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# Detection of current and potential hazelnut plantation areas in Trabzon, North East Turkey using GIS and RS

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***Abstract:*** *Monitoring agricultural products requires the periodic determination of land cover and the production of land use policies in an optimum way. The hazelnut is one of the important Turkish agricultural exports and Turkey provides 77% of the world's hazelnuts. In Turkey, hazelnut production exceeds the demand; new regulations have been enacted to create new land use policies. By putting into practice regulations restricting hazelnut plantation areas, a more efficient and productive hazelnut harvest policy could be created. Therefore, more information on existing land cover is required to determine optimum (or ideal) potential hazelnut areas (PHA) and to forecast future crop production. The principle aim of this study is to create a methodology for determining existing PHA, using Geographic information system (GIS) and remote sensing (RS) techniques regarding to support hazelnut policy developers and economists. This study was basically carried out in the province of Trabzon, which is one of the most important hazelnut production areas in Turkey. Landsat ETM+ image was used to generate a current land cover classification. Using the supervised classification method, overall accuracy was determined to be 84.7%. Suitable hazelnut areas were determined according to criteria settled by government regulations.*

***Key words:*** *Hazelnut, Agriculture, GIS, Remote sensing, Land cover.*

## Introduction

Turkey is the highest producer of hazelnuts in the world with a 77% of total production. Italy and USA follow Turkey with 13% and 5%, respectively (Koksal, 2000; URL-1, 2001). The hazelnut is mostly harvested for commercial purposes in the Black Sea region in Turkey in an area covering approximately 540.000 hectares over 13 provinces. Most of these areas are not suitable for other agricultural uses having more than 20% slope. Lands having secondary importance are productive for other agricultural products covering approximately 100.000 hectares. In Turkey, the hazelnut gardens on average are between 0.4 and 1 hectare in size and are generally sloping. Ideally, a soil pH value of 6-7 and high rainfall of 1250 mm are good conditions for growing hazelnut. On average, 600-1000 kg hazelnut is grown per hectare in Turkey that is under the world average. It is 2000-3000 kg in Italy and 1700-2500 kg in the USA (Marti, 2001). The annual hazelnut production in Tukey is given in Fig. 1. In order to increase the yield rates and monitor the hazelnut harvest, spatially based information produced by different institutions should be accurately collected and analyzed every year in an effective way. Land cover of the area should be determined precisely and relevantly to make necessary analyses on potential hazelnut areas and harvest amount. Geographic Information System (GIS) is a powerful tool for collecting, processing and analyzing spatial information (Longley *et al.,* 2001; Yomralioglu, 2002; Lioubimtseva and Defourny, 1999). The applications for specifying potential agricultural areas have been seen in many studies (Silva and Blanco, 2003; Priya and Shibasaki, 2001; Zuviria and Valenzuela, 1994). On the other hand, Remote Sensing (RS) has an important role in rapidly providing data for GIS, especially for determining the land cover analyses (Maxwell *et al.*, 2003; Oetter *et al.*, 2000). RS is accepted as an effective way to acquire data for agricultural production in an accurate and time related manner in wide areas. Landsat satellite images have been used successfully for classifying different crop types since 1972 (Lobell *et al.*, 2003; Cohen and Shoshany, 2002; Panigrahy and Chakraborty, 1998; Panigrahy and Sharma, 1997; Haack and Jampoler, 1994). There have been many studies to determine agricultural products via satellite images and different methods are used to decide which satellite images determine agricultural products more effectively (Cihlar *et al.*, 2000; Aplin *et al.*, 1999). However, there were not any RS based studies directly specify existing and possible hazelnut areas.

In this study, the existing land cover areas were determined by focusing on a particular dated Landsat satellite image. Potential hazelnut areas were also constructed according to current regulations, then, these areas were compared with the existing pattern and a raster based spatial database system was established for planning works.

