



Determination of horizontal and vertical distribution of Calabrian pine stands in Turkey using SRTM satellite data and GIS

Hakan Yener*

Istanbul University, Faculty of Forestry, Department of Geodesy and Photogrammetry, 34473-Bahçeköy, Turkey

*Corresponding Author email : yenerh99@gmail.com

Abstract

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 SRTM (Shuttle Radar Topography Mission) satellite data and 1/25,000 scale Forest Information System database, horizontal and vertical distribution of Calabrian pine (*Pinus brutia* Ten.), which is spatially the most extensively spread needled tree species in Turkey, (to elevation classes) is determined and the generated results (map, table etc.) are presented.

Key words

Calabrian pine, DEM, FIS, GIS, SRTM satellite data

Introduction

Forests and forest areas are among the most important natural resources in Turkey. 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 (Yener and Inan, 2010).

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, 1993). 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 (Koç, 1993). 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 (Koç, 1993; Koç and Yesil, 1996; Yener and Inan, 2010).

Geographic information systems (GIS) are composed of software, hardware, data, and users; graphic and non-graphic (thematic-attribute) data is organized together in these systems; a series of new data can be obtained from available data by means of multiple analysis and query facilities; 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 (Yener and Inan, 2010).

Forests 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 (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 (Koç *et al.*, 1996). Today, using different sources and methods, digital terrain models and digital elevation models can be generated. No matter which methods was used to generate

digital elevation model data, geographical information layers such as slope, aspect, elevation classes for the forest information system (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 (Shuttle Radar Topography Mission) 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).

This study aims to determine horizontal and vertical distribution of Calabrian pine (*Pinus brutia* Ten.). For this purpose, 1/25,000 scale Forest Information System (FIS) data were used along with the SRTM satellite data used for the Digital Elevation Model.

Materials and Methods

Study area : The study area covers entire Turkey which lies between 36° - 42° N latitude and 26° - 45° E longitude. There are 27 Regional Forest Directorates within a total of 79081876.20 ha area (Fig.1).

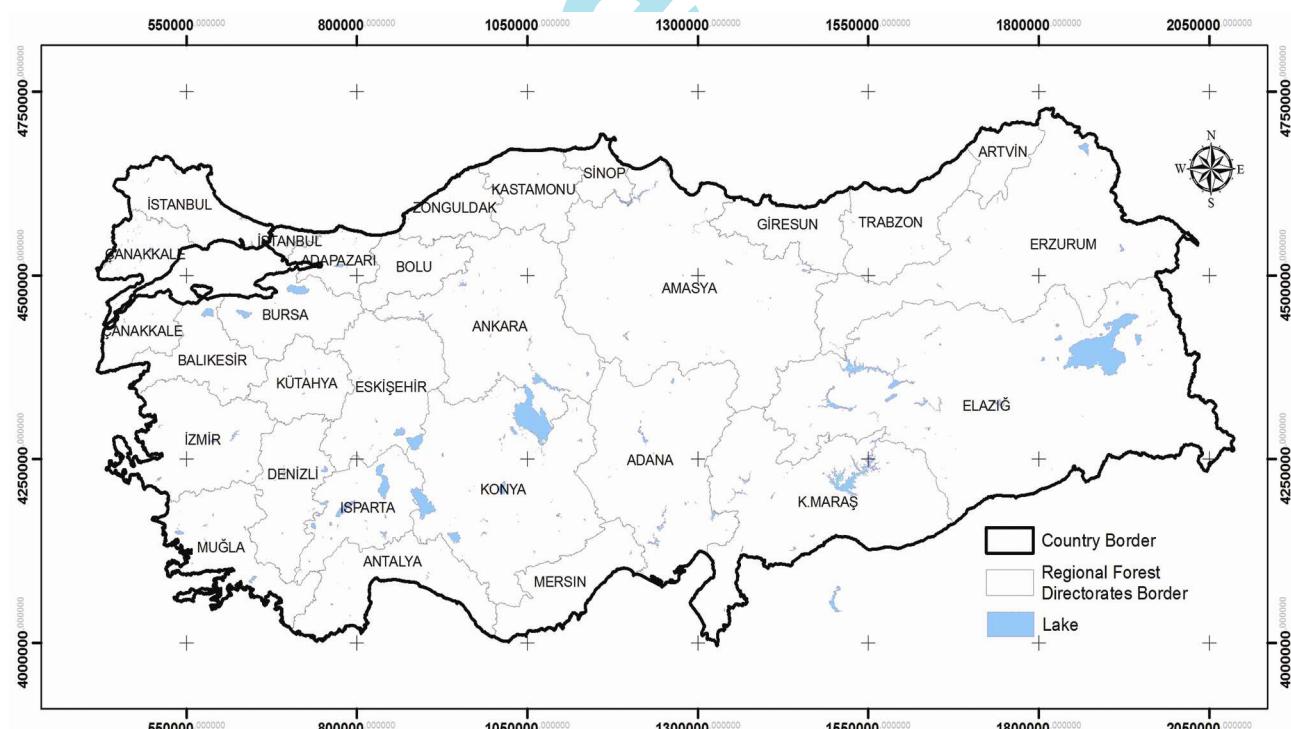


Fig. 1 : Map showing study area

According to 2004 forest inventory, the total forestland is about 21.2 million ha 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). Calabrian pine constitute 4412244.82 hectares of these coniferous forest areas.

Forest Information System (FIS) database : Digital 1/25,000 scale FIS vector data acquired from Forest General Directorate was used in the determination of horizontal and vertical distribution of Calabrian pine stands. This digital vector data includes of stand types map and Regional Forest Directorates border layers.

