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Full Length Research Paper

Examining environmental condition on the growth areas of Turkish hazelnut (*Corylus colurna L.)*

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Hazelnut has nutritional and economic value as an agricultural product. Hazelnut, mostly grown in Turkey, has not been planted in all agricultural areas, and the yield and the quality of hazelnut differentiate depending on place where it is grown. This can be a result of response of environmental conditions. In this study, recent hazelnut growth areas were determined by Remote Sensing techniques for Trabzon province of Turkey. By using Geographical Information Systems (GIS) techniques, environmental data such as elevation, slope, aspect, geology, and soil data were produced and analyzed to examine environmental conditions on the growth areas of Turkish hazelnut. Spatial analysis shows that environmental and topographic differences affect the hazelnut growth. According to determined environmental conditions, potential hazelnut growth areas should be determined for effective agricultural plantation.

Key words: Agricultural technology, hazelnut, remote sensing, geographical information systems.

INTRODUCTION

Hazelnut is the nut of Hazel (Corylus genus) belonging to Betulaceae family of Fagales ordo (USDA, 2003). According to some historians, homeland of hazelnut was Anatolia located in Turkey and spread from North Anatolia throughout the world after grown in China in B.C. (Taskin, 2005). This genus consists of deciduous trees and large shrubs grown naturally in the temperate northern hemisphere (Bean et al., 1999; Erdogan and Mehlenbacher, 2002). Hazelnut is a hard-shelled and roughly spherical fruit about 15 - 25 mm long and 10 - 15 mm in diameter, with an outer fibrous husk which are partly to fully enclose the nut. The flowers are monoecious which the male and female flowers are located in different part of plant. They open very early in spring before leaves and gets mature about 7 - 8 months after pollination and falls out of the husk when ripe. The shape and structure of nut play important role for identifying different species of hazels. There are about 17 species of corylus genus, such as *corylus colurna* which is common in Turkey (OSU, 2009; Rushforth, 1999; Chen et al., 1999). Hazelnut contain high amounts of vitamins, has nutritional value, and are used on various food products (USDA, 2009; Cristofori et al., 2008; Babadogan, 2008; Giovanninni et al., 2008).

Beside main hazelnut producers such as Italy, USA, Spain, Caucasus region, and China, Turkey has 73% of hazelnut production of the world (FAO, 2007). Hazelnut products consist 3.4% of total export and 30% of agricultural export of Turkey. The yield and quality of hazelnut vary in different growth areas of Turkey. Hazelnut growth areas are equal to 600.000 ha approximately while it was 210.000 ha in 1960 and 435.000 ha in 1990 (Fiskobirlik, 2009; USDA 2004; Gonenc et al., 2006; Kilic et al., 2009). The more hazelnut has been planted, the less the yield per hectare has been produced. The yield of hazelnut is 600 – 1000 kg per hectare in Turkey when compared with other countries, 2000 – 3000 kg in Italia and 1700 – 2500 kg in USA (Yaman, 2003; Kutkan, 2002; Marti, 2001; Kaya, 1998).

Hazelnut cultivation, therefore, should be planned and improved strategically. The reasons for differences in growth patterns are often a result of response of environmental stimuli (Liu, et al., 1993). According to 2844 numbered law about "Planning Hazelnut Production and

Abbreviations: GIS, Geographical information systems; **RS,** remote sensing; **UTM,** universal transversal mercator; **DEM,** digital elevation model.

Figure 1. Location of the study area.

Determining Hazelnut Plantation Areas" and related directive in 2002, hazelnut should be produced on the areas; the elevation less than 750 m, the slope more than 6%, agricultural class as the third grade, and land use capacity as the fourth and higher grade (Official Gazette, 2002). The growth of Turkish hazelnut begins in May and occurred mainly in June and July. This growth becomes more-uniform seasonal. Root growth begins at soil temperatures between 12 ¯ 15°C in the spring and ends at -6 - 8°C in the fall (Harries et al., 1995). In addition to this, environmental conditions such as elevation, slope, sun and wind, rainfall, soil, geology, climate, water quality, and the like can affect hazelnut production potential and yield prediction (Katana, 2000; Odekunle et al., 2007; Me et al., 2005; Azarenko et al., 1997; Botu and Turcu, 2001).

Determining hazelnut growth areas depends on analyzing maps and satellite images by Geographical Information Systems (GIS) techniques (Official Gazette, 2009). GIS and Remote Sensing (RS) technologies provide great advantages in data acquisition and management. While RS enables to produce the data about hazelnut growth areas and environment from satellite images (Lillesand and Kiefer, 2000), GIS techniques provide opportunities for combining and analyzing environmental data spatially in order to support sustainable development of agricultural areas (Aydinoglu et al., 2010; Grauke and Thompson, 2003; Cohen and Shoshany, 2002; Yomralioglu et al., 2009).