## Materials and Methods

**The study area:** This study was undertaken in Trabzon province in the East Black Sea region of Turkey. There are three administration units in Turkey; province, county and village. The largest being the province, has the greatest authority over civilian activity in urban and rural areas. The boundary of the Trabzon province was taken as the limit of the study area. The Province of Trabzon is situated between 39º 15' - 40º 15' west-east longitudes and 41º 8' - 40º 30' north-south latitudes in the middle of East Black Sea region (Fig. 2). Total area of the

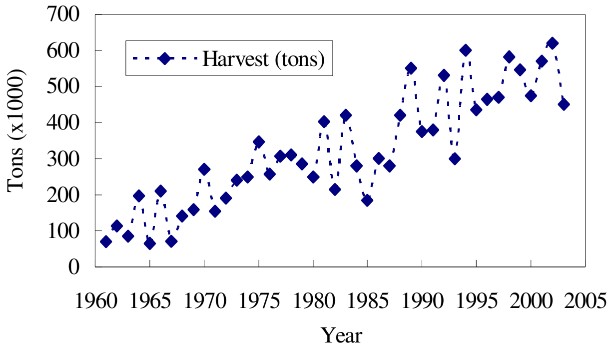


**Fig. 1:** Hazelnut amounts produced in Turkey (URL-2, 2004).

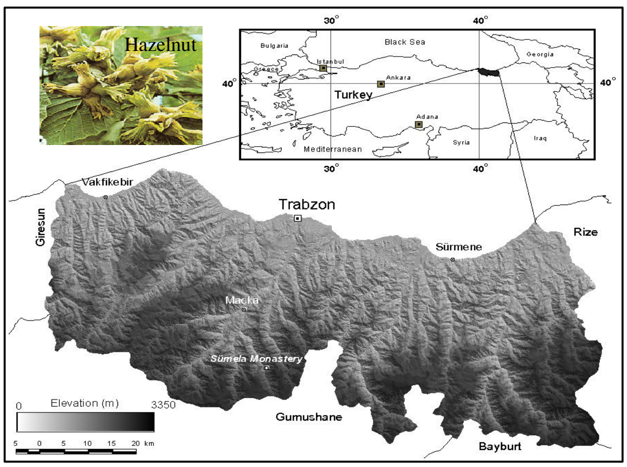


**Fig. 2:** Study area.

province is 4660 km$^2$ with a population of 975 137. The main commercial agricultural products are hazelnuts and green tea in the district. Apart from the agricultural areas, the other main land cover types are forest and pasture areas. Proximity to the sea results in a temperate climate where summers are generally warm, winters are mild with an overall annual average temperature of 14.5 ºC and annual average precipitation of Trabzon province is 838.4 mm (Anonymous, 2001b).

**Soil data:** Land use capability class (LUCC) and agricultural soil classes (ASC) information being two of the most significant information available on soil maps indicate the suitability of the land for agricultural crop growth. In Turkey, The General Directorate of Rural Services within the Ministry of Agriculture and Rural Affairs is responsible for the production of these soil maps and related information. First, soil maps produced by this institution on a scale of 1/100.000 were digitized by using a Universal Transverse Mercator (UTM) coordinate system. Then, descriptive data of LUCC and ASC was added to the database. The LUCC comprise 8 classes on this map and they range from I to VIII according to soil damage and restrictions. Under good land administration, the first four classes indicate a good capability for growing some cultivated species and forest, pasture and grass plants. Classes V, VI and VII are appropriate for local native plants. When soil and water protection measures are implemented, some plants can also be grown on V and VI class land. For class VIII, there would be a need for effective rehabilitation work in order to grow plants, however, it is unlikely that such work would be cost effective in the existing market conditions. ASC is divided into three classes on the soil map. The first class is labeled absolute agricultural land and involves I and II classes of LUCC while the second ASC involves III class of LUCC. The last ASC class involves IV, V, VI, VII and VIII of LUCC where vineyards-gardens and special yield lands are planted (Balcı, 1996; Anonymous, 1996).

**Relief data:** The Digital Elevation Model (DEM) was digitized from 1/100.000 scaled Standard Topographic Maps. The contours on these maps are drawn at 50 m intervals. The DEM of the study area was created by using ArcGIS software. The Slope Map (classified in percentages) and elevation figures were generated by using this DEM. The pixel dimensions of this Slope Map are 28 x 28 m. When considered in relation to slope, three quarters of the total area of Trabzon City consists of areas with a slope rate of above 30%. Furthermore, areas with a slope rate of 50% or above constitute 40% of the total area of the province.