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 60m distance and elevations are obtained as such (Bildirici *et al.*, 2010).

SRTM digital elevation model (DEM) data is compiled by the CGIAR-CSI (Consultative Group for International Agriculture Research Consortium for Spatial Information) that is processed at 90m 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).

90m SRTM version 4.0 data generated by Jarvis *et al.* (2008) and downloaded from CIAT-CSI SRTM web site

(<http://srtm.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 CIAT (International Centre for Tropical Agriculture) 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).

Preparation of SRTM data and acquirement of elevation classes geographical information layer : Consisting of 8 pieces image data in total; SRTM version 4.0 digital elevation model data combined in Erdas Imagine 9.1 software environment and it transformed into the same coordinate system with FIS data. Then, using Turkey boundary layer obtained from FIS data, SRTM data was truncated (Fig. 2).

This truncated 90m pixel sized digital elevation model data in raster format was classified into the predetermined 7 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 1/25,000 scale FIS data in vector format. Thus, elevation class map of the study area was obtained in vector format (Fig. 3).

Elevation class map in 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. Following this, distribution of 7 elevation classes was determined by the queries conducted in FIS database (Table 1).

Preparation of FIS database : As it was also indicated earlier, this study aims to determine horizontal and vertical distribution of Calabrian pine, which is spatially one of the most extensively spread needled tree species in Turkey, (to elevation classes) on the basis of Regional Forest Directorates.

To achieve this aim, an attribute using "Cz" alias was opened in the FIS database for Calabrian pine. Then, with the queries in stand types data layer in FIS database, "1" was assigned to pure Calabrian pine stand; "2" was assigned to mixed stand where Calabrian pine is the primary tree species; "3", was assigned to mixed stand where Calabrian pine is either secondary or tertiary tree species; "4" was assigned to degraded (pure+mixed) Calabrian pine stands; and "0" was assigned to areas where there is no Calabrian pine. As a result of these operations, FIS database was ready to determine horizontal and vertical distribution of Calabrian pine (to predetermined elevation classes) on the basis of Regional Forest Directorates.

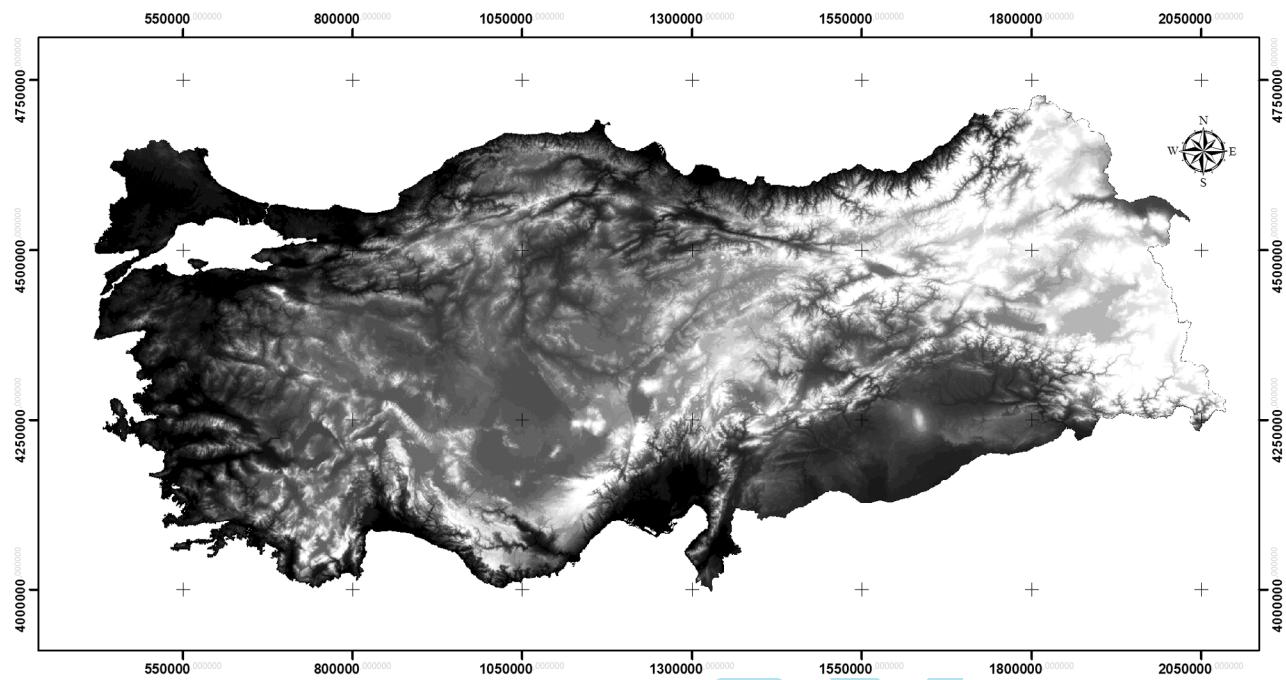


Fig. 2 : SRTM Digital Elevation Model data downloaded from CIAT-CSI SRTM web site (<http://srtm.csi.cgiar.org>) and truncated by Turkey country boundary layer

