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Full Length Research Paper

Determination of horizontal and vertical distribution of tree species in Turkey via Shuttle Radar Topography Mission (SRTM) satellite data and geographic information system: the case of Crimean pine (*Pinus nigra*)

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Forest areas in Turkey are generally spread on rugged terrain and different elevations. Site factors such as location, elevation from sea level, aspect and slope are effective on an ecosystem's climate, soil characteristics, and hence vegetation. Description of such characteristics will allow for the description of forest ecosystems living on these sites and comparison of such ecosystems to each other. Factors such as elevation, aspect and slope can easily be generated from digital elevation models. In this study, using a digital elevation model obtained from Shuttle Radar Topography Mission (SRTM) satellite data and 1/100,000 scale Forest Information System database, horizontal and vertical distribution of *Pinus nigra (Crimean Pine)*, which is geographically the largest spread needled tree species in Turkey, (to elevation classes) was determined and the generated results (map, table etc.) were presented.

Key words: Shuttle Radar Topography Mission (SRTM), Geographic Information System (GIS), Forest Information System (FIS), Digital Elevation Model (DEM), Crimean pine.

INTRODUCTION

As it is the case in many other areas in the world, forests and forest areas are among the most important natural resources in Turkey as well. The fact that forests are renewable resources further increases their importance. Forest areas have not only the forest presence located above them, but also other subsurface and surface resources. Today, besides their economic value, forest areas also possess a series of values and functions that cannot be explained economically. This characteristic of forests has posed the need for planning and operating forests in all over the world in terms of multi purpose use and sustainability principles. Such a planning depends on correct, reliable, up-to-date, and easily accessible data and methods and tools to process this data.

Advances in computer software and hardware generated digital data and digital map concepts and the first automatic mapping system was used in the beginning of 1970s (Koç, 1995). Continued advances in this area have led to the development of digital mapping systems and the emergence and development of vector orientated geographic information systems later on. On the other hand, the first raster based geographic information system Canada Geographic Information System (CGIS) was designed in 1963 and completed in 1971 (Lee, 1995). Later, considering the advantages and disadvantages of both two systems (raster and vector), hybrid geographic information systems were developed to benefit from advantages of both systems (Inan, 1998). Besides these developments towards processing and analysis of geographic data, methods to obtain geographic data have also developed considerably. The developments in digital photogrammetry (analytical plotter), the increase in resolution of satellite images, the developments towards generating data from these images, also the developments in software and hardware for transforming classical maps and similar geographical data into digital data are important developments allowing people to satisfy their needs for geographical data faster, more accurately and cheaper and they contribute to technical and economical feasibility of geographic information systems in this respect (Yener, 1998).

Geographic information systems (GIS) are composed of software, hardware, data, and users; graphic and non-graphic (thematic-attribute) data organized together in these systems; a series of new data obtained from available data by means of multiple analysis and query facilities; all these systems serve as a decision support system to administrators and planners. As is the case in many developed countries, GIS is also used in our country as Forest Information System (FIS) that allows more efficient execution of forestry studies.

Our forests are generally spread on rugged terrain and different elevations. Site factors such as location, elevation from sea level, aspect and slope are effective on an ecosystem's climate, soil characteristics, and hence vegetation (Çepel, 1988). Description of these factors will allow description and comparison of forest ecosystems living on these sites. A digital terrain model can be used to determine the physiographic characteristics of a terrain (Yener, 1993). Today, using different sources and methods, digital terrain models and digital elevation models can be generated by means of the items listed below:

(i) Direct measurement of required reference points by terrestrial measurements,
(ii) Stereo evaluation of aerial photographs and certain satellite data (Ikonos, Spot, Quikbird etc.) by photogrammetric method,
(iii) Digitization of available topographic maps,
(iv) Radar interferometry technique (for example, Shuttle Radar Topography Mission (SRTM) satellite data),
(v) Light Detection and Ranging (LIDAR) sensor data that measures the time required for the laser beams sent to the Earth's surface to return by being reflected from the surface and objects located on the surfaces and generate a direct digital elevation model.

No matter which of the indicated methods was used to generate digital elevation model data, geographical information layers such as slope, aspect, elevation classes for the FIS prepared on the basis of GIS that is important for many forestry studies will be generated from this model.

Digital elevation models can be generated from remote sensing data regarded as SRTM data. SRTM data is composed of digital elevation data obtained by means of radar sensors located in a space shuttle. Within the scope of an international project including Germany, Italy, and United States of America, digital elevation data of an area encompassing 80% of the land on earth including also our country was obtained as a result of the receptions collected in February 2000 (JPL, 2008).

In this study, it was aimed at determining the horizontal and vertical (elevation classes) distribution of Crimean Pine (*Pinus nigra*), which is geographically the largest spread needled tree species in Turkey (OGM, 2011), on the basis of Regional Forest Directorates. FIS data at 1/100,000 scale and SRTM satellite data for digital elevation model were used to attain this aim.

MATERIALS AND METHODS

Study area

The study area covers entire Turkey which lies between 36° to 42° North latitude and 26° to 45° East longitude. There are 27 Regional Forest Directorates within a total of 79,566,427.30 ha area (Figure 1).

According to 2004 forest inventory, the total forestland is about 21.2 million hectares and it covers 27.2% of the country's land. 50% of the forests are productive and the rest are degraded. Forestland is occupied by about 60% coniferous and 40% broadleaved tree species. Among the broadleaved, oak species are the most dominant while Calabrian pine and Crimean pine dominate the coniferous species. 18% of the country's forests are located in the Aegean Region, 14% are in Marmara, 13% are in the Eastern Black Sea, 11% are in the Western Black Sea, 11% are in the Eastern Mediterranean, 11% are in the Central Anatolia, 8% are in the Western Mediterranean, 8% are in the Eastern Mediterranean and the remaining 6% are located in the Southwestern Anatolia. In terms of tree species, the country's forests are composed of 11,404,000 ha coniferous (Conifers), 7,681,000 ha deciduous (broadleaved) and 2,204,000 ha mixed coniferous and deciduous forest areas (OGM, 2011). Crimean Pine constitutes 2,473,815.73 hectares of these coniferous forest areas.

In terms of the topographical structure, Turkey has high plateaus and very variable hilly and mountainous terrain. The average elevation is about 1130 m and only 10% of the land's elevation is between 0 to 250 m. About 20% of land in the country has less than 15% slope, while the remaining 80% has more than 15% slope. In terms of physical geography, Turkey is divided into four sections as coastal regions, high Anatolian plateau, high-mountainous region (Eastern Anatolia), and Thrace low region. Peripheral mountains extend along the north-south coast of Turkey. These mountains generally form broad plateaus lying in the east-west orientation. Peripheral mountains get closer to each other and become more frequent in eastern Turkey. The same mountains get closer to each other and become more frequent in the west as well, but elevations of these mountains are not as high as the ones in the east. Including valleys between them, they descend perpendicularly to the Aegean coast while keeping parallel to each other. Central Anatolia, surrounded by peripheral mountains, is composed of plateaus and high plains. Low plains and coastal plains of Turkey cover a smaller area. These are found more in the western and southern parts of the country, in Thrace, and also near some large river deltas (Anonymous, 2008).

Three climate types, Black Sea, Mediterranean and continental climate, are dominant in Turkey (Anonymous, 2006).