**Remote sensing imagery and land cover:** Land cover mapping requires that surface features are being classified into various categories. The level or detail is dependent on many factors including: the objectives of mapping, the information need, the spatial and radiometric resolutions of the sensor, the environmental conditions of the target area and the analytical techniques to be applied (Apan, 1997). In the Eastern Black Sea region, the principle challenges in generating land cover are rough topographic structure, mixed vegetation types and scattered agricultural land. Therefore, there were some difficulties encountered in processing remotely sensed data in the region.

**Image processing:** In this study, a single date image of Landsat ETM+ (Path 173; Row: 32) on October 19, 2000 was used to generate land cover types. Using the image, after extracting an application area of approximately 120x90 km covering administrative boundaries of Trabzon province, other studies, as required, were implemented on this area. The Landsat ETM+ image has 6 multi-spectral bands with 28 m resolution, 1 thermal band with 60 m resolution and a panchromatic band with 15 m resolution.

First, a geometric correction of the panchromatic band to the UTM coordinate system was completed using topographic maps scaled to 1/25.000 produced by the General Directorate of Mapping. In the geometric correction process, first degree linear transformation and bilinear re-sampling methods were used. After the re-sampling process from map to image with a 28m pixel resolution, a total of 0.7 pixel RMS error (RMSE) was obtained with 25 Ground Control Points (Reis, 2003).

**Collecting training areas:** Data for training areas should be gathered from the land considering the acquisition date of the satellite image. Obtaining an accurate classification depends on