In this study, recent hazelnut growth areas of Trabzon province of Turkey were determined and calculated by RS techniques. Environmental conditions in view of elevation, slope, aspect, soil, and geology were determined for Trabzon province. Relations between hazelnut growth areas and these environmental data were analyzed by GIS techniques.

The results were examined to determine potential hazelnut cultivation areas in terms of environmental conditions.

MATERIALS AND METHODS

Study area

Trabzon province of Turkey, a major Turkish hazelnut producer, was chosen as a study area. Trabzon is situated between 39° 7' - 40° 30' east-longitudes and 40° 30' - 41° 7' north-latitudes in the middle of East-Blacksea Region and covers about 4659 km^2 (Figure 1). According to 2007 census, population of Trabzon is 740,569 with a density of 161 people per square kilometer (TURKSAT, 2008). With its historical and cultural wealth and unique geographical position, Trabzon can be accepted as the centre of East-Black Sea region of Turkey where hazelnut has been grown densely. Elevation begins at sea-level and exceeds 3000 m with steep slopes. Mountains, hills, and high plateaus generally take part in inner land of the region.

Besides the agricultural areas of hazelnuts and green tea, other land cover types are forest and pasture. This region has temperate climate summers and a rainy season normally lasting from September - April. According to results of 22-years observation in Trabzon, February is the coldest month with an average temperature of 6.7°C, August is the hottest month with an average temperature of 23.2°C. The annual precipitation of Trabzon is 838 mm, and precipitations disperse every month symmetrical (MEF, 2008).

Producing environmental data by geographical information systems

GIS is a computer-based system for the capture, storage, retrieval, analysis and display of geographic data that is related to the earth directly or indirectly (Longley et al., 2001). The data in GIS is generated from remote sensing through aerial and satellite images and conventional maps like topographic maps, geology maps, and so on (Ripa et al., 2006). In this study, GIS techniques were used to produce environmental data and to examine hazelnut growth environmentally. Following the six environmental data layers; elevation, slope, aspect, lithology, agricultural class, and land use capacity were produced and analyzed for hazelnut growth areas. ESRI ArcGIS 9.x software was used to combine the data and achieve spatial analysis. For all geographic data sets, the datum is ITRF-96 (International Terrestrial Reference System), the ellipsoid is GRS-80 (Geodetic Reference System-1980), and coordinate system is Universal Transversal Mercator (UTM).

Elevation data sets were extracted from 1 - 25.000 scaled Digital

Figure 2. The hazelnut growth areas presented over DEM of Trabzon province.

Topography Maps produced by the General Command of Mapping. Digital Elevation Model (DEM) of Trabzon was produced from these data sets as shown in Figure 2. This DEM is a cell-based representation of a continuous surface and was used as input to quantify the characteristics of the land surface of the earth. Slope and aspect were derivative of the DEM. Slope and aspect data of Trabzon were produced from DEM data by GIS 3D analysis functions. Slope represents the rate of change of elevation for each DEM cell. The lower the slope value, the flatter the terrain, the higher the slope value, the steeper the terrain. Aspect identifies the down slope direction of the maximum rate of change in value from each cell to its neighbours, that is, it can be thought as the slope direction (ESRI, 2009). From 1 - 25.000 scaled Geology Maps produced by Regional Directorate of Mineral Research and Exploration were digitized and combined on geographic database. Later, lithology data that is, the classification of rocks on the earth was produced. In addition, the data about agricultural classes and land use capacity of Trabzon was produced from the maps of Provincial Directorate of Agriculture.

Determining land cover by remote sensing

Hazelnut harvested by farmers has been sold to the state offices and hazelnut traders. An information system is not available to determine the place hazelnut was grown, because cultivation areas of farmers have not been registered spatially. Data acquisition methods such as field surveying, laser scanning, and aerial photogrammetry are costly, labour intensive, and time consuming because of steep topographic conditions of the Black Sea Region of Turkey where hazelnut grows mostly. As well as RS enables to produce environmental data and land cover data from satellite images that provides a good alternative because of its general availability, large ground coverage, sufficient contents, and higher spatial and spectral resolution (Huang and Fu, 2002; Aydinoglu et al., 2010). In addition to this, analyzing these data by GIS provides opportunities for a wide range of environmental analysis including geology, agriculture, meteorology, and the like (Ceballos and Lopez, 2003; Cihar et al., 2000; Priya and Shibasaki, 2001; Franco, 1997).