Black Sea climate

The Black Sea climate occurs mainly on the slopes of the Northern Anatolian Mountains, overlooking the Black Sea. All seasons are rainy in the Black Sea climate. In the Eastern Black Sea part, the maximum precipitation is observed in autumn whereas the minimum precipitation falls in spring. Annual precipitation is 2000 to 2500 mm. In the Western Black Sea part, the maximum

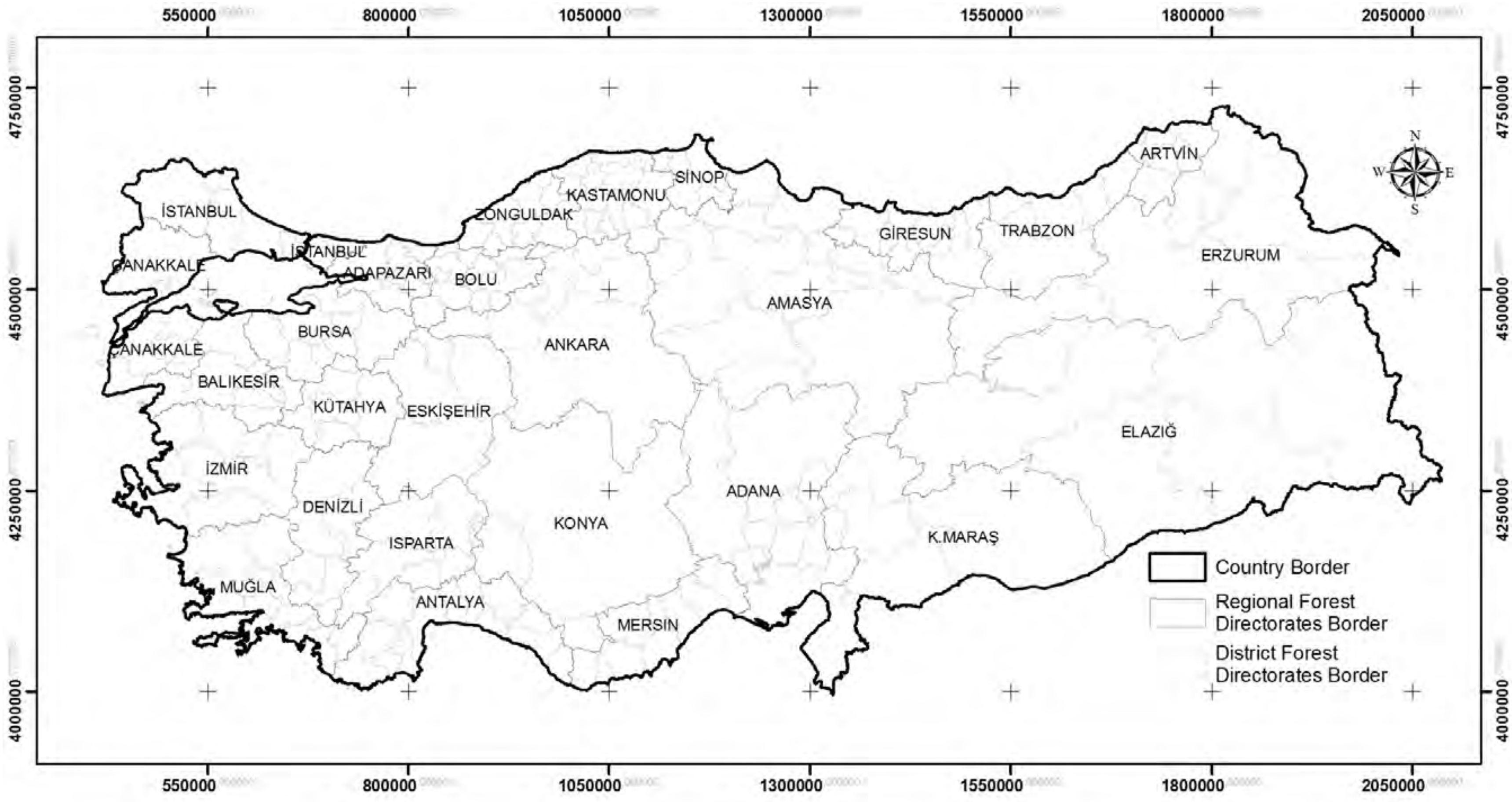

Figure 1. Study area.

precipitation is recorded in autumn and the minimum precipitation falls in spring. Annual precipitation is 1000 to 1500 mm. In the Central Black Sea part, the maximum precipitation is observed in winter while the minimum precipitation is recorded in summer. Annual precipitation is 700 to 1000 mm. In areas with the Black Sea climate, average number of days with snowfall is 18 days. The annual average temperature is 13 to 15°C. The average temperature in January is 6 to 7°C, and in July is 21 to 23°C. Annual temperature difference is 13 to 15°C. Natural vegetation is present in the forest and Alpine meadows occur in high areas.

The Mediterranean climate

This is observed most evidently along the shores of the Mediterranean; it is also effective in Aegean and Marmara regions as well. In Mediterranean climate, summers are hot and dry; winters are mild and rainy. The maximum precipitation falls in the winter; the minimum falls in summer. The difference between summer and winter precipitation is very high. The annual average precipitation is between 600 to 1000 mm. The annual average temperature is 18 to 20 °C. The average temperature in January is 8 to 10 °C. The average temperature in July is28 to 30 °C. Annual temperature difference is 15 to 18

°C. The fact that mountains lie perpendicular to the shore in the Aegean Region has allowed the Mediterranean climate to reach inlands. In the Mediterranean climate observed in the Marmara Region, summers are cooler than the Mediterranean coast; winters are colder and snowy. Characteristic vegetation of Mediterranean climate is scrubs composed of plants such as olive, laurel, myrtle, and thyme.

Continental climate

Continental climate is observed in Central Anatolia, Eastern Anatolia and Southeastern Anatolia regions and Inner Western Anatolia part. In continental climate, summers are hot and dry; winters are cold and snowy. In Central Anatolia, the maximum precipitation falls in the spring; the minimum precipitation falls in the summer. The average precipitation in Central Anatolia is 300 to 400 mm. The average winter temperature of Central Anatolia is 1 to 2 °C, average summer temperature is 22 to 23 °C, and annual average temperature is 10 to 12 °C. Precipitation in the Inner Western Anatolia part of the Aegean region is lower with respect to the coastal area. The annual average temperature in the northeastern part of Eastern Anatolia Region is 4 to 6 °C. The average winter temperature in Northeastern Anatolia is -7, -10 °C whereas the average summer temperature is 17 to 19 °C. Annual precipitation is 500 to 600 mm. The average precipitation in Southeastern Anatolia is 400 to 700 mm. There are not many frosts in winter in Southeastern Anatolia Region; however, severe dry hot weather is dominant in summer. The annual average temperature in Southeastern Anatolia is 15 to 16 °C, winter temperature is 3 to 4°C, and summer temperature is 30 to 35°C.

Forest Information System (FIS) database

Digital 1/100,000 scale FIS vector data acquired from Forest General Directorate to be used in the determination of horizontal and vertical distribution of tree species was used in the study. These vector data are produced with a combined inventory method. Initially, infrared aerial photographs of the area at 1/15,000 scale are shot, and then these photographs are scanned at high resolution by the Photogrammetry Office of the Regional Forest Directorate and afterwards evaluated three-dimensionally in computer environment. Stand types are interpreted over the stereo model and digitized, and then draft maps of stand types are created. Following that, Forest Management Planning Team takes measurements in temporary trial areas set at 300 m intervals. Draft maps are finalized based on these measurements and stand types maps are created. These maps are digitized and included in the Forest Information System as a data layer.