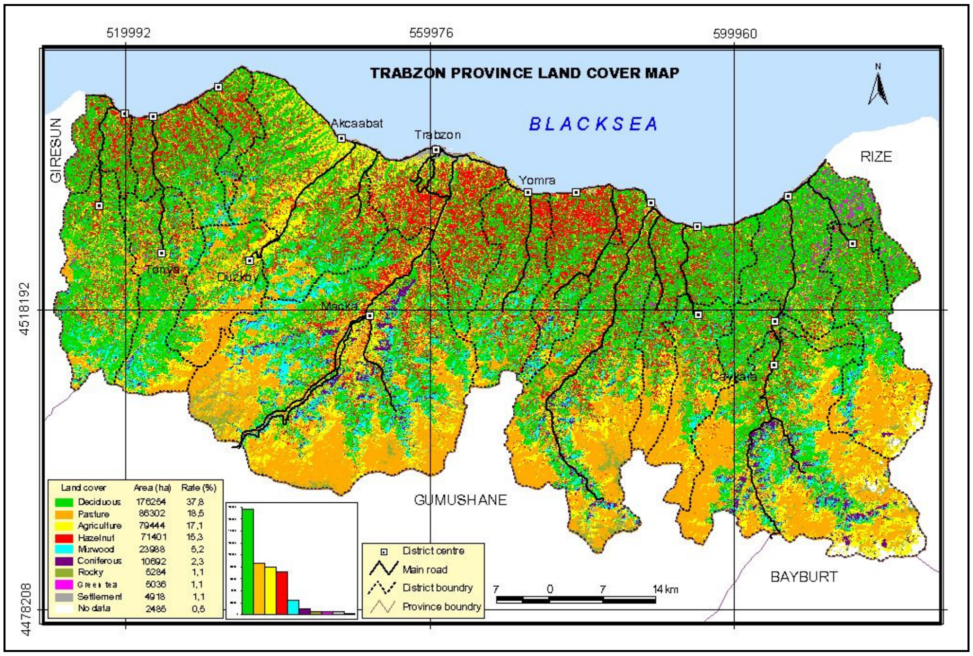


**Fig. 3:** The land cover of the Trabzon province.

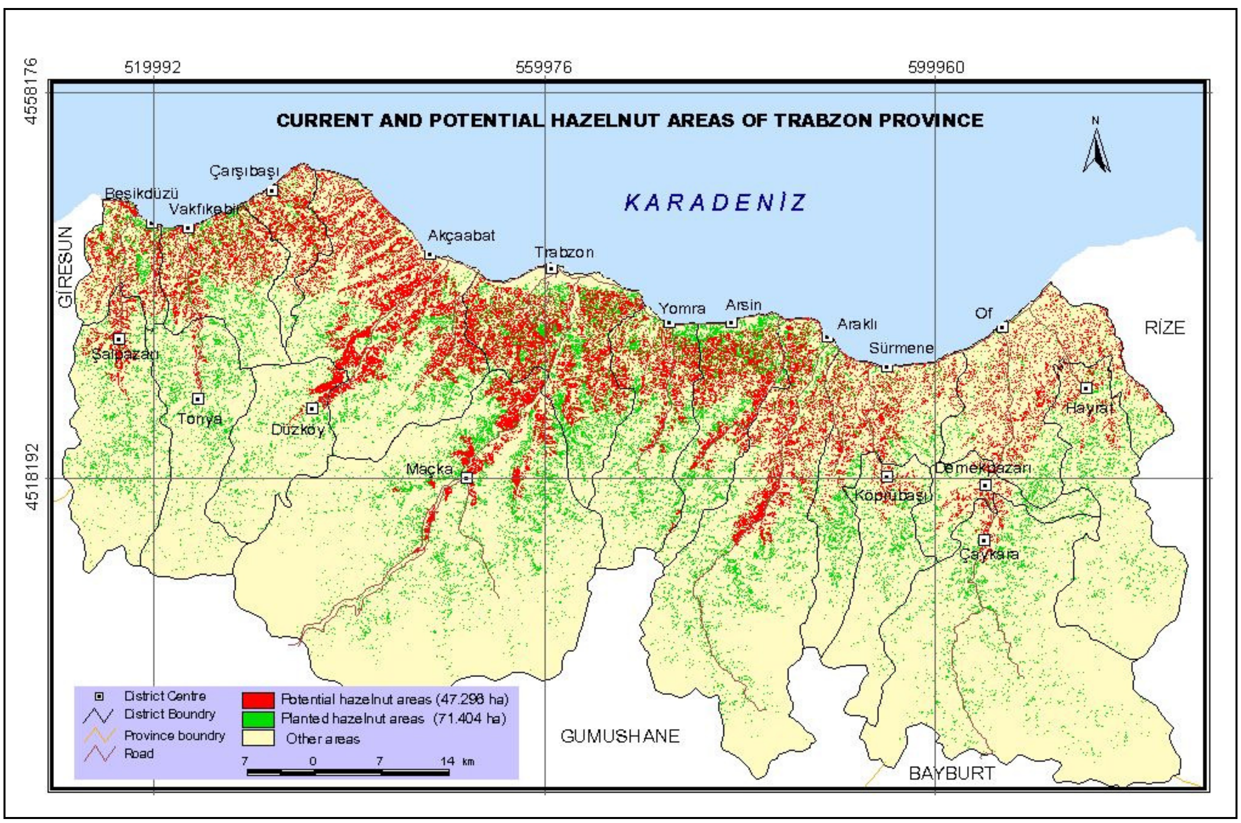


**Fig. 4:** Current and potential hazelnut areas of Trabzon province.

determining training areas homogeneously on land and defining them in appropriate sizes (Lillesand and Kiefer, 2000). In this study, a total of ten land cover classes were appropriately chosen. These were pasture, water, deciduous, coniferous, mixed wood, green tea, hazelnut, rocky, settlement and agriculture. Training area data for these classes were

