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Classification and mapping forest sites using geographic information system (GIS): a case study in Artvin Province

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Abstract The productivity of forest sites has been indirectly determined with solo wood production objective in forest management. Forest site productivity should, however, be determined directly in order to implement ecosystem based multipurpose forest management philosophy. This article tackles the problem in distinguishing and mapping forest sites using both direct method and indirect method in Genya Mountain located in central of Artvin State Forest Enterprise. About 112 sample plots were designed and distributed over the area. In each sample plot, soil samples were collected and the classical timber inventory measurements were taken. According to direct method, Soil Moisture Regime (SMR) method is preferred due to a water deficiency in the study area. Water holding capacity was used as an essential criterion for the classification of the forest site. Forest site classifications were assigned regarding the physiographic factors such as landform, aspect, and slope. Five different forest sites classes; dry, moderate fresh, fresh, humid and hygric were determined. According to direct method, the guiding curve was used to generate anamorphic site index (SI) equations and three site index classes; good (SI=I–II), medium (SI=III) and low (SI=IV–V) were determined. Some important differences between the methods were realized. The forest sites determined with site index estimation method indicate that site index I and II is 505.99 ha, III 1095.79 ha and IV and V 992.95 ha, whereas forest sites determined with direct method related to dry site of 937.58 ha, moderate fresh site of 931.90 ha, fresh site of 1,797.71 ha, humid site of 80.48 ha and hygric site of 356.55 ha. The forest site maps of both methods were created using GIS functions. The forest sites of open and degraded areas should be determined according to direct method.

Keywords Forest sites classification · GIS · Productivity · Direct method · Indirect method · Water holding capacity

Introduction

The natural resources such as timber, nonwood forest products, soil, air and water gradually became polluted or are destroyed because of misuse or mismanagement of natural resources. Added to that, intensive consumption, industrialization, urbanization and rapid increase of population in the world are some of the impelling causes. Consequently, unfavorable natural disturbances such as flood, avalanche, landslide, erosion, acid rain, greenhouse effects and changes of climate are primary results of such mismanagement.

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They have also threatened the stability of forest ecosystems, agriculture and the production of nutrient by influencing site. As a result of this phenomenon; deforestations, desertification, pollution of environment and genetic loss of biodiversity have gained importance for understanding the sustainable development of the world. As such, the importance of sustainable development and sustainable forest management came into a picture (SPO 2001).

In the twenty-first century, forestry activities should be meticulously planned and undertaken, mainly because of the number and diversity of resource stakeholders, which continues to grow. Forests are increasingly in demand by forestry companies (timber production), maple syrup producers, hunters, and fisherman, gatherers of wild berries and medicinal plants, and outdoor enthusiasts. For an ecosystem to remain a source of life, it is important that appropriate forestry practices be defined. This objective cannot be achieved without having good quality ecological information – information that expresses ecosystem diversity at multiple scales (Grondin et al. 2003). The first step towards sustainable forest management, on which all other decisions depend, is to ensure that the tree species are suited to the site conditions, whether the aim is a timber plantation or a native woodland community. The professional ability of the forester to read the site conditions and select well suited tree species is of fundamental importance. Forest manager tended to select from a short list of species and adjust the site conditions (ground preparation) to ensure optimal growth, so that the skill of matching species to site type declined (Banner and Pojar 1987).

In many classifications of forest land, the use of site as the primary ecological unit is well established (Pfister 1977; Bailey et al. 1978; Grey 1980; Spurr and Barnes 1980). Site is generally viewed as the integrated complex of all environmental factors within a prescribed area. A site can also be defined as the function of the interplay between climate, topography, parent material and vegetation over a specific time (Bailey et al. 1978). Site classification refers to any form of classification system which stratifies biotic and/or abiotic land features with appropriate mapping system.

To develop accurate long-term forest management plans, it is necessary to ascertain the site quality of each individual stand within a forest management unit so that its future growth and development can be forecasted. For years, foresters and ecologists have been trying to develop a reliable site quality classification system that can be widely applied over a range of species and regions. Two principal approaches, direct and the indirect method have been used. Ecologists base their classification of site on the ground vegetation because such plant communities are the result of various climatic, edaphic, and topographic factors associated with the stand's growth potential. Indirect method rely more on simpler, indirect methods such as the site-index concept (Alemdag 1991).

According to forest management regulations, the main goal is to supply national requirement for forest crops by producing the most quality timber in a site. To benefit the multiple values of forests, site classification must be carried out for forest management planning (Seckin and Kahveci 1993). It is necessary to determine and restrict forest sites by classifying and mapping the site attributes for sustainable forestry. Without the site classification of landscape and the generation of the associated site maps in Turkey causes failure of any forest management applications (Baskent et al. 2003).