Shuttle Radar Topography Mission (SRTM) data

SRTM is a project by American NASA institution to develop continuous and high-resolution digital elevation model of all land located approximately between 60°north and south latitudes (Farr and Kobrick, 2000). The space shuttle developed for this purpose was launched in February 2000 and gathered data for 11 days using synthetic aperture radar (SAR) method. In this method, it is possible to collect data by sending microwave signals to the surface of the earth without being affected from the location of the sun, weather conditions, and surface contrast. Stereo view is provided with the second receptor (antenna) mounted on the SRTM space shuttle with a 60 m distance and elevations are obtained as such (Bildirici et al., 2008).

SRTM digital elevation model (DEM) data is compiled by the Consultative Group for International Agriculture Research Consortium for Spatial Information (CGIAR-CSI) that is processed at 90 m resolution for entire Earth and made available to everyone over an Internet mapping interface free of charge. This product is of great value to scientists working on terrain analysis; data is easily downloadable in a ready-to-use format (Gorokhovich and Voustianiouk, 2006).

90 m SRTM version 4.0 data generated by Jarvis et al. (2008) and downloaded from IAT-CSI SRTM web site (http://srtm.csi.cgiar.org) was used in this study. These data are in WGS84 datum and distributed in ARC GRID, ARC ASCII, Geotiff, and decimal degree formats. Data were generated from the original USGS/NASA SRTM data. These data were processed by the International Centre for Tropical Agriculture (CIAT) to ensure continuity in topographic surfaces. The areas for which there is no data in the original SRTM data (data gaps) were completed by using interpolation methods introduced in Reuter et al. (2007).

It is indicated that at 90% confidence level, vertical and horizontal absolute position accuracy of SRTM3 data is below 16 and 20 m respectively (Bamler, 1999; JPL, 2008). According to these values, it is estimated that the topographic data to be obtained can be used in many studies that do not require very high terrestrial resolution (Çoban and Eker, 2009).

Preparation of SRTM data and acquirement of elevation classes geographical information layer

90 m (eight in total) SRTM version 4.0 digital elevation model data of the study area in geotiff format arranged as 6000 x 6000 pixels downloaded from the CIAT-CSI SRTM website (http://srtm.csi.cgiar.org) were combined in ERDAS Imagine 9.1 software environment and coordinate conversion was applied; UTM, ED50 Datum, Zone 35 North coordinate system was assigned. Hence, the data has become evaluable together with 1/100,000 scale FIS data.

Then, using Turkey boundary layer obtained from FIS data, SRTM data was truncated (Figure 2). This truncated 90 m pixel sized digital elevation model data in raster format was classified into the predetermined five elevation classes using “recode” command in the GIS analysis module of ERDAS Imagine 9.1 software (Table 1). Raster-vector conversion was applied to evaluate this data in raster format later with 1/100,000 scale FIS data in vector format and elevation class map of the study area was obtained in vector format (Figure 3).

Elevation class map converted into vector format was transferred to ArcGIS 9.2 software environment and using the “overlay” function of geographic information systems, they were combined with the available FIS data and transformed into a geographic information layer that belongs to the Forest Information System. Following this, distribution of 5 elevation classes was determined by the queries conducted in FIS database (Table 1).

Preparation of FIS database

As it was also indicated earlier, it is aimed in this study to determine horizontal and vertical distribution of *Pinus nigra* (Crimean pine), which is geographically the largest spread needled tree species in Turkey, (to elevation classes) in terms of Regional Forest Directorates.

To achieve this aim, an attribute using “Çk” alias was opened in the FIS database for Crimean pine, and with the queries in stand types data layer in FIS database, “1” was assigned to pure Crimean pine stand; “2” was assigned to mixed stand where Crimean pine is the primary tree species; “3” was assigned to mixed stand where Crimean pine is either secondary or tertiary tree species; and “0” was assigned to areas where there is no Crimean pine. As a result of these operations, FIS database was ready to determine

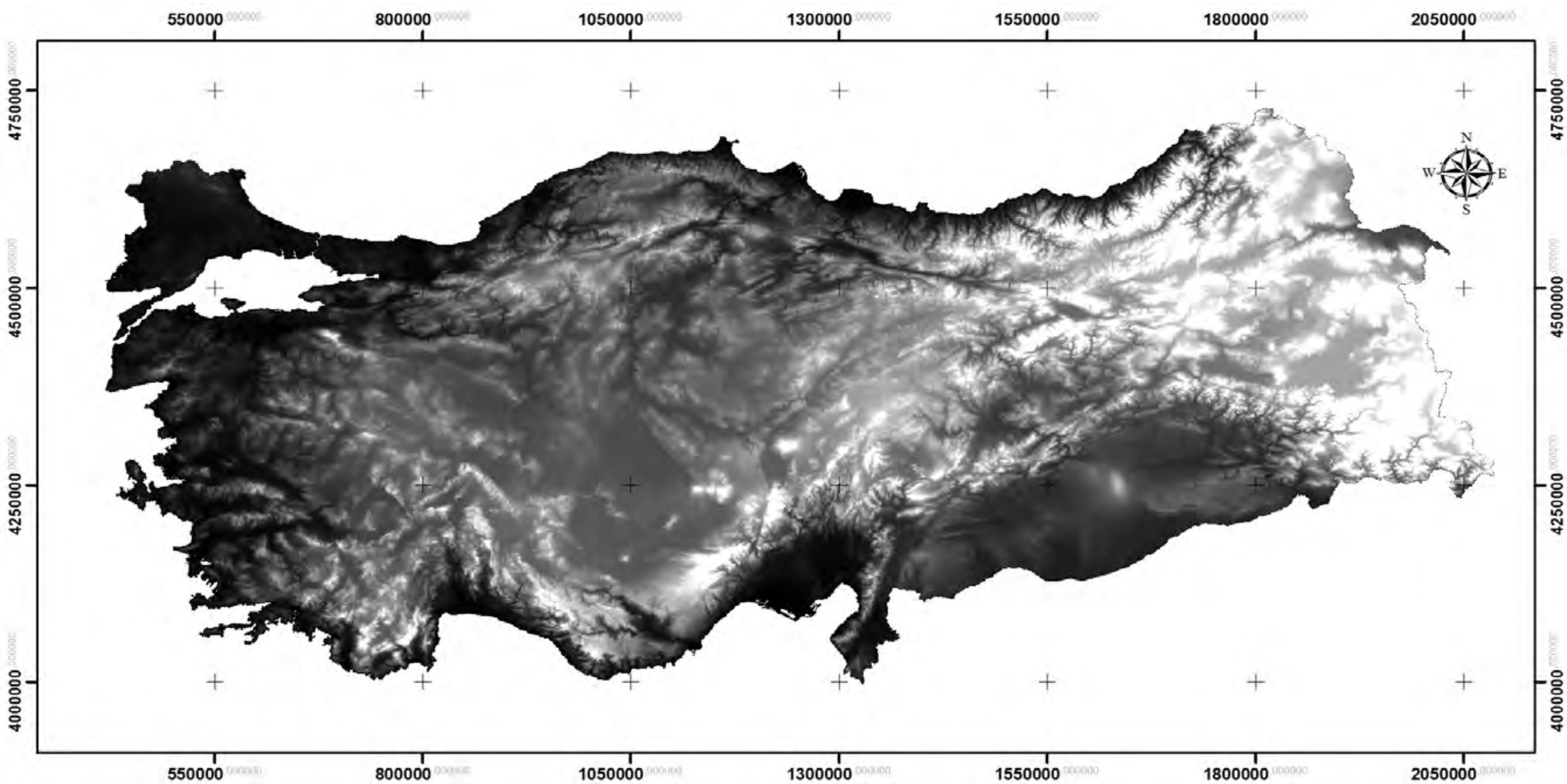

Figure 2. SRTM Digital Elevation Model data downloaded from CIAT-CSI SRTM web site (http://srtm.csi.cgiar.org) and truncated by Turkey country boundary layer.

