, and climatic elements were used as inputs in the rootstock suitability maps.

Land Evaluation Model and Methodology

In order to be able to evaluate the soil of the working area for viniculture, several features are required: the formation of the necessary infrastructure, detailed analysis of geographical layers of topography, soil and climate (which are the main components of the terroir concept), the relationships between these layers, and a detailed analysis of the effects of said relationships and individual layers on the selection of rootstock and type.

A pixel-based (100x100m) spatial land assessment model was constructed using high-resolution topographic features of the study area and soil properties which were derived from the detailed soil map and, laboratory analysis of the soil samples (Yiğini and Ekinci, 2023). To create the evaluation model, a grid with a resolution of 100x100 meters was created to cover the entire study area and the land evaluation model was built on this grid, which divides the island into 100x100 meter land cells. Basically, each element (pixel) represents a piece of land having with an area of 10,000 square meters. In order to form the land evaluation model, the attributes and sub-attributes that constitute the terroir of each pixel come from the soil, climate, and topographic layers obtained from auxiliary layers (Figure 3).

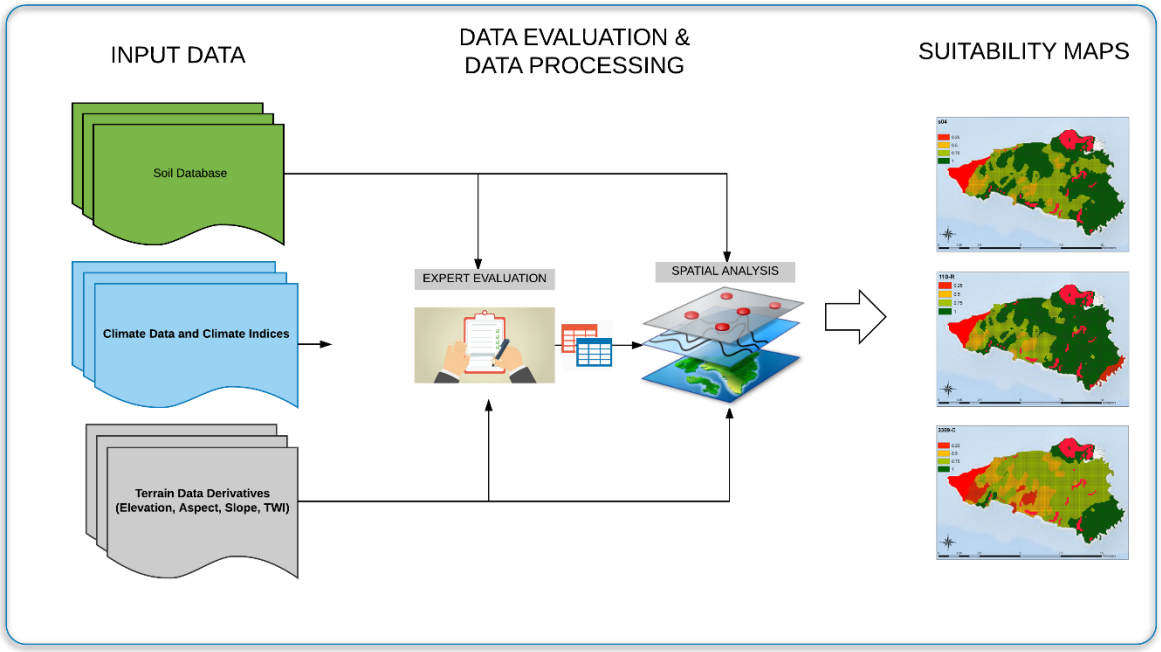

Figure 3. Workflow diagram for viticultural zoning

Soil Layer

Soil, which has an important role in selection of rootstocks and types, is observed in the soil layer in the land evaluation section of the study. The soil attributes consist of data from the land surveys and the detailed soil map. The data representing the soil layer was transferred to the pixels in two ways:

1. The soil profile analysis results representing the soil series were spatially transferred to the 100x100 meters pixels.
2. The soil parameters, which are suitable for interpolation with geo-statistical methods, were converted to raster data sets with a resolution of 100x100 meters using the profile analysis results by co-kriging method. The data contained in the raster prediction maps generated in this way are carried to the pixels prepared for the land evaluation study.