At the basic land unit scale, ecological units are designed and mapped in the field based on properties of local topography, rock types, soils and potential natural vegetation. These factors influence the structure and composition of plant communities, hydrologic function, and basic land capability. Land types are the ecological units mapped at this scale. Ecological units provide a means for analyzing the feasibility as well as the effects of management alternatives. To discern the effects of management on ecosystems, we often need to examine conditions and processes (Rowe 1980). For example, the effects of timber harvesting are manifest not only at a land unit scale, but also at micro-site and landscape scales. Ecological units defined at different hierarchical levels will be useful in conducting multi-scaled analyses for managing ecosystem and documenting environmental effects (Brenner and Jordan 1991; Jensen et al. 1991).

Long term sustained yield capability can be estimated based on productivity potentials measured for fine scale ecological units. Therefore, it is essential that forest sites be characterized toward productive and sustainable forest management to conduct up-to date forestry practices. Developing as well as conducting harvesting activities on the ground in the absence of forest site information is highly ineffective or insufficient, calling for recognizing the potential production capacity and conditions of forest sites. To help develop site classification maps, modern information technologies such as GIS have been used in forestry.

The objective of this research is to identify forest sites in Genya Mountain located in a management district of Artvin State Forest Enterprise using both direct method and indirect method. The research also focuses to classify and map the forest sites using the spatial analysis functions of GIS. As well, the study further involves in comparing and contrasting the productivity of the site determined through both direct method and indirect method.

Study area

The study area covers in Genya Mountain within the management district of Artvin State Forest Enterprise, between 41°32′00″–41°07′30″ north latitudes and 41° 32′00″–41°53′00″ east longitudes, an area within the Eastern Black Sea region of Turkey (Fig. 1). Elevation ranges from 750 to 2047 m with an average of 1,430 m. The study area situates on a steep topographic surface with a slope ranging from 32 to 90%, with an average of 65%. Mean annual temperature is 6.6°C and the precipitation is 1,157 mm (Erinc 1984; Anonymous 2001). The study area covers mixed stands of spruce (*Picea orientalis*) and beech (*Fagus orientalis*) and pure stands of spruce (*P. orientalis*).

Material

The research examines data for classifying and interpreting a specific forest site according to the degree of site productivity. Forest site classification was delineated by edafic, climatic and topographic features such as elevation, aspect, slope and landform surface. Existing stand type maps were digitized with Arc/Info 9.0 and the sample plots were distributed over the area on a 300×300 m interval. But, some plots were eliminated taking into consideration physiographic factors such as aspect, slope, land surface and 112 sample plots and soil profile using global position system were systematically established with 300×300 m intervals. In each sample plot; physiographic (altitude, aspect, slope and landform), edaphic (soil properties) and climatic conditions (rainfall and temperature) were investigated. Total 375 unit soil samples were taken and analyzed each soil sample at the Soil Scientific and Ecology Laboratory at the Faculty of Forestry at the Karadeniz Technical University. In each soil sample, were performed analyzes such as soil texture (sand, silt and clay), organic matter, field capacity, wilting point, water capacity holding (field capacity – wilting point), amount of soil skeleton, amount of tiny soil, soil pH, soil type, main rock. Moreover, the physiological soil depth was determined to during the study area. Furthermore, in each sample plot; the classical timber inventory (stand age and tree height) measurements were taken. Both soil properties and classical inventory dates to identify forest sites in Genya Mountain located in a management district of Artvin State Forest Enterprise using both direct method and indirect method.

Methods

Any estimates of forest sites, whether from individual tree measurements (indirect) or direct estimates based on soil and topographic features, are only point observations of variable condition in the landscape. Because land managers deal with large areas, point forest site estimates must be translated into a site classification applicable to larger areas. In general, two different methods were used to estimate forest sites at a landscape level using point observations; direct method and indirect method. Some reasons necessitate the use of both methods. As known, while practical, the indirect method is not quite suitable for determining site index in heavily managed (i.e., degraded) forest and obviously open areas (treeless land). Almost half of forest areas are degraded in Turkey creating a serious problem to determine appropriate site index value. On the other hand, it is quite time consuming and expensive to use ecological method for identifying forest sites. Therefore, we used both methods to compare and contrast each other in order to come up with the lessons and limitations of them in determining forest sites appropriately for forest management regulations.