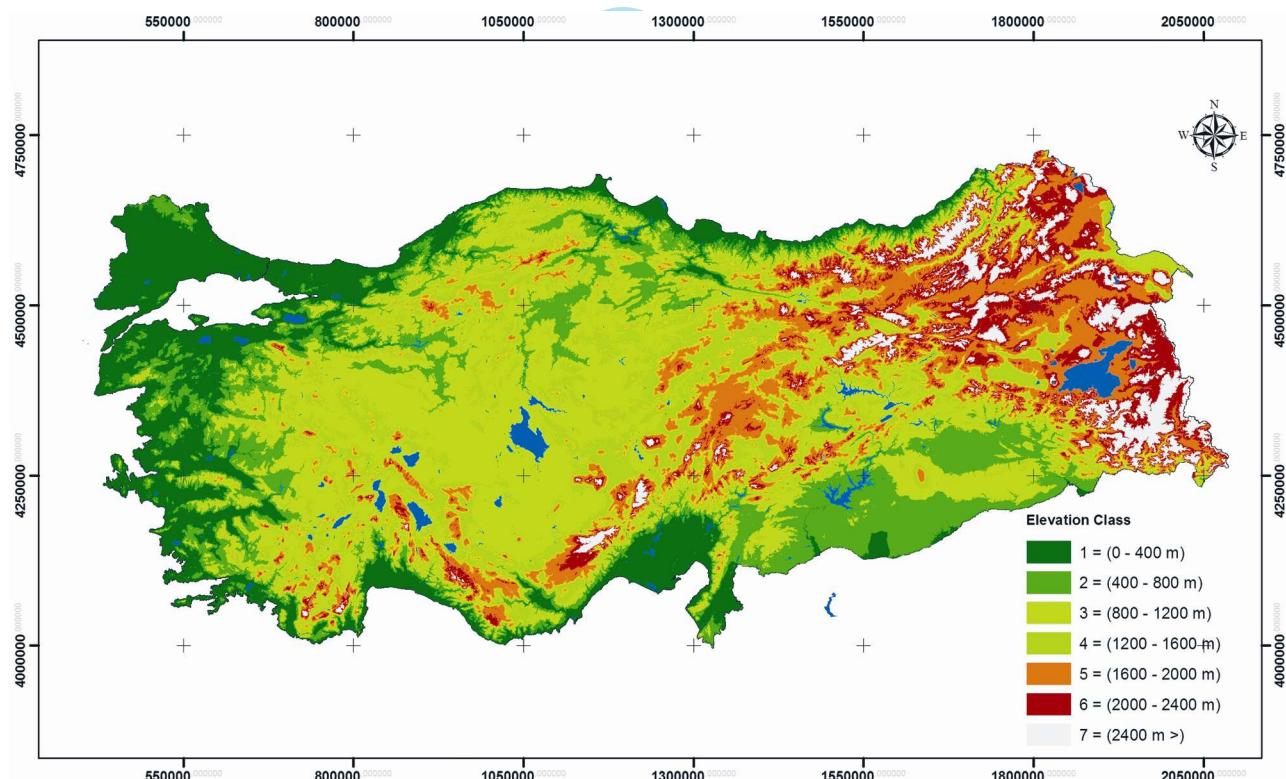


Fig. 3 : Elevation class map of Turkey

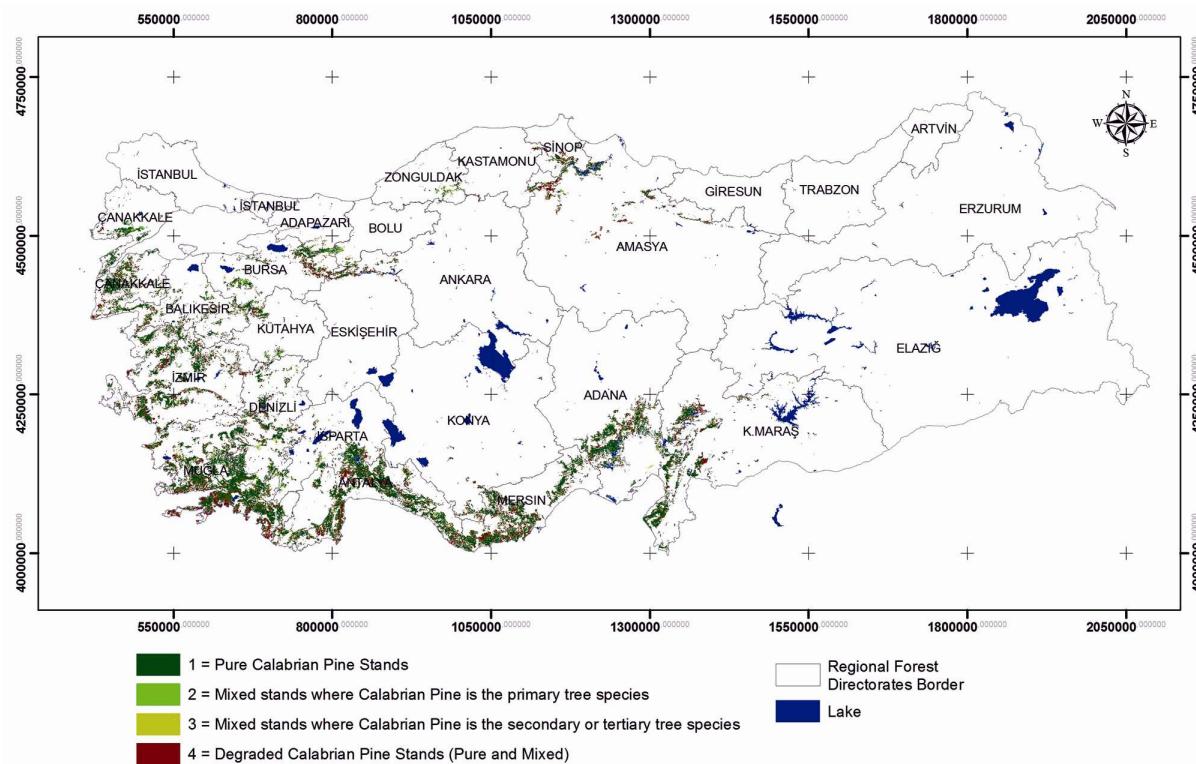


Fig. 4 : Distribution of Calabrian pine Stands to Regional Forest Directorates in Turkey