Each of the pixels forming the grid-based map prepared for the land evaluation model are assigned to data coming from the topographic, climate, and soil layers, according to its location. The database, created in this way, was also evaluated by software to compare and analyse the prepared rootstock tables with their ecological requirements and to determine the ranking scores. Thus, it became possible to determine how suitable the each pixel for each of the selected rootstocks, taking into account all the components of the terroir. As a result of the evaluations made, ranking tables were created in the database for the selected rootstocks and these tables were used to generate the suitability maps.

Topography Layer

The topography layer has important parameters for viniculture. The island's basic topographic elements were created using the SRTM 100m digital elevation model in the ArcGIS 10.2, SAGA GIS, and Global Mapper software programs. The 100-meter resolution slope, elevation, and aspect data of the study area was generated in raster format. This data was used in the land survey and mapping studies, as well as in land evaluation studies. To provide input to the land assessment model, the slope, height, and aspect values are transferred to each pixel of the grid data that constitutes the study area by using the ArcGIS "Zonal Statistics" tool.

Climate Layer

The climate layer holds the meteorological parameters, which represent long term averages of data. The Meteorological Station in Bozcaada of the General Directorate of State Meteorological Services, which has been observing meteorological conditions for 32 years.

Since there is only one station on the island, the meteorological data is assumed to be the same throughout the study area. Climate, data were analysed by using the indices calculated from the meteorological data. These indices were mainly used for the variety suggestion in the study area. The calculated indices are; Branas Heliothermic Index (Branas, 1974), Huglin Heliothermic Index (Bahar, 2010, Vaudour, 2003, Steel, 2007; Carbonneau et al., 2007), Latitude-Temperature Index (Bahar et al. 2010, Steel, 2007), Drought Index (Çelik et al., 2007), Cool Night Index (Tonietto, 1999), Degree-Day Indicator (Bahar et al. 2010), and the Jones Index (Jones, 2007) (Table 2).

Table 2. Climate derivatives used in the index calculations

Parameter	**Value**	**Unit**
Latitude	39.50	-
Longitude	26.00	-
Elevation	28.00	m
Vegetation period (1/IV--30/X)	210	days
Sunlight (V.Per.) (1/IV--30/IX)	1701.30	hours
Anuual Total Precipitation (1/IV--30/IX)	465.80	mm
Precipitation in the vegetation period (1/IV--30/IX)	103.60	mm
Total Active Temperature (1/IV--30/IX)	3573.00	°C
Total Temperature (1/IV--30/IX)	1980.00	degree-days

Results and Discussion

The location of Bozcaada in the Aegean Sea, and the humid/cool N, NNE and NE winds in general, creates favourable conditions for viticulture. Climate, which is one of the basic elements of land evaluation, is evaluated in the light of indices calculated using meteorological data. These indices are the Branas Heliothermic Index (Branas, 1974), Huglin Heliothermic Index (Bahar, 2010; Vaudour, 2003; Steel, 2007; Carbonneau et al., 2007), Latitude-Temperature Index (Bahar et al. 2010; Steel, 2007), Drought Index (Çelik et al., 2007), Cool Night Index (Tonietto, 1999), Degree- Day Indicator (Bahar et al. 2010), and the Jones Index (Jones, 2007). While the rootstock suggestions are the main product of this study, soil zones oriented variety suggestions were also made using the abovementioned climatic indices (Table 3).

Table 3. Calculated climatic indices in the study area

Index	**Value**
Branas Heliothermic Index	6.08
Huglin Heliothermic Index	2109.87
Latitude-Temperature Index	471.50
Drought Index	0.29
Cold Night Index	14°C - 18°C
Winkler Index	1980
Jones Index	19.43

The variety suggestions were made only to the soil zones since the study area is relatively small (36 km^2) and the climate data were obtained from the only meteorological station in the area. The suggested varieties are; Altesse, Cabarnet Franc, Caladoc, Cinsaud, Cot, Gamay, Grenach Blanc, Mauzac, Merlot, Negrette, Nielluccio, Roussanne, Servant and Tempranillo. Within the scope of the study, the basic ecological requirements of the rootstocks were included in the land assessment model and their suitability for the study area was evaluated and mapped. These rootstocks were determined by assessing the soil resources, topographic characteristics, and climate parameters of the island together in a GIS environment. The 19 rootstock suitability maps created within the scope of the study have been presented using basic colours to make them easily understandable and evaluable by non-scientific community and the farmers in the area. Suitability maps for the selected rootstocks (Fercal, Salt Creek, 110-R, 1616-C, Berlandieri, 140-Ruggeri, 420-A, 3309-C, 44-53, 5C, SO4, 8B, 99r, 5BB, Dodridge, 41-B, Gravesac, and 1103-P). Some of these are presented in Figure 4.