**Table – 1:** Classification error matrix for the supervised classification of the 2000 Landsat ETM+ image.

| **Land cover (type)** | **BD** | **A** | **R** | **P** | **MW** | **C** | **S** | **D** | **SD** | **W** | **GT** | **H** | **Total** | **User's accuracy (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bright deciduous (BD) | 547 | 74 | 0 | 3 | 0 | 0 | 2 | 37 | 33 | 0 | 433 | 51 | 1180 | 46,4 |
| Agriculture (A) | 9 | 921 | 59 | 39 | 42 | 49 | 83 | 2 | 43 | 0 | 14 | 70 | 1331 | 69,2 |
| Rocky (R) | 0 | 14 | 1032 | 22 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 2 | 1096 | 94,2 |
| Pasture (P) | 0 | 52 | 78 | 2167 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 2328 | 93,1 |
| Mixwood (MW) | 0 | 0 | 0 | 0 | 911 | 139 | 0 | 21 | 24 | 0 | 0 | 0 | 1095 | 83,2 |
| Coniferous (C) | 0 | 0 | 0 | 0 | 68 | 2411 | 0 | 0 | 44 | 0 | 0 | 0 | 2523 | 95,6 |
| Settlement (S) | 0 | 18 | 219 | 0 | 2 | 0 | 1678 | 0 | 1 | 49 | 0 | 2 | 1969 | 85,2 |
| Deciduous (D) | 2 | 0 | 0 | 5 | 129 | 6 | 0 | 817 | 48 | 0 | 0 | 0 | 1007 | 81,1 |
| Shadow deciduous (SD) | 28 | 12 | 0 | 8 | 17 | 64 | 0 | 14 | 1649 | 0 | 18 | 33 | 1843 | 89,5 |
| Water (W) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 467 | 0 | 0 | 467 | 100,0 |
| Green tea (GT) | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 86 | 0 | 120 | 71,7 |
| Hazelnut (H) | 30 | 95 | 0 | 22 | 4 | 0 | 0 | 24 | 91 | 0 | 4 | 1366 | 1636 | 83,5 |
| Total | 650 | 1186 | 1388 | 2266 | 1174 | 2669 | 1789 | 915 | 1933 | 516 | 555 | 1554 | 16595 | |
| Produced accuracy (%) | 84,2 | 77,7 | 74,3 | 95,6 | 77,6 | 90,3 | 93,8 | 89,3 | 85,3 | 90,5 | 15,5 | 87,9 | | 84,68 |

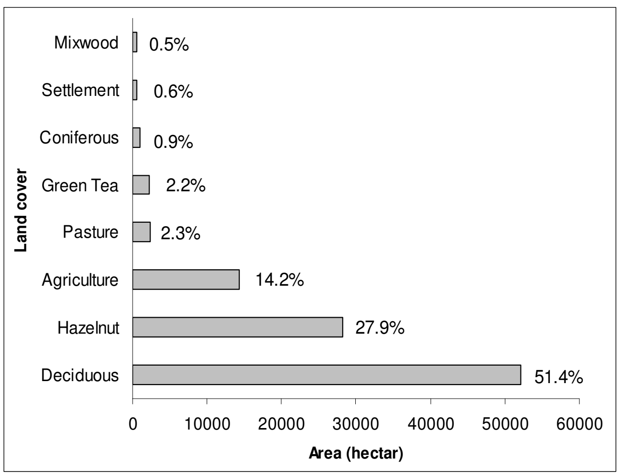


**Fig. 5:** Distribution of land cover within the general PHA.

obtained using mobile GPS in two different seasons (May and September).

**Classification stage and error matrix:** When the first supervised classification results were examined, it was seen that some classes were badly affected by shadow and brightness caused by the rough topographic structure. Consequently, field work was carried out to check the results and it was seen that shady or bright areas, due to sensing angle of the image, were generally located in heavily vegetated areas especially by or near the sea and in the valleys.

After the first classification process, some extra field works were carried out to determine the deficiencies and also collect additional training samples for land cover types considered to be inadequate. In order to minimize the problem of shade and brightness, deciduous trees in which this problem was mostly encountered were divided into three classes So, training areas for deciduous, shadow deciduous and bright deciduous were collected, and this data was added to the supervise classification process.

Upon the addition of extra data for new training areas, the supervised classification process was carried out again. During the supervise classification process each of the following algorithms was tested: minimum distance, mahalanobis distance and maximum likelihood with several thresholds. It was seen that the Standard Maximum Likelihood Method provides the best results with multi-spectral bands (bands 1, 2, 3, 4, 5 and 7) when the supervised approach is used. Afterwards, to analyze this classification, the overall accuracy percentage, user's and producer's accuracy and the Kappa coefficient that provide the statistical evaluation (Stehman, 1996) of these accuracy values were calculated. The overall accuracy of this classification was 84.68 percent and the Kappa coefficient was 0.829. Both the user accuracy and producer accuracy are listed in Table 1.