In this study, to determine hazelnut growth areas of the study area, land cover maps were produced by RS techniques. Land cover refers to the physical material covering the surface of the earth, such as vegetation, water, forest, and physical features. Landsat ETM+ satellite image acquired in July 10, 2007 was used to generate the land cover types with ErMapper software. Application area is 120 x 90 km covering Trabzon province. The Landsat ETM+ image has six multi-spectral bands with 28 m resolution, one thermal band with a 60 m resolution, and a panchromatic band with 15 m resolution (Reis and Yomralioglu 2006; Guler et al., 2007; Turan et al., 2010). Supervised classification was done on this image with the using of training areas in the study area. The study area was divided into nine land cover types including hazelnut growth areas, presented over DEM on Figure 2. The overall accuracy of this classification is 84.92%, with a Kappa coefficient of 0.820.

Determining Relationship between environmental data and hazelnut areas

For each environmental layer, the data on the hazelnut growth areas were extracted by spatial analysis functions of GIS. Hazelnut growth areas were categorized in view of classes of elevation levels, slope and aspect groups, geology and soil groups. Covering area and corresponding percentage of the classes were calculated for hazelnut growth areas and all the study area separately. This analysis was done with an accuracy of 625 m^2, equal to a cell-based representation of 25 x 25 m. The columns of result tables include the following sections respectively:

(a)The classes of environmental data such as elevation levels and aspect groups.
(b) Area and percentage (%) of the classes in the study area.
(c) Distribution graph of the classes in the study area.
(d) Area and percentage (%) of the classes in the hazelnut growth areas.
(e) Distribution graph of the classes in the hazelnut growth areas.
(f) The ratio of hazelnut growth areas to the area in the classes, ($\%_f$) = ($Area_d$) / ($Area_b$).

Table 1. Hazelnut growth areas in view of elevation levels.

Elevation	Trabzon Province		Hazelnut Growth		
(m)	Area(ha)	%	Area(ha)	%	(d/b)%
0-250	73775	15,8	14432	20,2	19,6
250-500	59891	12,9	17182	24,0	28,7
500-750	54295	11,7	13624	19,1	25,1
750-1000	48805	10,5	9631	13,5	19,7
1000-1250	47344	10,2	7138	10,0	15,1
1250-1500	44917	9,6	4916	6,9	10,9
1500-1750	38904	8,4	1914	2,7	4,9
1750-2000	38998	8,4	1557	2,2	4,0
2000-2250	33226	7,1	836	1,2	2,5
2250-2500	18898	4,1	212	0,3	1,1
2500-2750	5930	1,3	20	0,0	0,3
>2750	853	0,2	1	0,0	0,1
	465834	100,0	71461	100,0	15,3
(a)	**(b)**		**(d)**		**(f)**
	Min:0m Max.:3228,3m **(c)** Mean: 1049,5m Std.Dev.:716,1		Min:1m Max.:2798,1m **(e)** Mean: 675,3m Std.Dev.:475,98		

RESULTS

Hazelnut growth areas of Trabzon

The land cover of Trabzon was categorized and allocated into one of nine classes including pasture, deciduous forest, coniferous forest, mixed forest, land used for cultivating green tea, hazelnut growth, rocky topography, settlement area, and agricultural area. Deciduous forest is 38% of the area with the largest proportion. There are some scattered cultivated land, owing to topography and small land parcels. While agriculture constitutes 17.06% of the province, pastoral land covers 18.5% of the province. Hazelnut, the major agricultural product of Trabzon, covers 15.3% of the area and is equal to 71461 ha as shown in Figure 2. It is announced that 55.000 tons hazelnut was grown in 2005 in Trabzon. That means, to hazelnut production of 770 kg per ha, confirming the yield of hazelnut approximately.

Elevation on the hazelnut growth areas

Elevation Map portrays twelve elevation levels, ranges from 0 - 3230 m above mean sea level as explained on Table 1. Elevation begins to increase along the north side of the study area. 16% of study area is the elevation between 0 - 250 m in case of filling coastal areas. Hazelnut was grown densely on the elevation close to 250 m and between 250 - 750 m. The higher elevation value, the less the hazelnut growth areas are covered on the study area.

Slope on the hazelnut growth areas

Slope map defining the rate of elevation change was divided into ten slope groups as shown on Table 2. Figure 3 shows hazelnut areas presented over slope groups. Areas with slopes of 18 - 30% cover 40.7% of the Trabzon province, and land with a slope of 36% or more occupies 7.9% of the province. The percentage of the hazelnut growth areas increases at the slope more than 6%, and hazelnut is harvested densely at the slope between 12 - 30%, equal to 40691 ha area.