In this study, the components of Bozcaada's terroir have been examined in detail and revealed in all aspects. The soil has been assessed, using the data regarding topography and climate components, and suitable rootstocks for the island soils have been determined. The land evaluation model presented in this study is a mathematical model supported by literature and expert opinions. Before these suggestions are put into practice, the advice of viniculture experts should be received and land trials and economic analyses should be done. In this study, the soil resources and climate/topographic components of the study area were examined in detail and their relationship with each other was also examined and evaluated for viniculture. As the geographical land evaluation model utilized in this study is easy to reproduce and change, it is quite easy to add new rootstocks into the system. Suggestions can be made on the parcel scale by including the resulting suitability maps and linked database together with cadastral layer.

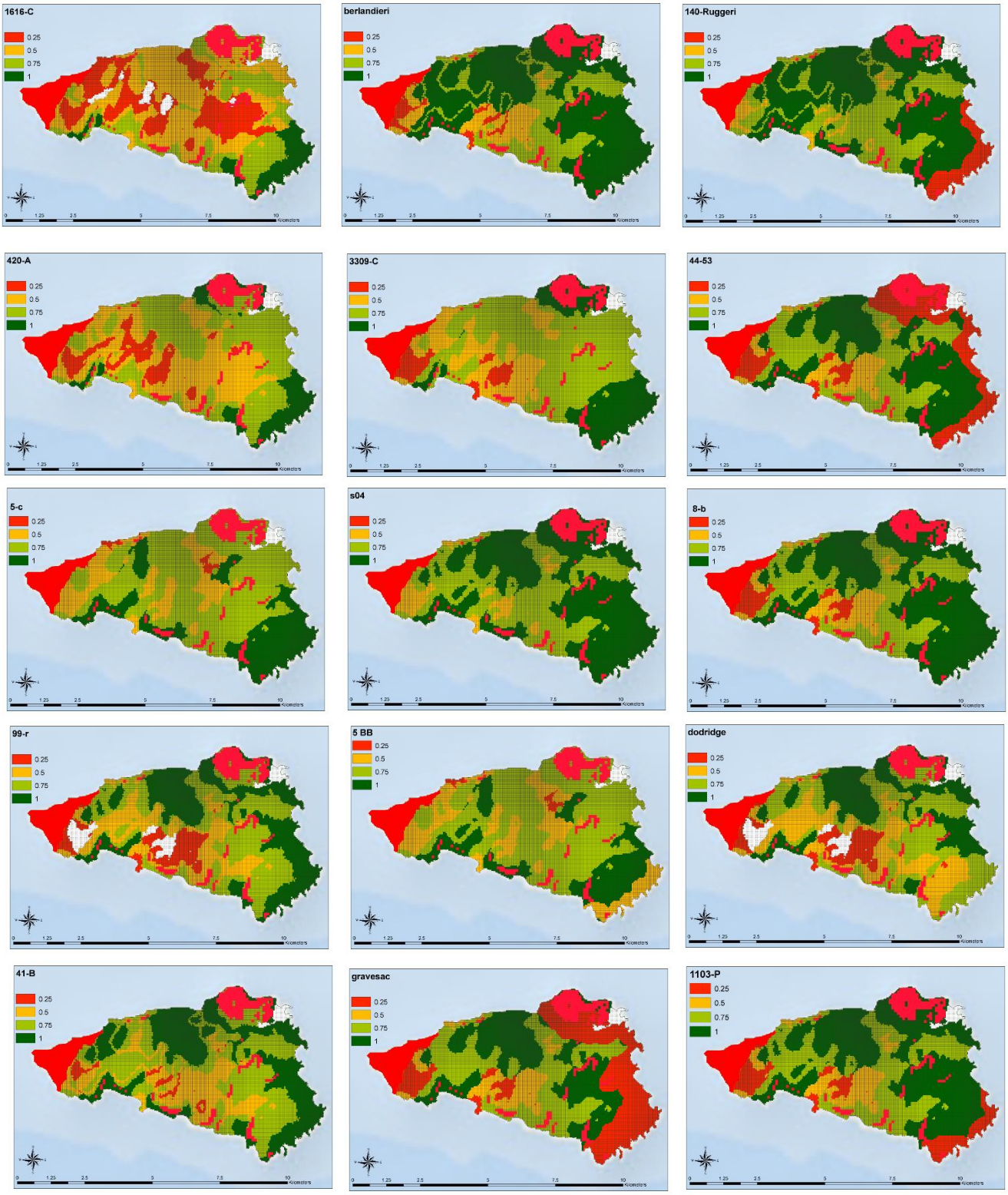

Figure 4. Rootstocks and suitability maps included in the land evaluation model.
Figure 4. Rootstocks and suitability maps included in the land evaluation model.

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Araştırmacıların Katkı Oranı Beyan Özeti

Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Çıkar Çatışması Beyanı

Makale yazarları aralarında herhangi bir çıkar çatışması olmadığını beyan ederler.

References

Bahar E., Korkutal İ., Boz Y., 2010. Evaluation of Tekirdağ Province Şarköy District in terms of Terroir, Şarköy Değerleri Semp.

Branas J., 1974. Precision Agriculture and Sustainability. "Precision. Agriculture 5: 359-387. Viticulture. Montpellier,Ecole National Superieure Agronomique.

Carbonneau A., 2001. Concepts "Terroir". GESCO 11. Journees du Groupe European d'etude des Systemes de Conduit de la Vigne, Montpellier, France, 3-7 Juillet, 2, 669.