As seen in the Table 1, the majority of the results acquired by classifying main land cover types (except for green tea and bright deciduous) have acceptable accuracy percentages. From these land cover types, water, coniferous and pasture were classified with an accuracy of over 90 percent. Settlement, rocky, shadow deciduous and hazelnut types were classified with an accuracy of approximately 85%. Land cover types including shadow deciduous, bright deciduous and domestic agricultural production mostly affected hazelnut plant accuracy assessment.

**Land cover amounts of Trabzon province:** Fig. 3 shows the Land cover types within the boundaries of Trabzon province. From all land types in the Province, deciduous class covers the

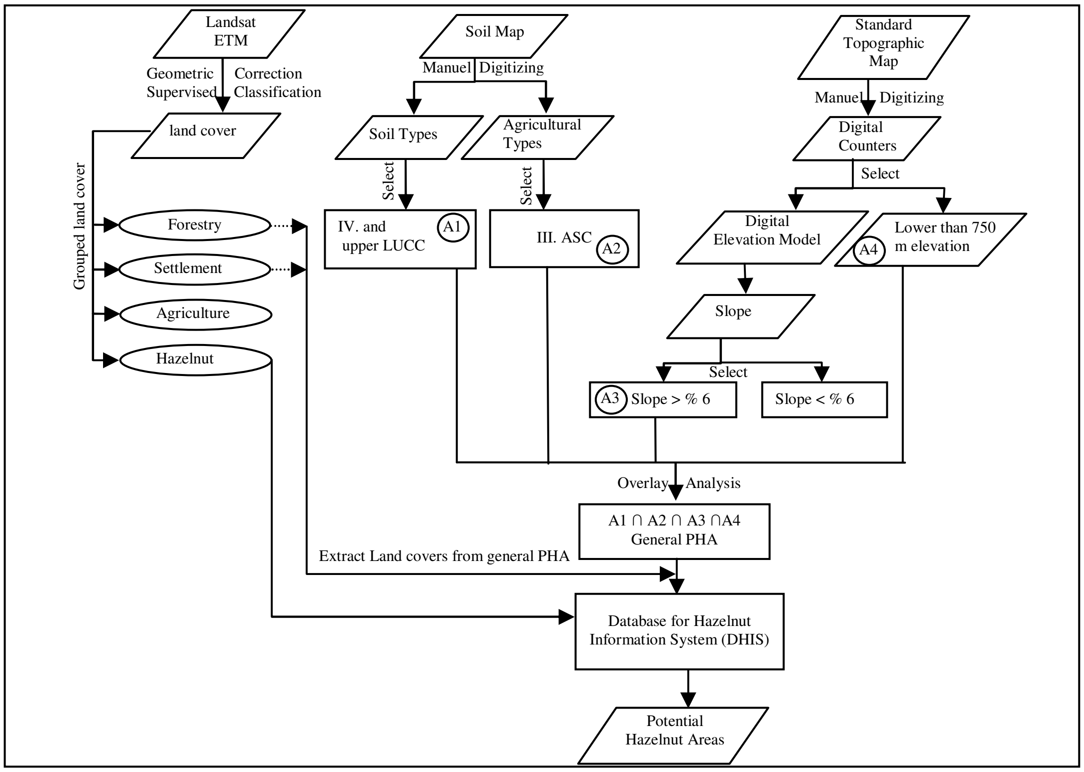


**Fig. 6:** Flowchart of PHA determination procedure.

largest area with 37.80%. In this class, deciduous tree types such as beech, hornbeam and chestnut are included. The area covered by agricultural land of 17.06% is nearly equal to the 18.53% that represents the area of pastoral lands. Agricultural land class includes all agricultural crops produced in the region in particular maize, tobacco and beans. Hazelnut areas with 15.33% are nearly as large as the area covered by agricultural land. Green tea areas cover a small area in the province with a minimal of 1.08%. The reason for determining unexpected small green tea areas (5.036 ha) in the Province is that these areas are mixed with deciduous tree types.