Table 1. Predetermined elevation classes, codes, and spatial distribution of these in Turkey.

Elevation class code	Elevation class (m)	Area (ha)	Area (%)
1	(0 - 1000)	33785299,86	42.46
2	(1000 - 1600)	26473681,66	33.27
3	(1600 - 2100)	12444282,93	15.64
4	(2100 - 2400)	3848016,66	4.84
5	(2400 >)	3015146,19	3.79
Total		**79566427,30**	**100**

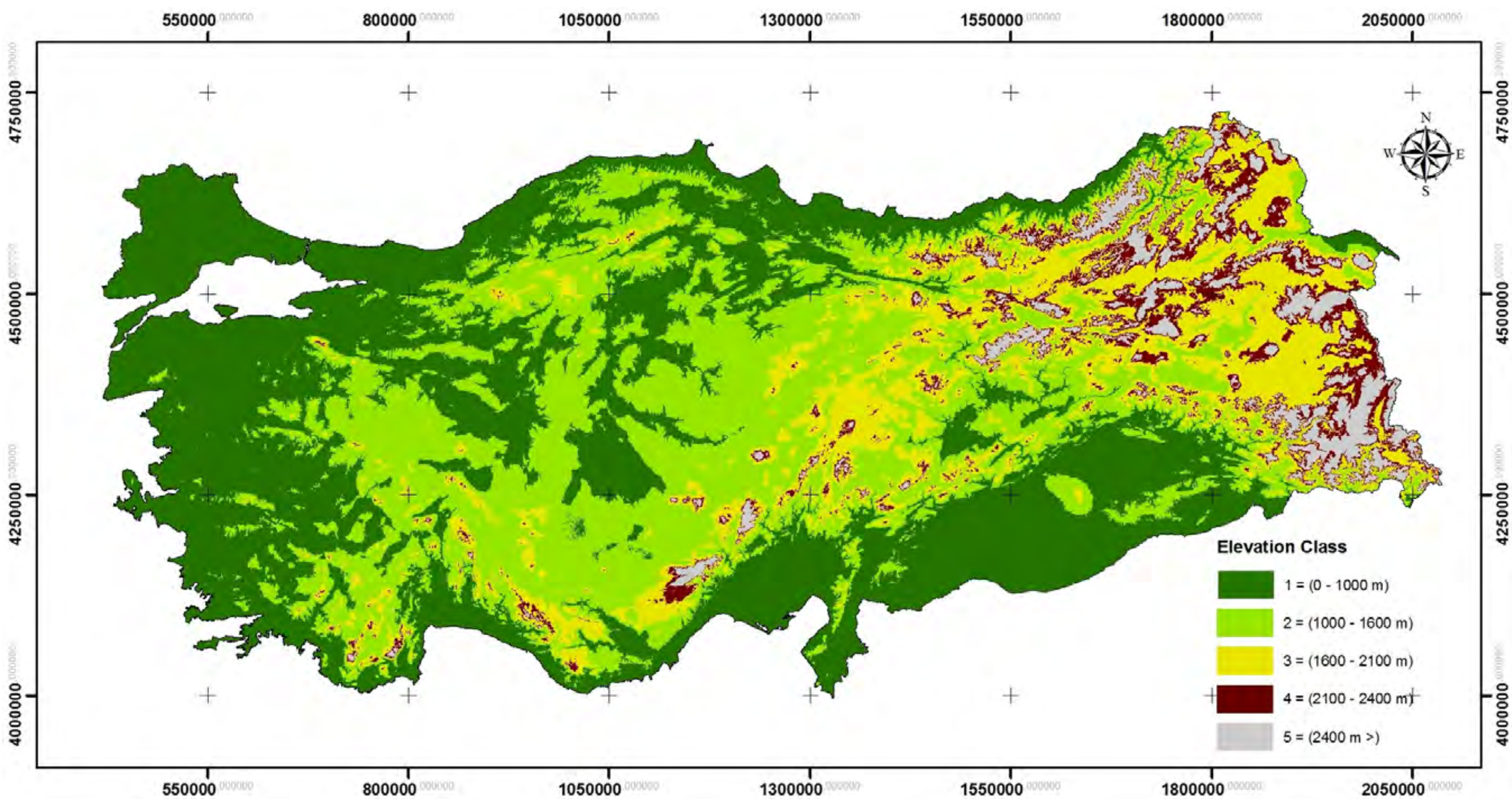

Figure 3. Elevation class map of Turkey.

horizontal and vertical distribution of Crimean pine (to predetermined elevation classes) in terms of Regional Forest Directorates.

FINDINGS AND DISCUSSION

Using the prepared FIS database, the map depicting the distribution of Crimean pine (Çk) into elevation classes in terms of Regional Forest Directorates is prepared (Figure 4). When the legend of the map in question is analyzed, it will be seen that figures such as (1, 0), (1, 1), (1, 2), (1, 3)… (5, 3) correspond to different colors. Here, for example, (1, 0) represents the areas in the elevation class no. 1 (0 to 1000 m) with no Crimean pine; (1, 1) represents the areas in the elevation class no. 1 with pure Crimean pine stand; (1, 2) represents the areas in the elevation class no. 1 with mixed stand where Crimean pine is the primary tree species; and finally (1, 3) represents the areas in the elevation class no. 1 with mixed stand where Crimean pine is the secondary or tertiary tree species.