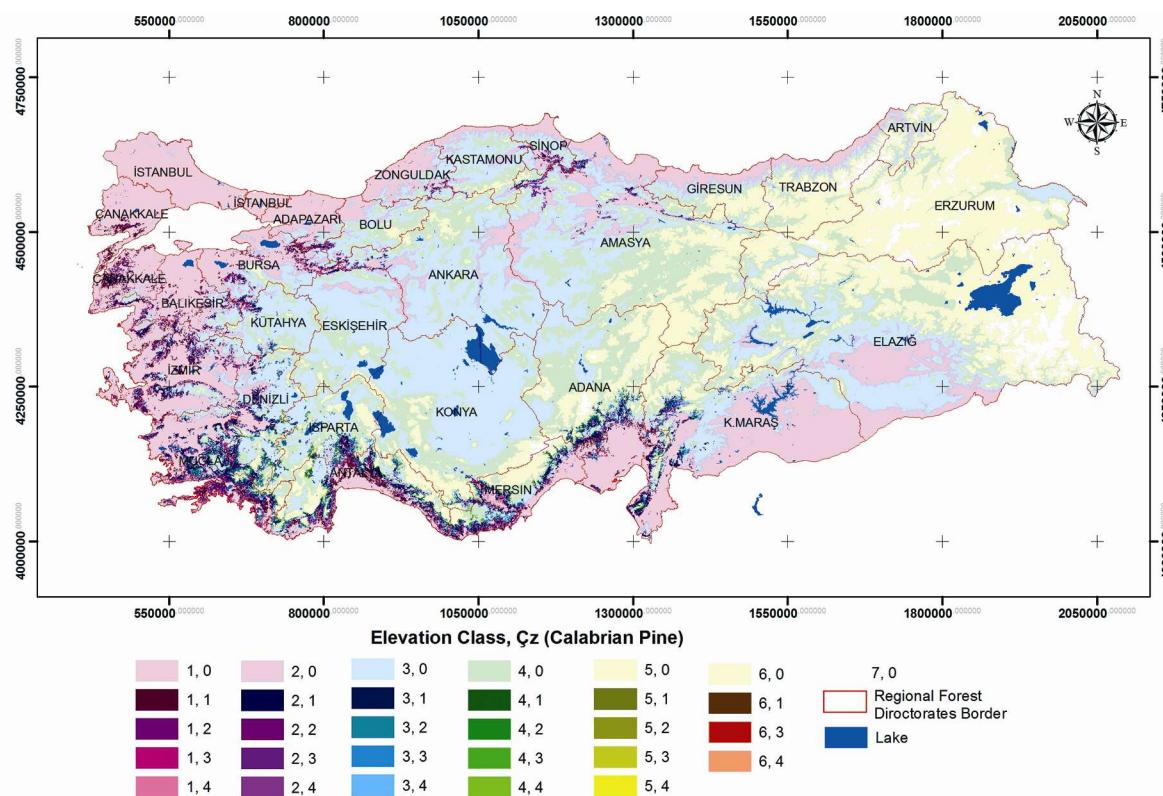


Fig. 5 : Distribution of Calabrian pine to predetermined elevation classes in Turkey

Results and Discussion

Using the prepared FIS database, the map depicting the distribution of Calabrian pine Stands to Regional Forest Directorates in Turkey (Fig. 4) and the distribution of Calabrian pine stands into elevation classes on the basis of Regional Forest Directorates in Turkey was prepared (Fig. 5). When the legend of the map in question was analyzed, it was seen that figures such as (1,0), (1,1), (1,2), (1,3), (1,4) (7,0) corresponds to different colors. Here, for example, (1,0) represents the areas in the elevation class no: 1 (0-400 m) with no Calabrian pine; (1,1) represents the areas in the elevation class no: 1 with pure Calabrian pine stand; (1,2) represents the areas in the elevation class no: 1 with mixed stand where Calabrian pine is the primary tree species; (1,3) represents the areas in the elevation class no: 1 with mixed stand where Calabrian pine was the secondary or tertiary tree species; and finally (1,4) represented the areas in the elevation class no: 1 with degraded (pure + mixed) Calabrian pine stands.

With the queries conducted on FIS database, spatial distribution (ha) of Calabrian pine 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 areal distribution (ha) of predetermined elevation classes to Regional Forest Directorates. In the following step, Table 3 indicates distribution of pure, mixed and degraded Calabrian pine stands to Regional Forest Directorates, Table 4 indicates distribution of pure, mixed, and degraded Calabrian pine stands to elevation classes on the basis of Regional Forest Directorates, and Table 5 indicates distribution of pure, mixed, and degraded Calabrian pine stands to elevation classes (ha, %) were obtained respectively.

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.