Carbonneau A., Deloire A., Jaillard B., 2007. La Vigne. Physiologie, Terroir, Culture. Dunod, Paris, ISBN: 9782100499984.

Çelik H., Ağaoğlu, Y.S., Fidan, Y., Maraslı, B., Söylemezoğlu, G., 1998, General Bağcılık. Sun Fidan A.Ş. Mesleki Kitaplar Serisi: 1. 251 s.

Çeli, S., 2007. Viticulture, Volume I, Extended Second Edition. 423s.

ESRI, 2014. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

FAO, 2006. Guidelines for Soil. Food and Agriculture Organization of The United Nations Rome, 2006.

IAGT, 2014. New York Vineyard Site Evaluation System, arcserver2.iagt.org Incorporated. 600p.

Jarvis A., Reuter H. I., Nelson A., Guevara E., 2008. Hole-filled seamless SRTM data V4, International Center for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org, 2014.

Jones, G.V., 2007. Climate Change: Observations, Projections, and General Implications for Viticulture and Wine Production. Economics Department Working Paper No: 7.Whitman College.

Kurtural, K. S., Wilson P. E., Imed, E., 2008. Vineyard Site Selection in Kentucky, Based on Climate and Soil Properties. University of Kentucky Cooperative Extension Service.

SAGA GIS, 2014. System for Automated Geoscientific Analyses.

Tonietto, J., 1999. Les macroclimats viticoles mondiaux et l'influence du mésoclimat sur la typicité de la Syrah et du Muscat de Hambourg dans le sud de la France: méthodologie de caráctérisation. Thèse Doctorat. Ecole Nationale Supérieure Agronomique, Montpellier, 233 pp.

Unwin T., 2012. Terroir: at the heart of Geography, in Dougherty, P. (ed.) The Geography of Wine: Regions, Terroir and Techniques, Amsterdam: Springer, 37-48.

Vaudour E., 2003. Les terroirs viticoles. Définitions, caractérisation, protection. Ed.Dunod, Paris,293 pp

White R. E., 2009. Understanding Vineyard Soils. Oxford University Press.

Yiğini, Y., Ekinci, H., 2023. Bozcaada Toprakları-II (Toprak Özellikleri, Haritalama ve Sınıflandırma) ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)11 (2): 428-442.