With the queries conducted on FIS database,

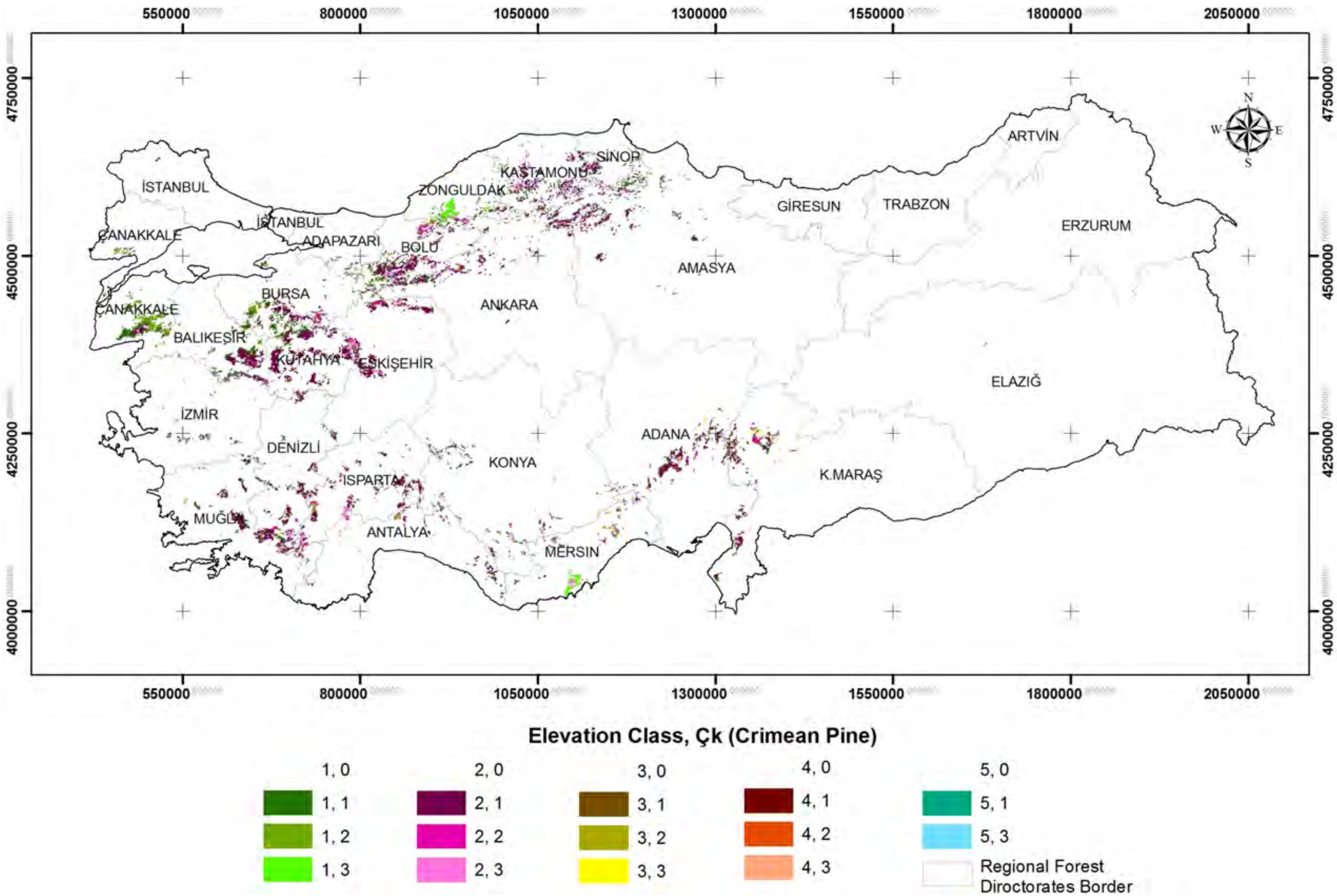

Figure 4. Distribution of Crimean Pine (Çk) to predetermined elevation classes.

spatial distribution (ha) of Crimean pine (Çk) to elevation classes on the basis of Regional Forest Directorates was determined and Table 2 was obtained. Moreover, the last column of Table 2 (total) was organized to indicate a real distribution of predetermined elevation classes to Regional Forest Directorates. In the following step, Table 3 indicating distribution of pure and mixed Crimean pine stands to Regional Forest Directorates,

Table 2. Distribution of Crimean Pine (Çk) to predetermined elevation classes in terms of Regional Forest Directorates in Turkey.

Regional forest directorate	Elevation class (m)	Crimean pine (Çk) stand (ha)				
		0	1	2	3	Total
Adana	(0-1000)	1257935,39	2191,01	1131,05	17,28	1261274,73
	(1000-1600)	2244409,57	64345,35	15804,07	1942,29	2326501,28
	(1600-2100)	919773,21	35080,58	6252,37	3225,44	964331,60
	(2100-2400)	124570,18	133,21	43,62	559,46	125306,47
	(> 2400)	98819,26			18,09	98837,35
	Total	4645507,61	101750,16	23231,11	5762,55	4776251,43
Adapazari	(0-1000)	751571,42	7608,33	3640,00	865,70	763685,45
	(1000-1600)	47795,25	1590,96	387,61	913,59	50687,41
	(1600-2100)	230,16				230,16
	(2100-2400)					
	(> 2400)					
	Total	799596,83	9199,30	4027,61	1779,29	814603,03
Amasya	(0-1000)	2536153,83	37398,47	3519,08	4231,06	2581302,44
	(1000-1600)	3875815,30	70112,49	9022,87	3194,63	3958145,29
	(1600-2100)	1448515,23	2937,34	1134,10	239,86	1452826,53
	(2100-2400)	95557,97	67,14			95625,11
	(> 2400)	23528,49				23528,49
	Total	7979570,83	110515,45	13676,05	7665,55	8111427,88
Ankara	(0-1000)	2074305,12	14120,96	842,65	286,86	2089555,59
	(1000-1600)	2423016,20	97831,81	6116,71	1280,58	2528245,30
	(1600-2100)	144767,51	7795,28	4692,25	1303,28	158558,32
	(2100-2400)	1048,31				1048,31
	(> 2400)	42,53				42,53
	Total	4643179,67	119748,05	11651,61	2870,73	4777450,06
Antalya	(0-1000)	1045454,71	1891,82	4924,00	85,68	1052356,21
	(1000-1600)	564265,26	19472,74	11216,56	5964,16	600918,72
	(1600-2100)	300672,23	6125,96	1491,42	674,82	308964,43
	(2100-2400)	79819,91	11,62			79831,53
	(> 2400)	24614,34				24614,34
	Total	2014826,45	27502,13	17631,98	6724,66	2066685,22
Artvin	(0-1000)	156559,47				156559,47
	(1000-1600)	218196,57	27,02			218223,59
	(1600-2100)	179472,03	294,46			179766,49
	(2100-2400)	75225,60	206,07			75431,67
	(> 2400)	105227,70	28,37			105256,07
	Total	734681,37	555,92			735237,29
Balikesir	(0-1000)	1261802,70	62351,92	13640,39	1120,18	1338915,19
	(1000-1600)	34178,04	65597,52	1572,44	596,50	101944,50
	(1600-2100)	849,12	519,22			1368,34
	(2100-2400)					
	(> 2400)					
	General Total	2214192,6	497739,66	85431,19	26519,46	22723882.2

Table 2. Contd.