**Determination of the potential hazelnut areas:** In Turkey, law number 2844 was brought into force in 1983. This act has aimed to increase hazelnut yield and regulate production by determining planting areas. The latest regulation was created in January 2002 to reduce the hazelnut areas and enhance productivity. According to this regulation, the hazelnuts can be harvested from;

a) areas in which the maximum elevation is 750 m.
b) agricultural soil class of III.
c) areas where slope is more than 6%.
d) IV or upper class of LUCC (Turkish official gazette, 2002).

According to regulation, potential hazelnut areas (PHA) will be determined using the land cover map obtained from the Landsat ETM+ image, the slope map obtained from the topographic map and the class of LUCC maps and the ASC maps obtained from soil map. The hazelnut trees will be removed from the sites, if they fall outside the categories listed above. The farmers will then be encouraged to grow alternative agricultural products.

Since the resolution of the land use map obtained from the satellite image is 28 m, the analysis of PHA is done in grid format with a pixel of 28 m. The criteria given above are used to determine the PHA in a GIS context and the ArcView 3.2 spatial analysis module was used (ESRI, 1996). Fig. 6 presents the flowchart of procedures followed in the determination of PHA. According to this analysis, there is total of 101.384 ha general PHA in Trabzon province which is 21.8% of whole province.

## Results and Discussion

In Trabzon, there is an area of 164.370 hectares between the elevation of 0 and 750 m, which is used as a criterion in determining the general PHA. 101.384 hectares of this area is assigned as a general PHA, determined without taking into consideration the existing land cover. When the current land cover is considered to determine the general PHA, it can be seen that the general PHA will be less than that calculated from the Landsat ETM+ satellite image. According to results of general PHA analyses with the land cover map, as given on the Fig. 5, the deciduous and the current hazelnut areas mostly overlapped on the planted hazelnut areas. The general PHA, determined according to the existing land cover, consists of deciduous trees (51.4%) and the current hazelnut areas (27.9%). When the forests including deciduous,

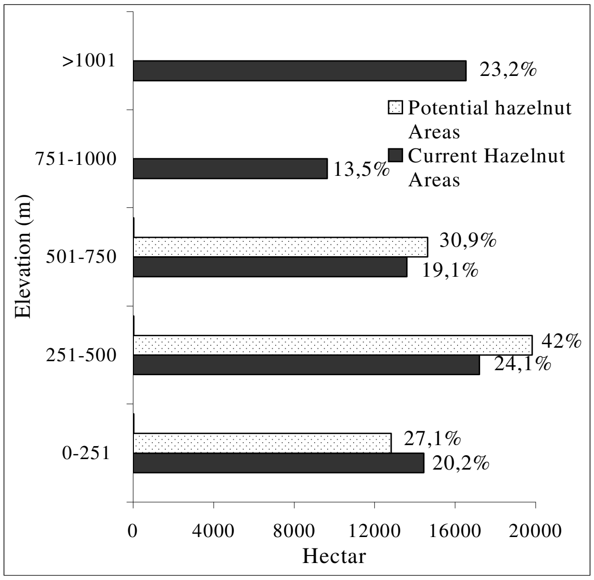


**Fig. 7:** The current and potential hazelnut areas according to elevation.

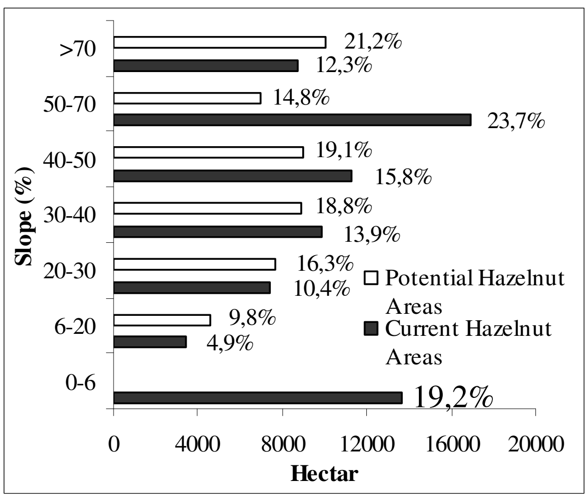


**Fig. 8:** The distribution of the PHA and current hazelnut areas according to the slope groups.

coniferous and mixwood and settlement areas were extracted from general PHA, the remaining was found to be 47.296 hectares (28.71%) which was considered to be the ideal PHA. As stated above, the existing hazelnut areas determined from Landsat ETM+ satellite image was calculated as 71.402 hectares. The difference between the ideal PHA and the current hazelnut plantation area can be calculated as 24.105 ha (5.17%).