Direct method

Direct methods assert the dependence of site productivity upon the soil factors. According to direct

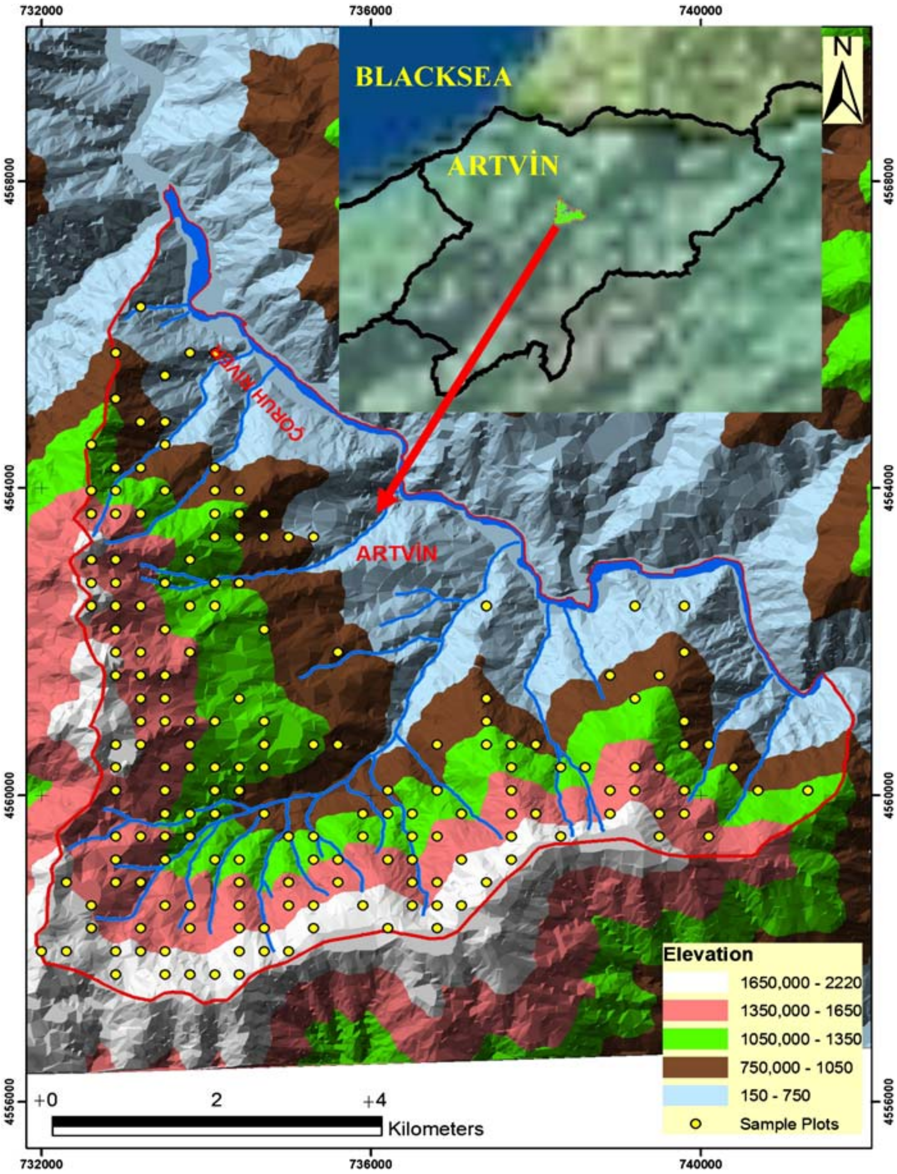


Fig. 1 The research area with the location of the sample plots

methods, site classification in the study is conducted by combining climate, physiographic (soil and its associated landforms) and vegetation classification procedures. River, ridge line, stream, slope and aspect were all taken into consideration for classifying forest sites. The research area was classified into four different elevation zones based on Digital Elevation Models that are data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. DEM may be used to generate three-dimensional graphics displaying terrain slope, aspect (direction of slope) and landform. The source of Digital Elevation model data (10×10 m pixel resolution) was gathered from contour line map with 10 m interval digitized from digital topographic maps, registered with 6–8 m root mean square (RMS) error with 3D modeling in GIS and initially classified into four elevation zones with; 750–1,050, 1,050–1,350, 1,350–1,650 and >1,650 m. The sample points in each of these zones were distributed according to physiographic structure of the area. The landform was stratified by slope and aspect subzones. East, North, North-West and North-East aspects were included in North aspect sub zone and the rest was grouped as south aspect subzone. The landscape was stratified into three slope groups;

Table 1 The climate values of study area (1,430 m)