Aspect on the hazelnut growth areas

Aspect can be effective on the production of agricultural products in case of the parameters such as exposure to sunlight, drying winds, and rainfall (degree of saturation). Aspect map of Trabzon was presented on the map of Figure 4. The aspect was classified into nine aspect groups; flat (-1°), north (0 - 22.5°, 337.5 - 360°), northeast (22.5 - 67.5°), east (67.5 - 112.5°), southeast (112.5 - 157.5°), south (157.5-202.5°), southwest (202.5 - 247.5°), west (247.5 - 292.5°), and northwest (292.5 - 337.5°). Analysis was performed to determine the distribution of hazelnut growth areas on the aspect groups. A signifi-

Table 2. Relationship between Hazelnut growth areas and slope groups.

Slope	Trabzon Province		Hazelnut Growth		(d/b)%
(%)	Area(ha)	%	Area(ha)	%	
0-6	40181	8,6	8174	11,4	20,3
6-12	47711	10,2	8889	12,4	18,6
12-18	75045	16,1	12687	17,8	16,9
18-24	90578	19,4	13994	19,6	15,4
24-30	99052	21,3	14010	19,6	14,1
30-36	76582	16,4	9984	14,0	13,0
36-42	26608	5,7	3162	4,4	11,9
42-48	4226	0,9	468	0,7	11,1
48-60	842	0,2	48	0,1	5,6
60-100	5010	1,1	46	0,1	0,9
	465834	100,0	71461	100,0	15,3
(a)	**(b)**		**(d)**		**(f)**
	Min:0 Max.:88,33% **(c)** Mean: 22,77% Std.Dev.:11,64		Min:0 Max.:87,75% **(e)** Mean: 19,93% Std.Dev.:10,54		

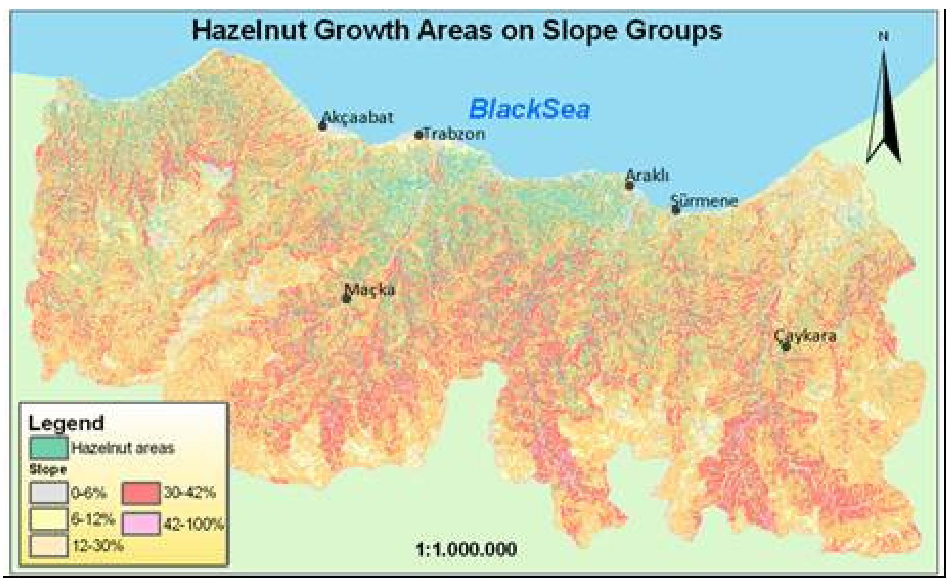

Figure 3. The map of hazelnut growth areas over slope groups.

cance rate of the study area is on the north facing slopes because elevation starts to increase from the north, the coast of Trabzon. As shown in Table 3, hazelnut has been grown densely on the slopes; the north-east and the east side along possible sunrise direction, the south-west and the west sides along possible sunset direction.

Geology on the hazelnut growth areas

Geology maps of the study area present lithological types (Figure 5) that often lead to a variety in the strength and permeability of rocks and soils. The lithology maps of the study area were differentiated into lithological types in view of the higher frequency ratio, respectively. Eocene, volcanic facies (*Ev*), basalt, andesite, pyroclastics, and intercalations of sandstone clayey limestone and siltstone(*Kru1*), rhyodacite, dacitic lava and pyroclastics (*Kru2*), Kackar granites (*γ*), Lias units (*Jlh*), Jurassic-Cretaceous units (*Jkr*), Aluvium (*Al*), and Pliocene (*Pl*). According to the results of statistical analysis on Table 4, most hazelnut areas are situated on lithological types;