Regional forest directorate	Elevation class (m)	Crimean pine (Çk) stand (ha)				
		0	1	2	3	Total
Bolu	(0-1000)	394136,73	40975,69	8692,21	4414,67	448219,30
	(1000-1600)	380668,96	100704,66	22480,77	3490,82	507345,21
	(1600-2100)	73916,45	2314,51	800,54	538,12	77569,62
	(2100-2400)	2290,68				2290,68
	(> 2400)					
	Total	851012,82	143994,86	31973,52	8443,60	1035424,80
Bursa	(0-1000)	1302330,94	71545,04	14549,70	2997,61	1391423,29
	(1000-1600)	116412,34	41474,39	8197,91	5030,93	171115,57
	(1600-2100)	17337,98	1554,63	1173,24	706,62	20772,47
	(2100-2400)	3738,98	8,08			3747,06
	(> 2400)	615,60				615,60
	Total	1440435,85	114582,14	23920,85	8735,16	1587674,00
Çanakkale	(0-1000)	1661928,78	57570,85	51726,83	3589,91	1774816,37
	(1000-1600)	1256,92	3910,35	1294,31		6461,58
	(1600-2100)	9,59	78,80			88,39
	(2100-2400)					
	(2400 m >)					
	Total	1663195,28	61560,00	53021,14	3589,91	1781366,33
Denizli	(0-1000)	1074749,30	12613,53	3652,32	6,29	1091021,44
	(1000-1600)	502068,03	83604,02	12986,74	1993,64	600652,43
	(1600-2100)	57370,74	16330,06	2051,91	268,56	76021,27
	(2100-2400)	5775,32	61,22	73,84		5910,38
	(2400 m >)	83,43				83,43
	Total	1640046,81	112608,83	18764,82	2268,49	1773688,95
Elaziğ	(0-1000)	3376970,31				3376970,31
	(1000-1600)	3544779,86	314,01	296,51		3545390,38
	(1600-2100)	3433756,61				3433756,61
	(2100-2400)	1290305,29				1290305,29
	(2400 m >)	1322022,55				1322022,55
	Total	12967834,62	314,01	296,51		12968445,14
Erzurum	(0-1000)	164621,18				164621,18
	(1000-1600)	946792,05				946792,05
	(1600-2100)	3076972,70				3076972,70
	(2100-2400)	1626122,82				1626122,82
	(2400 m >)	1120226,81				1120226,81
	Total	6934735,57				6934735,57
Eskişehir	(0-1000)	1082219,69	9845,22	2613,74	79,56	1094758,21
	(1000-1600)	1302432,95	99828,29	10557,78	11987,12	1424806,14
	(1600-2100)	71704,95	3942,76	210,99	1638,99	77497,69
	(2100-2400)	3963,74	8,02			3971,76
	(2400 m >)	304,38				304,38
	General Total	50072079,29	1044423,79	226790,54	63262,68	51406555,90

Table 2. Contd.

Regional forest directorate	Elevation class (m)	Crimean pine (Çk) stand (Ha)				
		0	1	2	3	Total
Giresun	(0-1000)	564598,38				564598,38
	(1000-1600)	396222,47				396222,47
	(1600-2100)	284625,34	66,37			284691,71
	(2100-2400)	66338,23	14,17			66352,40
	(2400 m >)	21490,36				21490,36
	Total	1333274,78	80,54			1333355,32
Isparta	(0-1000)	444763,68	1322,55	1061,66	208,44	447356,33
	(1000-1600)	1003367,93	79309,97	14982,79	18423,60	1116084,29
	(1600-2100)	209206,96	17378,57	3145,42	1821,34	231552,29
	(2100-2400)	20521,92	2,51			20524,43
	(2400 m >)	2986,25				2986,25
	Total	1680846,75	98013,60	19189,87	20453,38	1818503,60
General total		53086200,80	1142517,93	245980,41	83715,68	54558414,82
Istanbul	(0-1000)	1610060,76	4127,70			1614188,46
	(1000-1600)	8,10				8,10
	(1600-2100)					
	(2100-2400)					
	(> 2400)					
	Total	1610068,86	4127,70			1614196,56
Izmir	(0-1000)	2344437,28	13973,59	349,98	1953,01	2360713,86
	(1000-1600)	119244,50	22585,21	5,12	1083,80	142918,63
	(1600-2100)	6930,98	652,82			7583,80
	(2100-2400)	15,39				15,39
	(> 2400)					
	Total	2470628,14	37211,62	355,10	3036,80	2511231,66
K.maraş	(0-1000)	3994357,72	10662,98	8012,46	107,06	4013140,22
	(1000-1600)	967047,85	41736,30	18931,09	2798,76	1030514,00
	(1600-2100)	362541,58	22150,34	7045,03	5849,19	397586,14
	(2100-2400)	59655,13	7,69	91,26	996,42	60750,50
	(2400 m >)	24004,31				24004,31
	Total	5407606,58	74557,31	34079,85	9751,43	5525995,17
Kastamonu	(0-1000)	525940,22	34338,72	251,95	7065,36	567596,25
	(1000-1600)	540247,61	117593,13	7501,38	23261,25	688603,37
	(1600-2100)	59390,35	9709,28	925,91	1306,83	71332,37
	(2100-2400)	3997,80	47,98			4045,78
	(2400 m >)	147,82				147,82
	Total	1129723,80	161689,12	8679,24	31633,44	1331725,60
Konya	(0-1000)	1182935,25	313,84	84,98	70,13	1183404,20
	(1000-1600)	3861740,85	38490,79	10252,69	5351,12	3915835,45
	(1600-2100)	554449,65	20390,08	2861,75	2105,21	579806,69
	(2100-2400)	60431,15	21,43			60452,58
	(2400 m >)	48115,89				48115,89
	General Total	69411900,96	147931982	302294,02	135663,82	71329178,62

Table 2. Contd.

Regional forest directorate	Elevation class (m)	Crimean pine (çk) stand (ha) 0	1	2	3	Total
	(0-1000)	296262,33	37153,61	2074,79	204,61	335695,34
	(1000-1600)	618551,35	183032,08	2094,17	4181,65	807859,25
Kütahya	(1600-2100)	14965,79	9269,17	111,74	1170,05	25516,75
	(2100-2400)	1157,67				1157,67
	(2400 m >)					
	Total	930937,15	229454,87	4280,70	5556,31	1170229,03
	(0-1000)	770906,73	1669,65	4463,11	23359,43	800398,92
	(1000-1600)	388687,66	12348,71	8238,96	13640,53	422915,86
Mersin	(1600-2100)	238917,96	5223,03	6809,68	4458,93	255409,60
	(2100-2400)	62942,60	7,94	144,73	85,43	63180,70
	(2400 m >)	26417,14				26417,14
	Total	1487872,09	19249,34	19656,47	41544,31	1568322,21
Muğla	(0-1000)	1698287,86	19479,10	65,59	3815,95	1721648,50
	(1000-1600)	205684,47	61922,49	1920,56	3538,37	273065,89
	(1600-2100)	34921,27	7620,79	342,66	61,45	42946,17
	(2100-2400)	8356,78				8356,78
	(2400 m >)	1264,66				1264,66
	Total	1948515,03	89022,37	2328,81	7415,77	2047281,98
General total		73779225,23	1817046,40	328560,00	190180,21	76115011,84
	(0-1000)	390521,46	21303,11	1801,95	3076,34	416702,86
	(1000-1600)	128516,69	19427,03	1412,27	7186,90	156542,89
Sinop	(1600-2100)	978,39	22,20		29,36	1029,95
	(2100-2400)					
	(2400 m >)					
	Total	520016,53	40752,35	3214,22	10292,61	574275,71
	(0-1000)	385247,05				385247,05
	(1000-1600)	375482,24				375482,24
Trabzon	(1600-2100)	715071,97				715071,97
	(2100-2400)	253589,35				253589,35
	(2400 m >)	195188,21				195188,21
	Total	1924578,83				1924578,83
	(0-1000)	726442,14	16027,61	7721,71	38938,85	789130,31
	(1000-1600)	139521,84	10670,92	2256,37	7950,64	160399,77
Zonguldak	(1600-2100)	2827,00		18,26	185,59	3030,85
	(2100-2400)					
	(2400 m >)					
	Total	868790,98	26698,52	9996,34	47075,08	952560,92
General total		77092611,57	1884497,27	341770,56	247547,90	79566427,30