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 16m and 20m error values respectively. In a similar study conducted on the 90m SRTM data set which was made available on the Internet by CGIAR-CSI (Consultative Group for International Agriculture Research Consortium for Spatial Information) free of charge, Gorokhovich and Voustianiouk (2006) introduced that absolute average horizontal error was at the interval of 4.07 m 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.* (2004) 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 90m pixel size at a number of 6000 x 6000 pixels covering an area of 540 km 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 km² 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 90m 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

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

Elevation class code	Elevation class (m)	Area (ha)	Area (%)
1	(0-400)	11432351,95	14,46
2	(400-800)	12017731,16	15,20
3	(800-1200)	21673684,64	27,41
4	(1200-1600)	14680854,24	18,56
5	(1600-2000)	10647199,22	13,46
6	(2000-2400)	5622378,38	7,11
7	(2400 >)	3007676,61	3,80
TOTAL		79081876,20	100,00

Table 2 : Distribution of Calabrian pine to predetermined elevation classes in terms of Regional Forest Directorates in Turkey

Regional Forest Directorates	Elevation class (m)	Calabrian pine stands (ha)					Total
		0	1	2	3	4	
ADANA	(0-400)	798136,27	80070,41	2909,49	2880,35	2880,35	886876,87
	(400-800)	71891,88	73061,77	1857,50	253,29	253,29	147317,73
	(800-1200)	800969,69	79566,96	5204,16	1894,46	1894,46	889529,73
	(1200-1600)	1579719,63	13222,64	3135,95	2164,10	2164,10	1600406,42
	(1600-2000)	879088,23	73,12	5,46	19,64	19,64	879206,09
	(2000-2400)	208764,35					208764,35
	(2400>)	98753,78					98753,78
	TOTAL	4437323,84	245994,91	13112,56	7211,84	7211,84	4710854,99
ADAPAZARI	(0-400)	584384,45	5326,33	672,00	1171,66	1292,72	592847,16
	(400-800)	120575,60	9824,23	3635,25	3152,95	1737,20	138925,23
	(800-1200)	68545,86	228,81	269,83	133,52	46,04	69224,06
	(1200-1600)	20989,44					20989,44
	(1600-2000)	233,04					233,04
	(2000-2400)						0,00
	(2400>)						0,00
	TOTAL	794728,38	15379,37	4577,08	4458,14	3075,95	822218,92
AMASYA	(0-400)	438057,68	15878,88	1434,44	192,07	9949,93	465513,00
	(400-800)	1100496,48	38358,24	6119,20	1502,72	45220,49	1191697,13
	(800-1200)	2230651,89	4484,15	789,62	349,78	14343,05	2250618,49
	(1200-1600)	2609571,29	56,39			328,77	2609956,45
	(1600-2000)	1360409,70				14,23	1360423,93
	(2000-2400)	185515,97					185515,97
	(2400>)	22348,65					22348,65
	TOTAL	7947051,66	58777,67	8343,26	2044,57	69856,48	8086073,64
ANKARA	(0-400)	6982,40	89,51	390,03		168,70	7630,64
	(400-800)	545683,85	8191,16	449,35	287,19	8606,56	563218,11
	(800-1200)	2773775,21	3745,16	242,01	489,46	3597,26	2781849,10
	(1200-1600)	1083272,85			0,01	5,99	1083278,85
	(1600-2000)	156867,66					156867,66
	(2000-2400)	2695,56					2695,56
	(2400>)	45,67					45,67
	TOTAL	4569323,21	12025,83	1081,38	776,66	12378,51	4595585,59
ANTALYA	(0-400)	329260,25	157995,94	2978,27	209,17	60365,02	550808,65
	(400-800)	118262,67	119373,75	2766,28	202,45	65450,12	306055,27
	(800-1200)	252430,16	104196,32	7099,09	2180,40	54242,08	420148,05
	(1200-1600)	315552,83	26849,60	7207,39	5163,17	18984,48	373757,47
	(1600-2000)	258267,94	203,20	103,24	185,29	1101,48	259861,15
	(2000-2400)	126077,01	5,43		0,88	106,60	126189,92
	(2400>)	24913,14					24913,14
	TOTAL	1424764,01	408624,24	20154,28	7941,35	200249,78	2061733,66
ARTVIN	(0-400)	32001,45					32001,45
	(400-800)	70716,36					70716,36
	(800-1200)	117564,16					117564,16
	(1200-1600)	155227,51					155227,51
	(1600-2000)	150706,97					150706,97
	(2000-2400)	107001,05					107001,05
	(2400>)	104292,73					104292,73
BALIKESIR	TOTAL	737510,22					737510,22
	(0-400)	725227,26	41555,15	3940,01	908,61	17953,64	789584,67

Cont....