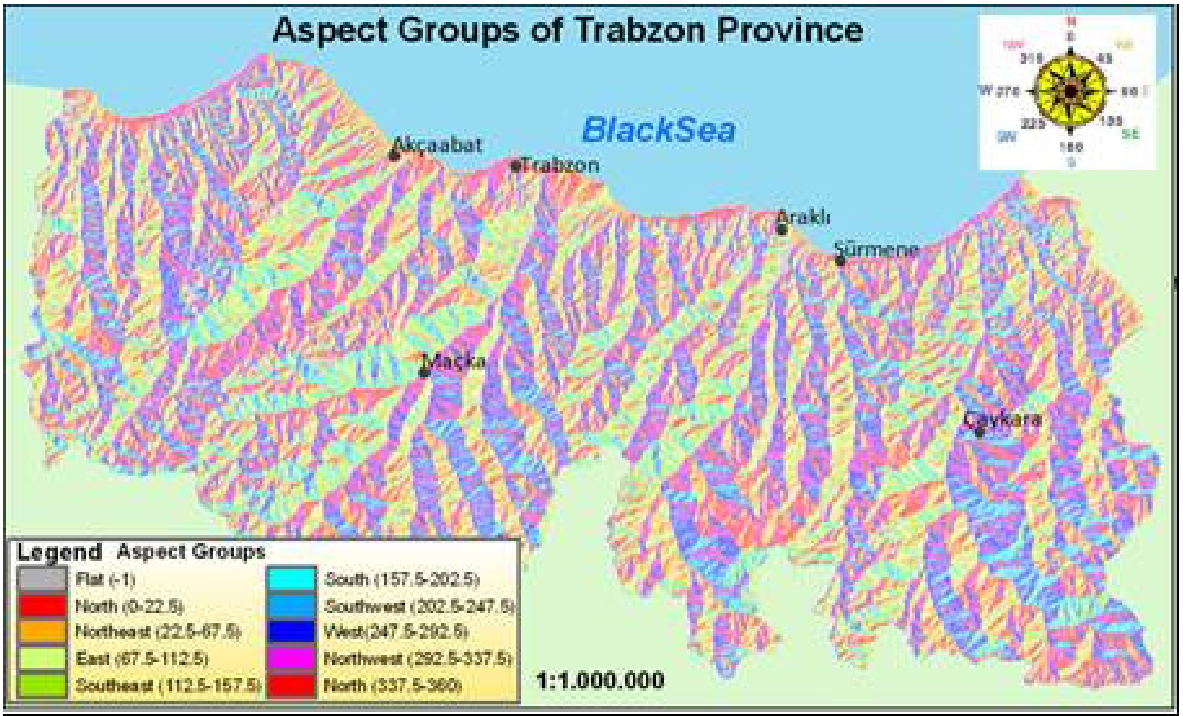

Figure 4. The map of aspect groups of Trabzon province.

Table 3. Relationship between Hazelnut growth areas and aspect groups.

Aspect	**Trabzon Province**		**Hazelnut Growth**		**(d/b)%**
(°)	**Area(ha)**	**%**	**Area(ha)**	**%**	
Flat	10620	2,3	2600	3,6	24,5
North	31498	6,8	3996	5,6	12,7
NorthEast	71119	15,3	13988	19,6	19,7
East	65501	14,1	12886	18,0	19,7
SouthEast	47224	10,1	5545	7,8	11,7
South	31158	6,7	3347	4,7	10,7
SouthWest	42924	9,2	8583	12,0	20,0
West	63301	13,6	10582	14,8	16,7
NorthWest	70406	15,1	6820	9,5	9,7
North	32084	6,9	3115	4,4	9,7
	465834	100,0	71461	100,0	15,3
(a)	**(b)**		**(d)**		**(f)**
	Min:-1 Max.:359,99 **(c)** Mean: 178,45 Std.Dev.:111,99		Min:-1 Max.:359,99 **(e)** Mean: 155,94 Std.Dev.:109,29		