Table 3. Distribution of pure and mixed Crimean Pine stands to Regional Forest Directorates

Regional forest directorate	Crimean pine (*Pinus nigra*) stand			Total (ha)
	1 (ha)	2 (ha)	3 (ha)	
Adana	101750,16	23231,11	5762,55	130743,82
Adapazari	9199,3	4027,61	1779,29	15006,20
Amasya	110515,45	13676,05	7665,55	131857,05
Ankara	119748,05	11651,61	2870,73	134270,39
Antalya	27502,13	17631,98	6724,66	51858,77
Artvin	555,92			555,92
Balikesir	128468,65	15212,83	1716,68	145398,16
Bolu	143994,86	31973,52	8443,6	184411,98
Bursa	114582,14	23920,85	8735,16	147238,15
Çanakkale	61560	53021,14	3589,91	118171,05
Denizli	112608,83	18764,82	2268,49	133642,14
Elaziğ	314,01	296,51		610,52
Erzurum				
Eskişehir	113624,29	13382,51	13705,68	140712,48
Giresun	80,54			80,54
Isparta	98013,6	19189,87	20453,38	137656,85
Istanbul	4127,7			4127,70
İzmir	37211,62	355,1	3036,8	40603,52
K_maraş	74557,31	34079,85	9751,43	118388,59
Kastamonu	161689,12	8679,24	31633,44	202001,80
Konya	59216,14	13199,42	7526,47	79942,03
Kütahya	229454,87	4280,7	5556,31	239291,88
Mersin	19249,34	19656,47	41544,31	80450,12
Muğla	89022,37	2328,81	7415,77	98766,95
Sinop	40752,35	3214,22	10292,61	54259,18
Trabzon				
Zonguldak	26698,52	9996,34	47075,08	83769,94
Total	1884497,27	341770,56	247547,90	2473815,73

1, Pure Crimean pine stands; 2, mixed stands where Crimean pine is the primary tree species; 3, mixed stands where Crimean Pine is the secondary or tertiary tree species.

Table 4 indicating distribution of pure and mixed Crimean pine stands to elevation classes on the basis of Regional Forest Directorates, and Table 5 indicating distribution of pure and mixed Crimean pine stands to elevation classes (ha, %) were obtained respectively.

The following results can be obtained if Tables 1, 2, 3, 4 and 5 are analyzed together:

(i) Based on the 1/100,000 scale Forest Information System data, pure Crimean pine stand covers an area of 1,884,497.27 ha; mixed stand where Crimean pine is the primary tree species covers an area of 341,770.56 ha; mixed stand where Crimean pine is the secondary or tertiary tree species covers an area of 247,547.90 ha and the total area covered with Crimean pine in overall Turkey is 2,473,815.73 ha.
(ii) Crimean pine is distributed as pure and/or mixed stands in 25 of the total 27 Regional Forest Directorates except Erzurum and Trabzon Regional Forest Directorates.
(iii) Vertical limit (elevation limit) of Crimean pine in Turkey is slightly over 2400 m in Adana and Artvin Regional Forest Directorates.
(iv) Only pure stands are present in Artvin, Elazig, Giresun, and Istanbul Regional Forestry Directorates, at (1000 to 2400 m), (1000 to 1600 m), (1600 to 2400 m), and (0 to 1000 m) altitudes respectively.
(v) Spatially, 42.46% of Turkey's land has an elevation of 0 to 1000 m, 33.27% has an elevation of 1000 to 1600 m, 15.64% has 1600 to 2100 m, 4.84% has 2100 to 4000 m, and 3.79% has an elevation higher than 2400 m.
(vi) Across Turkey, 65.59% of pure Crimean pine stand is located in elevation class no. 2 (1000 to 1600 m), 25.39% is located in elevation class no. 1 (0 to 1000 m), 8.99% is located in elevation class no. 3 (1600 to 2100m) and 0.03% is located in elevation class no. 4 (2100 to 2400m) (vii) (see Table 5). Throughout Turkey, 61.74% of pure

Table 4. Distribution of pure and mixed Crimean Pine stands to elevation classes in terms of Regional Forest Directorates

Regional forest directorate	Pure and mixed Crimean pine stand (ha)					Total
	(0-1000 m)	(1000-1600 m)	(1600-2100 m)	(2100-2400 m)	(>2400 m)	
Adana	3339,34	82091,71	44558,39	736,29	18,09	130743,82
Adapazari	12114,03	2892,16				15006,19
Amasya	45148,61	82329,99	4311,30	67,14		131857,04
Ankara	15250,47	105229,10	13790,81			134270,38
Antalya	6901,50	36653,46	8292,20	11,62		51858,78
Artvin		27,02	294,46	206,07	28,37	555,92
Balikesir	77112,49	67766,46	519,22			145398,17
Bolu	54082,57	126676,25	3653,17			184411,99
Bursa	89092,35	54703,23	3434,49	8,08		147238,15
Çanakkale	112887,59	5204,66	78,80			118171,05
Denizli	16272,14	98584,40	18650,53	135,06		133642,13
Elaziğ		610,52				610,52
Erzurum						
Eskişehir	12538,52	122373,19	5792,74	8,02		140712,47
Giresun			66,37	14,17		80,54
Isparta	2592,65	112716,36	22345,33	2,51		137656,85
Istanbul	4127,7					4127,7
İzmir	16276,58	23674,13	652,82			40603,53
K_maraş	18782,50	63466,15	35044,56	1095,37		118388,58
Kastamonu	41656,03	148355,76	11942,02	47,98		202001,79
Konya	468,95	54094,60	25357,04	21,43		79942,02
Kütahya	39433,01	189307,9	10550,96			239291,87
Mersin	29492,19	34228,2	16491,64	238,10		80450,13
Muğla	23360,64	67381,42	8024,9			98766,96
Sinop	26181,40	28026,20	51,56			54259,16
Trabzon						0,00
Zonguldak	62688,17	20877,93	203,85			83769,95
Total	709799,43	1527270,80	234107,16	2591,84	46,46	2473815,69

Table 5. Distribution of pure and mixed Crimean pine stands to elevation classes (ha, %)

Elevation class (m)	Pure Crimean Pine stand (ha)	Pure Crimean pine stand (%)	Pure and mixed Crimean pine stand (ha)	Pure and mixed Crimean pine stand (%)
(0-1000)	478485,30	25,39	709799,43	28,69
(1000-1600)	1235930,24	65,59	1527270,80	61,74
(1600-2100)	169456,25	8,99	234107,16	9,46
(2100-2400)	597,08	0,03	2591,84	0,11
(2400>)	28,37	0,002	46,46	0,002
Total	1884497,27	100,00	2473815,69	100,00

and mixed Crimean pine stand is located in elevation class no. 2 (1000 to 1600 m), 28.69% is located in elevation class no. 1 (0 to 1000m), 9.46% is located in elevation class no. 3 (1600 to 2100 m) and 0.11% is located in elevation class no. 4 (2100 to 2400 m) (Table 5).
(viii) 33.27% of Turkey's land (26,473,681.66 ha) is in the elevation class no. 2 (1000 to 1600 m) and pure Crimean pine stands cover 4.67% of this area whereas pure + mixed Crimean pine stands cover 5.77% of this area.
(ix) 42.46% of Turkey's land (33,785,299.86 ha) is in the elevation class no. 1 (0 to 1000 m) and pure Crimean

pine stands cover 1.42% of this area whereas pure + mixed Crimean pine stands cover 2.1% of this area.
(x) 15.64% of Turkey's land (12,444,282.93 ha) is in the elevation class no. 3 (1600 to 2100 m) and pure Crimean pine stands cover 1.36% of this area whereas pure + mixed Crimean pine stands cover 1.88% of this area.
(xi) 4.84% of Turkey's land (3,848,016.66 ha) is in the elevation class No. 4 (2100 to 2400m) and pure Crimean pine stands cover 0.02% of this area whereas pure + mixed Crimean pine stands cover 0.07% of this area.