Regional Forest Directorates	Elevation class (m)	Calabrian pine stands (ha)					Total
		0	1	2	3	4	
BOLU	(400-800)	375183,22	45941,07	5746,33	3602,74	21270,2	451743,56
	(800-1200)	167345,23	2131,24	768,32	1125,62	1111,08	172481,49
	(1200-1600)	44757,91				3,98	44761,89
	(1600-2000)	1367,27					1367,27
	(2000-2400)	17,53					17,53
	(2400>)						0,00
	TOTAL	1313898,42	89627,46	10454,66	5636,97	40338,9	1459956,41
	(0-400)	99743,04	13,55			76,21	99832,80
	(400-800)	164109,15	4932,09	4454,15	1907,43	3708,83	179111,65
	(800-1200)	358587,16	812,39	671,17	1095,04	439,18	361604,94
BURSA	(1200-1600)	319062,54	8,80		5,79		319077,13
	(1600-2000)	74618,84					74618,84
	(2000-2400)	5794,40					5794,40
	(2400>)						0,00
	TOTAL	1021915,13	5766,83	5125,33	3008,26	4224,23	1040039,78
	(0-400)	561935,23	38873,42	2427,38	795,7	22598,52	626630,25
	(400-800)	436396,73	42710,97	10016,26	4421,86	29340,56	522886,38
	(800-1200)	328933,11	2794,58	1928,26	1674,59	2546,58	337877,12
	(1200-1600)	62723,09					62723,09
	(1600-2000)	18393,59					18393,59
ÇANAKKALE	(2000-2400)	6015,06					6015,06
	(2400>)	615,6					615,60
	TOTAL	1415012,41	84378,97	14371,9	6892,15	54485,66	1575141,09
	(0-400)	1311864,82	157280,27	15625,38	3503,60	59202,26	1547476,33
	(400-800)	159994,08	23967,73	4861,02	3418,84	11220,62	203462,29
	(800-1200)	16659,90	0,63		21,23	24,16	16705,92
	(1200-1600)	2193,26				0,84	2194,10
	(1600-2000)	83,54					83,54
	(2000-2400)						0,00
	(2400>)						0,00
DENIZLI	TOTAL	1490795,60	181248,63	20486,40	6943,66	70447,89	1769922,18
	(0-400)	70222,47	4878,57	496,71	13,16	3281,57	78892,48
	(400-800)	269291,05	84059,16	546,09	41,99	36255,03	390193,32
	(800-1200)	751843,11	112422,58	10030,59	7152,23	34371,13	915819,64
	(1200-1600)	278771,27	10789,24	5295,76	5032,05	6703,08	306591,40
	(1600-2000)	69498,25	33,17	0,44	6,50	170,07	69708,43
	(2000-2400)	12025,01					12025,01
	(2400>)	83,43					83,43
	TOTAL	1451734,59	212182,72	16369,58	12245,93	80780,88	1773313,70
	(0-400)	37271,28					37271,28
ELAZIG	(400-800)	1757459,91	8,97				1757468,88
	(800-1200)	2758686,00			219,90		2758905,90
	(1200-1600)	2326364,02					2326364,02
	(1600-2000)	2881053,16					2881053,16
	(2000-2400)	1834740,51					1834740,51
	(2400>)	1315680,52					1315680,52
ERZURUM	TOTAL	12911255,40	8,97		219,90		12911484,28
	(0-400)	3103,22					3103,22
	(400-800)	3693,46					3693,46
	(800-1200)	331363,90					331363,90

Cont....

Regional Forest Directorates	Elevation class (m)	Calabrian pine stands (ha)					Total
		0	1	2	3	4	
ESKISEHIR	(1200-1600)	768375,98					768375,98
	(1600-2000)	2417459,20					2417459,20
	(2000-2400)	2273063,44					2273063,44
	(2400>)	1119292,82					1119292,82
	TOTAL	6916352,03					6916352,03
	(0-400)	13598,96	3160,93	9,07		1960,99	18729,95
	(400-800)	193606,66	11059,17	134,95	4,28	7295,72	212100,78
	(800-1200)	1658982,52	1296,93	150,29	129,07	2201,81	1662760,62
	(1200-1600)	631965,22	6,81				631972,03
GIRESUN	(1600-2000)	79101,01					79101,01
	(2000-2400)	8762,47					8762,47
	(2400>)	206,80					206,80
	TOTAL	2586223,64	15523,84	294,31	133,34	11458,53	2613633,66
	(0-400)	225437,03					225437,03
	(400-800)	224149,12					224149,12
	(800-1200)	247168,78					247168,78
	(1200-1600)	261071,81					261071,81
	(1600-2000)	236481,88					236481,88
ISPARTA	(2000-2400)	110231,66					110231,66
	(2400>)	21514,73					21514,73
	TOTAL	1326055,01					1326055,01
	(0-400)	9705,00	12262,09	50,70	2,69	1456,80	23477,28
	(400-800)	28217,01	28104,68	108,46	38,40	5032,39	61500,94
	(800-1200)	743086,31	53862,10	7667,96	2742,60	19397,61	826756,58
	(1200-1600)	607656,23	11802,54	5770,27	5283,05	10394,76	640906,85
	(1600-2000)	199609,43	51,43	133,49	41,06	337,67	200173,08
	(2000-2400)	45810,52					45810,52
ISTANBUL	(2400>)	3083,30					3083,30
	TOTAL	1637167,80	106082,84	13730,88	8107,80	36619,22	1801708,54
	(0-400)	1471568,11	1744,03	535,45	161,87	257,54	1474267,00
	(400-800)	142426,84					142426,84
	(800-1200)	1287,09					1287,09
	(1200-1600)						
	(1600-2000)						
	(2000-2400)						
	(2400>)						
IZMIR	TOTAL	1615282,04	1744,03	535,45	161,87	257,54	1617980,93
	(0-400)	1172263,90	134606,82	7556,87	1503,55	68252,66	1384183,80
	(400-800)	537899,12	157611,92	5416,46	2704,99	75610,23	779242,72
	(800-1200)	247492,08	15401,14	2305,16	1812,09	12746,83	279757,30
	(1200-1600)	51533,76	38,51	3,83	15,61	284,32	51876,03
	(1600-2000)	7323,67					7323,67
	(2000-2400)	211,41					211,41
	(2400>)						0,00
	TOTAL	2016723,95	307658,39	15282,32	6036,24	156894,06	2502594,96
K.MARAS	(0-400)	468652,16	22329,27	362,72	68,47	6181,37	497593,99
	(400-800)	2699651,70	87361,58	2558,29	636,78	31754,12	2821962,47
	(800-1200)	966215,71	69704,31	4400,50	1449,14	46711,40	1088481,06
	(1200-1600)	627431,42	7104,47	1443,11	636,60	9555,54	646171,14
	(1600-2000)	356881,03	105,54	1,14	8,59	829,59	357825,89