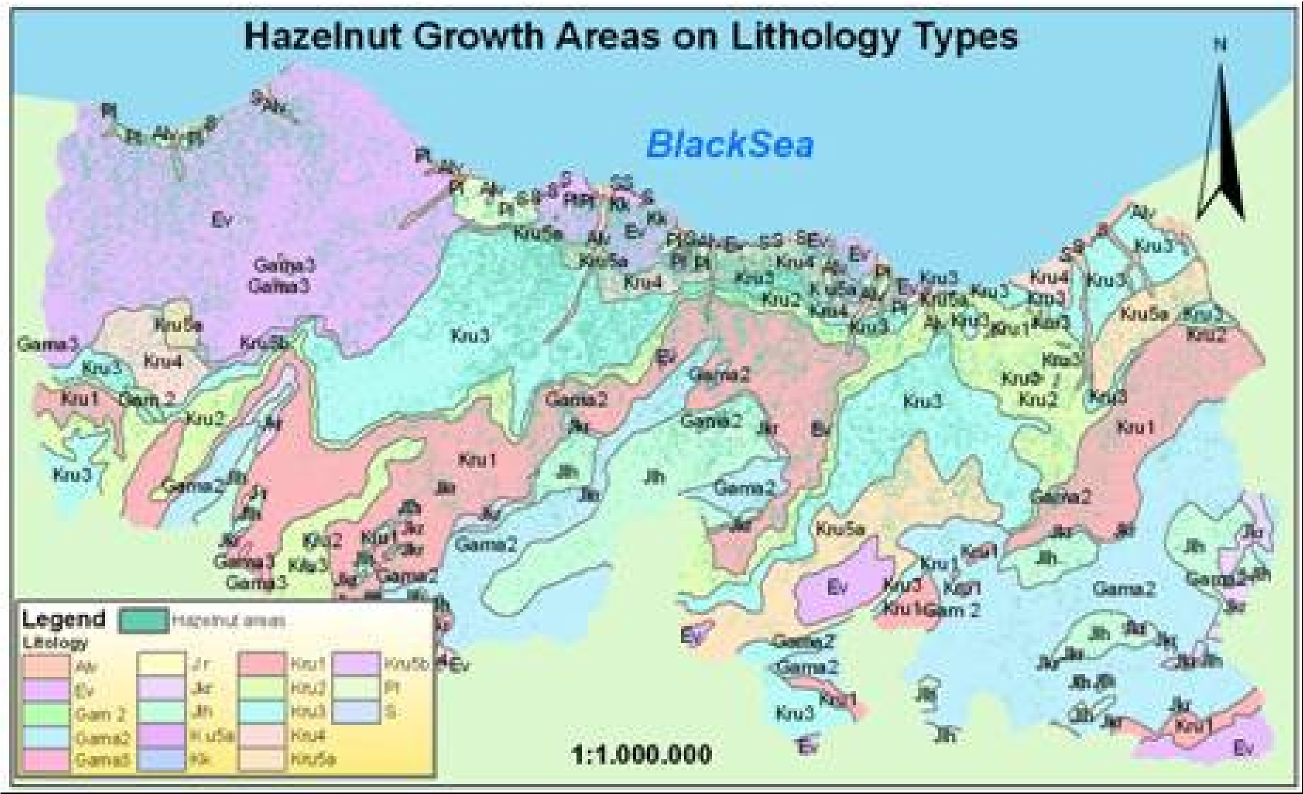

Figure 5. The Map of hazelnut growth areas over Lithology types.

Table 4. Relationship between Hazelnut growth areas and lithology types.

Lithology	Trabzon province		Hazelnut growth		(d/b) %
	Area (ha)	%	Area (ha)	%	
K u5a	614	0.1	380	0.5	61.8
Kk	128	0.0	47	0.1	36.7
Kru4	13367	2.9	3871	5.4	29.0
Pl	4497	1.0	1290	1.8	28.7
Kru3	76079	16.3	15883	22.2	20.9
Ev	92436	19.8	19107	26.7	20.7
Kru5b	1258	0.3	223	0.3	17.8
S	351	0.1	59	0.1	16.9
Kru2	43328	9.3	6626	9.3	15.3
Alv	8650	1.9	1300	1.8	15.0
Kru5a	23847	5.1	3520	4.9	14.8
Kru1	81344	17.5	11401	16.0	14.0
Gam 2	486	0.1	52	0.1	10.7
Jlh	35140	7.5	3152	4.4	9.0
Jkr	6864	1.5	525	0.7	7.6
Gama2	76843	16.5	4013	5.6	5.2
Gama3	425	0.1	13	0.0	3.1
J r	177	0.0	0	0.0	0.,0
Total	465834	100.0	71461	100.0	15.3