In the same manner, it is possible to conduct similar assessments for other tree species. Distribution of tree species into slope classes and aspects, which is not included as it is outside the scope of this study, can be determined by obtaining slope classes and aspect maps at desired percentage steps from the SRTM Digital Elevation Model data and combining this with current FIS data.

CONCLUSION AND FURTHER SUGGESTIONS

There are many studies in the literature on the determination of the accuracy of SRTM data. It is indicated in Bamler (1999) and JPL (2008) that vertical and horizontal absolute position accuracy of SRTM3 data at 90% confidence level was below 16 and 20 m error values respectively. In a similar study conducted on the 90 m SRTM data set which was made available on the Internet by CGIAR-CSI free of charge, Gorokhovich and Voustianiouk (2006) introduced that absolute average horizontal error was in the interval of 4.07 and 7.58 m; and they reached accuracy levels better than the standard vertical accuracy level that is indicated as 16 m in the website for SRTM data. Çoban and Eker (2009) compared topographic data they obtained from SRTM and 1/25,000 scale topographic maps and they concluded that there was an areal difference of 7% when the two data was compared in terms of average slope of the terrain; approximately 2% when the aspect maps were compared; and approximately 3% when elevation classes were compared. They identified that digital terrain models that can be obtained by processing SRTM data can provide information on topographic characteristics of the terrain such as slope, aspect, and elevation classes. Again it was suggested in a similar comparison by Jarvis et al. (2009) on Honduras, Ecuador, and Columbia in South America that the error in SRTM data was related to the aspect of the terrain; moreover, they indicated that when maps smaller than 1/25,000 scale was in question, instead of using these, it was more appropriate to use digital elevation models to be obtained from SRTM data.

A SRTM image of 90 m pixel size at a number of 6000 x 6000 pixels covering an area of 540 x 540 km corresponds to approximately 2005 standard topographic maps at 1/25,000 scale whereas entire Turkey with an area of 795,664.27 km^2 corresponds to approximately 5472 standard topographic maps at 1/25,000 scale. In other words, approximately 5472 1/25,000 scale standard topographic maps need to be evaluated to generate Digital Elevation Model of entire Turkey whereas a total of eight 6000 x 6000 pixels at 90 m pixel size SRTM satellite data is ready to be used directly as Digital Elevation Model without requiring any further operation. The use of standard topographic maps requires high costs, intensive workload and bureaucratic operations. However, if it does not require high sensitivity, then it is possible to reach information for a large area quickly by using SRTM data. In conclusion, the use of SRTM data in determination of topographic characteristics can prove a considerably fast, easy, and economical option.

Since it is aimed at determining horizontal and vertical distribution of Crimean pine in Turkey in this study, SRTM data was solely used to generate terrain elevation classes. It is possible to generate geographic information layers such as slope classes or aspect maps to be used in forestry studies from SRTM data using the same methodology and to integrate these with FIS to reach important information for many research studies with analyses and queries to be performed on the information. Besides all these, it is possible to benefit from SRTM digital elevation model data in many studies such as catchment area modeling, visibility analysis, calculation of terrain average elevation, generation of horizontal and vertical sections, calculation of excavation-filler volumes, and determination of potential areas under risk in case of tsunami or floods.

REFERENCES

Anonymous (2006). Climate of Turkey. URL: http://www.cografyam.org/turkiyeiklimi.htm, Access:29.11.2011
Anonymous (2008). Soils of Turkey.(04.08.2008) URL: http://www.gencziraat.com/Toprak-Bilgisi/Turkiye-Topraklari-8.html,
Bamler R (1999). The SRTM Mission: A World-Wide 30 m Resolution DEM from SAR Interferometry in 11 Days. Photogrammetric Week,URL: http://www.ifp.uni-stuttgart.de/publications/phowo99/phowo99.en.htm, http://www.ifp.uni-stuttgart.de/publications/phowo99/bamler.pdf, Access: 19.12.2009.
Bildirici İÖ, Üstün A, Uluğtekin N, Selvi HZ, Abbak AR, Buğdaycı İ, Doğru Ö (2008). The Compilation of the Digital Elevation Model for Turkey based on SRTM: The results of the project. Project Number: 106Y130, URL: http://www.tsym3.selcuk.edu.tr/_docs/106Y130_oztug_bildirici.pdf. Access: 16.02.2009.
Çepel N (1988). Forest Ecology, Gençlik Basımevi, Istanbul.
Çoban HO, Eker M (2009). Some Topographical analysis with SRTM data: An example of Isparta Regional Forest Directorate, Süleyman Demirel University, Rev. Fac. For. A2: 76-91.
Farr TG, Kobrick M (2000). Shuttle radar topography mission produces a wealth of data, EOS Transactions AGU, 81: 583- 585.
Gorokhovich Y, Voustianiouk A (2006). Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its relation to the terrain characteristics, Remote Sensing of Environment 104: 409-415.
Jarvis A, Reuter HI, Nelson A, Guevara E (2008). Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org.
Jarvis A, Rubiano J, Nelson A, Farrow A, Mulligan M (2009). Practical use of SRTM data in the tropics- Comparisons with digital elevation

models generated from cartographic data. CGIAR-CSI, Working document No.198, URL: http://srtm.csi.cgiar.org/PDF/Jarvis4.pdf. Access: 14.12.2012

Inan M (1998). Effects of land use changes on stream-flow and water quality parameters in Yeniçiftlik Creek. Master's thesis, Istanbul University, The Graduate School of Natural and Applied Sciences, Istanbul, Turkey.

JPL (2008). SRTM (Shuttle Radar Topography Mission). Jet Propulsion Laboratory, California Institute of Technology, USA, URL: http://www2.jpl.nasa.gov/srtm/ index.html. Access: 16.02.2009

Koç A (1995). Generation of the computer-aided Thematic Forest Maps and the Forest Information System. Ph.D. thesis, Istanbul University, The Graduate School of Natural and Applied Sciences, Istanbul, Turkey.

Lee YC (1995). UBITEK Lectures in Geographic Information Systems. Space Technologies Department, Marmara Research Center. 13-26 March, Gebze-KOCAELİ.

OGM (2011). Forest Atlas: Main tree species prevailing in our forests. URL: http://www2.ogm.gov.tr/yukle/atlas.zip, Access: 15.05.2011

Reuter HI, Nelson A, Jarvis A (2007). An evaluation of void filling interpolation methods for SRTM data, Int. J. of Geographic Information Sci. 21(9): 983-1008.

Yener H (1998). Forest Information System. Ph.D. thesis, Istanbul University, The Graduate School of Natural and Applied Sciences, Istanbul, Turkey.

Yener H (1993). Digital Terrain Models. Master's thesis, Istanbul University, The Graduate School of Natural and Applied Sciences, Istanbul, Turkey.