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Regional Forest Directorates	Elevation class (m)	Calabrian pine stands (ha)					Total
		0	1	2	3	4	
KASTAMONU	(2000-2400)	105993,50				336,88	106330,38
	(2400>)	25666,89					25666,89
	TOTAL	5250492,41	186605,17	8765,76	2799,57	95368,90	5544031,81
	(0-400)	70118,52	154,20	388,15	232,46	410,97	71304,30
	(400-800)	242254,74	4760,34	410,65	946,62	5557,08	253929,43
	(800-1200)	586165,03	455,79	21,28	13,05	1598,54	588253,69
	(1200-1600)	341082,00		7,19		25,01	341114,20
	(1600-2000)	69260,52				1,20	69261,72
	(2000-2400)	7342,34					7342,34
	(2400>)	144,68					144,68
KONYA	TOTAL	1316367,84	5370,34	827,27	1192,13	7592,81	1331350,39
	(0-400)	5037,75	840,53	35,04		301,90	6215,22
	(400-800)	15785,87	7881,17	147,71		4705,75	28520,50
	(800-1200)	3652317,33	10569,37	274,44	14,19	8738,52	3671913,85
	(1200-1600)	1255839,37	5245,26	768,99	401,12	4239,67	1266494,41
	(1600-2000)	531408,20	65,96			19,12	531493,28
	(2000-2400)	102529,84					102529,84
	(2400 >)	47704,90					47704,90
	TOTAL	5610623,25	24602,30	1226,19	415,31	18004,96	5654872,01
KÜTAHYA	(0-400)	467,41	0,34			29,51	497,26
	(400-800)	75023,43	13824,68	1629,08	622,00	7917,48	99016,67
	(800-1200)	713725,31	8734,27	3478,10	2837,11	4350,82	733125,61
	(1200-1600)	310618,65	30,54	55,96	40,61	12,13	310757,89
	(1600-2000)	24373,61					24373,61
	(2000-2400)	2448,00					2448,00
	(2400 >)						0,00
	TOTAL	1126656,41	22589,83	5163,14	3499,73	12309,94	1170219,05
MERSIN	(0-400)	286318,25	63810,33	195,55	18,61	44206,76	394549,50
	(400-800)	110027,63	110800,57	1184,30	36,40	47625,22	269674,12
	(800-1200)	132064,68	80385,44	3598,38	449,57	43921,77	260419,84
	(1200-1600)	261345,37	16501,69	3628,15	958,45	15131,05	297564,71
	(1600-2000)	228548,28	112,91	61,61	31,45	105,89	228860,14
	(2000-2400)	92603,84					92603,84
	(2400 >)	25922,14					25922,14
	TOTAL	1136830,20	271610,94	8668,00	1494,48	150990,69	1569594,31
MUGLA	(0-400)	678775,38	175208,57	869,13	192,54	117819,87	972865,49
	(400-800)	245025,25	199572,64	7106,90	3360,50	98025,11	553090,40
	(800-1200)	131650,18	124031,50	8548,71	5255,70	46400,77	315886,86
	(1200-1600)	122265,93	8375,34	1852,82	2403,95	6886,39	141784,43
	(1600-2000)	39131,58	13,85	53,35	130,26	189,27	39518,31
	(2000-2400)	12809,34			7,56	15,67	12832,57
	(2400 >)	982,71					982,71
	TOTAL	1230640,37	507201,89	18430,91	11350,51	269337,09	2036960,77
SINOP	(0-400)	131932,42	8379,94	385,71	284,03	6312,65	147294,75
	(400-800)	156745,70	14901,55	782,81	573,66	14647,17	187650,89
	(800-1200)	180754,91	44,72	5,88	12,09	866,23	181683,83
	(1200-1600)	59728,35					59728,35
	(1600-2000)	1172,03					1172,03
	(2000-2400)						0,00
	(2400 >)						0,00

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	TOTAL	530333,41	23326,20	1174,41	869,78	21826,05	577529,85
TRABZON	(0-400)	159479,49					159479,49
	(400-800)	153264,40					153264,40
	(800-1200)	149446,21					149446,21
	(1200-1600)	297322,35					297322,35
	(1600-2000)	598665,20					598665,20
	(2000-2400)	371510,90					371510,90
	(2400>)	196365,73					196365,73
	TOTAL	1926054,29					1926054,29
ZONGULDAK	(0-400)	333204,63	2280,30	1896,37	564,24	42,52	337988,06
	(400-800)	290093,94	6749,35	4490,65	3094,23	284,32	304712,49
	(800-1200)	242238,60	353,43	210,26	248,50		243050,79
	(1200-1600)	60061,26	241,04	76,69	7,27		60386,26
	(1600-2000)	2917,42	49,09				2966,51
	(2000-2400)						0,00
	(2400>)						0,00
	TOTAL	928515,85	9673,21	6673,98	3914,25	326,84	949104,13
GENERALTOTAL		74669631,37	2796004,58	194849,05	97354,44	1324036,75	79081876,20

Table 3 : Distribution of pure, mixed and degraded Calabrian pine stands to Regional Forest Directorates