When agricultural areas obtained from Landsat imagery are subtracted from the ideal PHA, there is a remaining PHA area of 32.909 hectares (7.06%). Therefore, it appears that there are 38.492 ha (8.26%) extra hazelnut planted areas in Trabzon. Eliminating the forest, settlement and agricultural areas from the areas where hazelnut production is allowed in accordance with current regulations quite restricts the plantation of hazelnuts in the province. A map showing current hazelnut plantation areas together with PHA is presented in Fig 4.

Fig. 7 shows the current and potential hazelnut areas classified by elevation. A total of 26.162 hectares (36.6%) are above 750 m and thus not appropriate for hazelnut plantation. Areas with an altitude below 750 m were determined as 45.239 hectares. When only the hazelnut areas below 750 m (45.239) are considered, a figure close to PHA (47.296) is obtained. In addition, it was seen that 1.653 ha hazelnut planted areas are above at elevation of 1000 m in the province. Therefore, hazelnut production in this kind of area can explain why the hazelnut quality is poor and hazelnut production per hectare is lower than average in the province.

The areas and percentages representing the slope groups of the current and potential hazelnut areas are given in Fig. 8. Of current hazelnut areas, an area of 13.674 ha (%19.2) is in the 0-6 slope group where planting is restricted in accordance with the regulations. Another important point from Figure 8 is that 36% of the total hazelnut areas are situated in areas with 50% of slope rate or higher.

The current hazelnut plantation is determined as 49.270 hectares in a study conducted by the Trabzon Agriculture and Rural Affairs in 2001. This number is not obtained directly from the measurements on the areas, but it is indirectly gathered from the declaration of the farmers. When this reported data and the data extracted from satellite image concerning the current hazelnut areas (71.404 ha) for the same region were compared, there is a difference of 22.131 hectares. The hazelnut harvest for the year of 2001 in the Trabzon province was 64.863 tones (Anonymous, 2001a). The quantity of hazelnut per hectare varies between 600-1000 kg in Turkey (Marti, 2001). The average hazelnut yield per hectare in Trabzon province between the years of 1990 and 2000 is 1090 kg (Anonymous, 2001a). Consequently, in order to realize the 2001 yield amount in the province, an area of between 64.000 and 100.000 hectares was required to be cultivated.

In this study, the various procedures were applied to determine the current and potential hazelnut harvesting areas in Trabzon, Turkey. First, the planted hazelnut areas were determined using a Landsat ETM+ satellite image. The Landsat satellite plays a crucial role in determining land cover. The study area has a rough topographic structure and vegetation has a high spatial heterogeneity in the region, spectral resolution of Landsat (30m) was not sufficient to adequately determine some vegetation types, such as green tea. However, acceptable results were obtained in determining the hazelnut areas using the supervised classification procedures of the Landsat ETM+ satellite image. It can be seen in this study that obtaining accurate land cover data from Landsat ETM+ satellite images is simple and rapid.

The PHA was determined according the criteria dictated by government regulations. The GIS technology was used and the criteria including: elevation, LUCC, agricultural soil classes and slope were used to determine the potential hazelnut areas. Determining the PHA and planning the hazelnut plantation areas and pulling up the hazelnut plants which have been planted inappropriately will provide a balance between the hazelnut supply and demand in Turkey and in the world. The similar studies in determining PHA specially conducted for Trabzon province in this case should also be conducted for the other provinces producing hazelnuts. Moreover, yearly amount of hazelnut harvest for Turkey can be estimated accurately from the model and so that a basis is supplied for the local and international enterprises and investors.

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