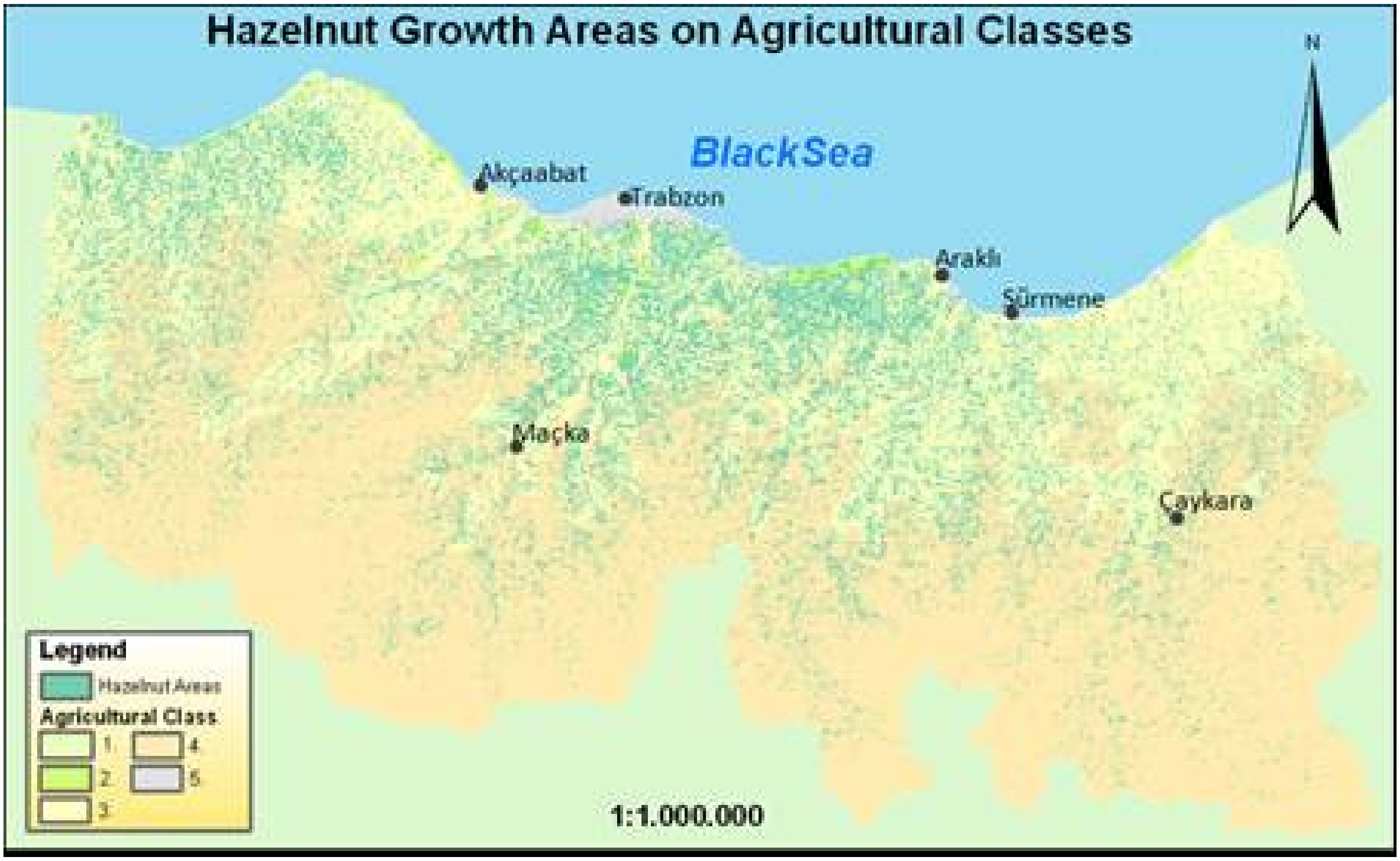

Figure 6. The map of hazelnut growth areas over agricultural classes.

Table 5. Relations between hazelnut growth areas and agricultural classes.

Agricultural class	Trabzon Province		Hazelnut Growth		(d/b) %
	Area (ha)	%	Area (ha)	%	
1	2125	0.5	487	0.7	22.9
2	3437	0.7	1137	1.6	33.1
3	156601	33.6	42724	59.8	27.3
4	299739	64.3	26760	37.4	8.9
5	3932	0.8	353	0.5	9.0
Total	465834	100.0	71461	100.0	15.3

Kru covering 58.7% of the province totally, *Ev* covering 26.7% of the province.

Soil on the hazelnut growth areas

According to agricultural classes and land use capacity determined by Directorate of Agriculture, soil effect on the hazelnut growth areas was examined for Trabzon province. In this way, the study area was divided into five-grade agricultural classes. Most of Trabzon provinces are in the third degree (33.6%) and the fourth degree (64.3%) of agricultural classes on Figure 6. Hazelnut are produced densely at third degree covering 27.2% of hazelnut growth areas unlike at fourth degree covering 8.9% of hazelnut growth areas as explained on Table 5.

The study area was divided into eight-grade land use capacity as shown in Table 6. Most of the study areas are situated at land use capacity as the sixth covering 28.5% of the area and the seventh covering 64.2% of the area. This means that the study area generally has land use capacity at low level. Although, hazelnut was grown at land use capacity as the sixth and the seventh, the ratio hazelnut growth areas to total area increases at land use

Table 6. Relations between Hazelnut Growth Areas and Land Use Capacity

Land use capacity	Trabzon province		Hazelnut growth		(d/b) %
	Area (ha)	%	Area (ha)	%	
1	3836	0.8	347	0.5	9.0
2	2266	0.5	679	1.0	30.0
3	3546	0.8	1232	1.7	34.,7
4	21801	4.7	6766	9.5	31.0
5	259	0.1	78	0.1	30.0
6	132947	28.5	14475	20.3	10.9
7	299075	64.2	47789	66.9	16.0
8	2104	0.5	96	0,.1	4.6
Total	465834	100.0	71461	100.0	15.3