Regional Forest Directorates	Calabrian pine stands (ha)				Total (ha)
	1	2	3	4	
Adana	245994,91	13112,56	7211,84	7211,84	273531,15
Adapazari	15379,37	4577,08	4458,14	3075,95	27490,54
Amasya	58777,67	8343,26	2044,57	69856,48	139021,98
Ankara	12025,83	1081,38	776,66	12378,51	26262,38
Antalya	408624,24	20154,28	7941,35	200249,78	636969,65
Artvin	—	—	—	—	0,00
Balikesir	89627,46	10454,66	5636,97	40338,9	146057,99
Bolu	5766,83	5125,33	3008,26	4224,23	18124,65
Bursa	84378,97	14371,9	6892,15	54485,66	160128,68
Çanakkale	181248,63	20486,40	6943,66	70447,89	279126,58
Denizli	212182,72	16369,58	12245,93	80780,88	321579,11
Elazig	8,97	—	219,90	—	228,87
Erzurum	—	—	—	—	0,00
Eskisehir	15523,84	294,31	133,34	11458,53	27410,02
Giresun	—	—	—	—	0,00
Isparta	106082,84	13730,88	8107,80	36619,22	164540,74
Istanbul	1744,03	535,45	161,87	257,54	2698,89
Izmir	307658,39	15282,32	6036,24	156894,06	485871,01
K.Maras	186605,17	8765,76	2799,57	95368,90	293539,40
Kastamonu	5370,34	827,27	1192,13	7592,81	14982,55
Konya	24602,30	1226,19	415,31	18004,96	44248,76
Kütahya	22589,83	5163,14	3499,73	12309,94	43562,64
Mersin	271610,94	8668,00	1494,48	150990,69	432764,11
Mugla	507201,89	18430,91	11350,51	269337,09	806320,40
Sinop	23326,20	1174,41	869,78	21826,05	47196,44
Trabzon	—	—	—	—	0,00
Zonguldak	9673,21	6673,98	3914,25	326,84	20588,28
Toplam	2796004,58	194849,05	97354,44	1324036,75	4412244,82

1 = Pure Calabrian pine stands; 2 = Mixed stands where Calabrian pine is the primary tree species; 3 = Mixed stands where Calabrian pine is the secondary or tertiary tree species; 4 = Degraded Calabrian pine stands

Table 4 : Distribution of pure, mixed and degraded Calabrian pine stands to elevation classes in terms of Regional Forest Directorates

Regional Forest Directorates	Pure, mixed and degraded Calabrian pine stands (ha)							Total (ha)
	(0-400m)	(400-800m)	(800 - 1200m)	(1200- 1600m)	(1600- 2000m)	(2000- 2400m)	(2400m>)	
Adana	88740,60	75425,85	88560,04	20686,79	117,86			273531,14
Adapazari	8462,71	18349,63	678,20					27490,54
Amasya	27455,32	91200,65	19966,60	385,16	14,23			139021,96
Ankara	648,24	17534,26	8073,89	6,00				26262,39
Antalya	221548,40	187792,60	167717,89	58204,64	1593,21	112,91		636969,65
Artvin							0,00	
Balikesir	64357,41	76560,34	5136,26	3,98				146057,99
Bolu	89,76	15002,50	3017,78	14,59				18124,63
Bursa	64695,02	86489,65	8944,01					160128,68
Çanakkale	235611,51	43468,21	46,02	0,84				279126,58
Denizli	8670,01	120902,27	163976,53	27820,13	210,18			321579,12
Elazig		8,97	219,90					228,87
Erzurum							0,00	
Eskisehir	5130,99	18494,12	3778,10	6,81				27410,02
Giresun							0,00	
Isparta	13772,28	33283,93	83670,27	33250,62	563,65			164540,75
Istanbul	2698,89							2698,89
Izmir	211919,90	241343,60	32265,22	342,27				485870,99
K.Maras	28941,83	122310,77	122265,35	18739,72	944,86	336,88		293539,41
Kastamonu	1185,78	11674,69	2088,66	32,20	1,20			14982,53
Konya	1177,47	12734,63	19596,52	10655,04	85,08			44248,74
Kütahya	29,85	23993,24	19400,30	139,24				43562,63
Mersin	108231,25	159646,49	128355,16	36219,34	311,86			432764,10
Mugla	294090,11	308065,15	184236,68	19518,50	386,73	23,23		806320,40
Sinop	15362,33	30905,19	928,92					47196,44
Trabzon							0,00	
Zonguldak	4783,43	14618,55	812,19	325,00	49,09			20588,26
Toplam	1407603,09	1709805,29	1063734,49	226350,87	4277,95	473,02		4412244,71

Table 5 : Distribution of pure, mixed and degraded Calabrian pine stands to elevation classes (ha %)

Elevation class (m)	Pure Calabrian pine stands (ha)	Pure Calabrian pine stands (%)	Mixed Calabrian pine stands (ha)	Mixed Calabrian pine stands (%)	Degraded Calabrian pine stands (ha)	Degraded Calabrian pine stands (%)	All Calabrian pine stands (ha)	All Calabrian pine stands (%)
(0-400)	926739,39	33,15	55861,26	19,12	425002,48	32,10	1407603,13	31,90
(400-800)	1093056,80	39,09	95231,02	32,59	521517,49	39,39	1709805,31	38,75
(800-1200)	675221,82	24,15	88963,36	30,44	299549,35	22,63	1063734,53	24,11
(1200-1600)	100272,87	3,59	51357,89	17,58	74720,12	5,64	226350,88	5,13
(1600-2000)	708,27	0,02	781,52	0,27	2788,16	0,21	4277,95	0,10
(2000-2400)	5,43	0,00	8,44	0,00	459,15	0,03	473,02	0,01
(2400 >)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL	2796004,58	100,00	292203,49	100,00	1324036,75	100,00	4412244,82	100,00

determination of topographic characteristics can prove a considerably fast, easy, and economical option.

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