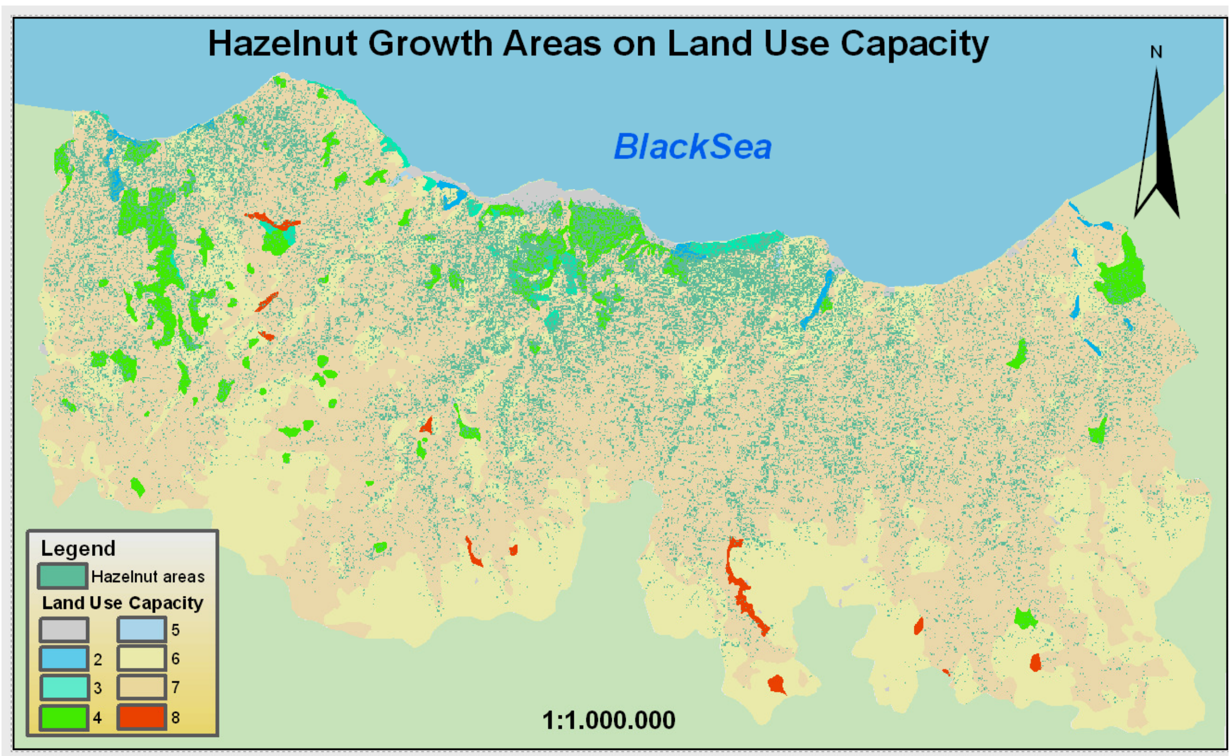

Figure 7. The map of hazelnut growth areas over land use capacity.

capacity as the fifth and higher grades on Figure 7.

DISCUSSION

In Turkey, Hazelnut has been cultivated by farmers without any agricultural policy. The yield and quality of hazelnut have differentiated in the cultivation areas. This can be a result of environmental and topographic conditions as well as agricultural methods and genetic stimuli. Although, hazelnut directives shed light on potential areas for hazelnut cultivation, the most suitable environmental conditions have not been determined yet. It should be emphasized that a lot of environmental variables can affect hazelnut production. However, a registration system for hazelnut farmers has not built and integrated to any GIS spatially, and it is impossible to produce and to analyze maps about all environmental variables affecting hazelnut growth.

In this way, this study enables to determine the hazelnut growth areas by RS techniques, the most effective way on the steep geography of the Black Sea region of Turkey that hazelnut grows densely. GIS techniques gave opportunities to produce environmental data such as elevation, slope, aspect, geology, agricultural class, and land use capacity. In addition, the relationships between hazelnut growth areas and environmental data were analyzed. The results show that hazelnut should be grown an elevation of about 250 m and lower than 1000 m especially because of humidity and temperate climate at low elevation levels. Hazelnut was grown on the slopes of between 6 and 30%, and the west and the east facing slopes especially. Hazelnut growth areas increase at agricultural class as the third and higher grades and land use capacity as the fifth and higher grades. Although, there is not certainty, lithological types on hazelnut growth areas are generally *Kru* and *Ev.*

The other environmental variables, of course, can affect the results of these analysis. Therefore, after determining more environmental variables for the most suitable hazelnut growth, potential hazelnut cultivation areas should be determined to improve the yield and the quality of hazelnut and to support agricultural policy of Turkey.

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