Parameters	Months												Annual Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Heat (°C)	−5.5	−3.8	0.6	6.0	10.9	16.3	18.5	18.3	14.0	9.1	3.5	−1.9	7.2
Maximum heat	1.7	3.1	7.6	13.7	16.9	19.5	21.1	21.3	19.3	15.1	8.4	3.4	12.6
Heat index (i)	0.0	0.0	0.0	1.3	3.3	6.0	7.2	7.1	4.8	2.5	0.6	0.0	32.8
Uncorrected PET (mm)	0.0	0.0	2.8	29.7	54.5	82.3	93.6	92.6	70.4	45.4	17.1	0.0	
Corrected PET	0.0	0.0	2.9	33.0	68.7	103.8	119.0	110.0	73.0	43.4	14.1	0.0	567.9
Precipitation (mm)	144.0	110.0	88.0	89.0	92.0	80.0	65.0	63.0	65.0	90.0	112.0	123.0	1121.0
Store change	–	–	–	–	–	−18.5	–	–	–	18.5	–	–	
Water holding capacity	18.5	18.5	18.5	18.5	18.5	–	–	–	–	18.5	18.5	18.5	18.5
Real evapotranspration (GET)	–	–	2.9	33.0	68.7	98.5	65.0	63.0	65.0	43.4	14.1	–	453.5
Water deficit	–	–	–	–	–	5.3	54.0	47.0	8.0	–	–	–	114.4
Surplus water	144.0	110.0	85.1	56.0	23.3	–	–	–	–	28.1	97.9	123.0	667.5
Surface flow	133.5	127.0	97.5	70.6	39.6	11.6	–	–	–	14.1	63.0	110.5	667.5
Moist ratio	144.0	110.0	29.2	1.7	0.3	−0.2	−0.5	−0.4	−0.1	1.1	7.0	123.0	
Daily PET	0.0	0.0	0.1	1.1	2.2	3.5	3.8	3.5	2.4	1.4	0.5	0.0	1.5
Drought index İn=12×GET/T_{om}					48.2	60.0	36.6	35.2	40.0				18.3
Water balance (mm)					Water deficit								−91.1

PET Potential Evapotranspiration (millimeter)

gentle slope (0–16%), medium slope (16–32%) and steep slope (>32%) using GIS surface analyses function. The landscape surface was further stratified into six surface subzones; ridge, top hillside, middle hillside, sub hillside, lowland and base land. The sample points were also grouped according to the physiographic stratification. Soil classification was carried out in each of the elevation – climate zones using the soil samples. Therefore, the soil was classified into bedrock types (andesite-basalt, riyodasit and granit), soil deepness [medium deep (50–75 cm), deep (75–100 cm) and quite deep (100–125 cm)], rockiness (sparsely distributed rocks and densely packed rocks) and soil texture (sandy loam, loam, clay loam, sandy clay loam).

Total eight features were determined for each soil sample by subjecting 375 soil samples to chemical and physical analysis. Topographic parameters were used to delimit the forest sites while bedrock, soil depth, rockiness and soil texture were used to determine ecological units. Given that forest site maps such as soil depth, soil texture, rockiness, topographic surface or landform, slope groups and thus forest sites were produced using some of the spatial analysis functions of GIS. Two methods were used for classifying and mapping forest sites in Turkey. First method is based on soil nutrient regime (SNR) where water deficit is nonexistent in summer months (Altun 1995). The second method is applied according to soil moisture regime (SMR), where water deficit exist in summer months (Kantarci 1972, 1978, 1980; Bakkaloglu 2003; Gunlu 2003). In this study, we gathered the climate data for study area from Artvin Meteorological Station as it is the nearest station to study area. We adapted these data to 1,430 m average altitude of study area and conducted climate analyses. Climatic data relating to study area were given in Table 1. Climatic analysis was carried

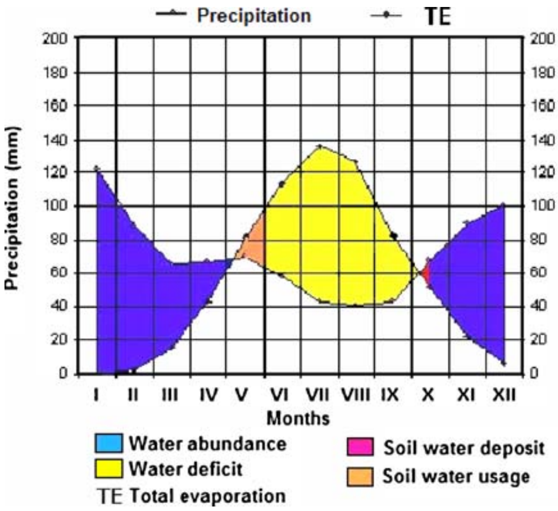


Fig. 2 The water balance of study area

out according to Thornthwaite method (Erinc 1984) and indicates that there was water shortage in summer months (Fig. 2). Therefore, SMR is used to classify the forest sites.

According to this method, available water holding capacity of soils is only taken into consideration. It is a very important parameter for forest sites, but not adequate alone in mapping and distinguishing sites. Moreover, main rock, soil type, soil skeleton with physiological soil depth, the most effective parameters for forest site classification of soils, are taken into consideration. Combining these parameters help generate ecological soil units Ecological unit systems stratify the landscape in a hierarchy according to physiography, geology, soil, topography, and vegetation. The basic management units and land types (or ecological land types) are visually identifiable areas that have similar soil and productivity conditions because of similar climatic and geologic processes (Fig. 3).

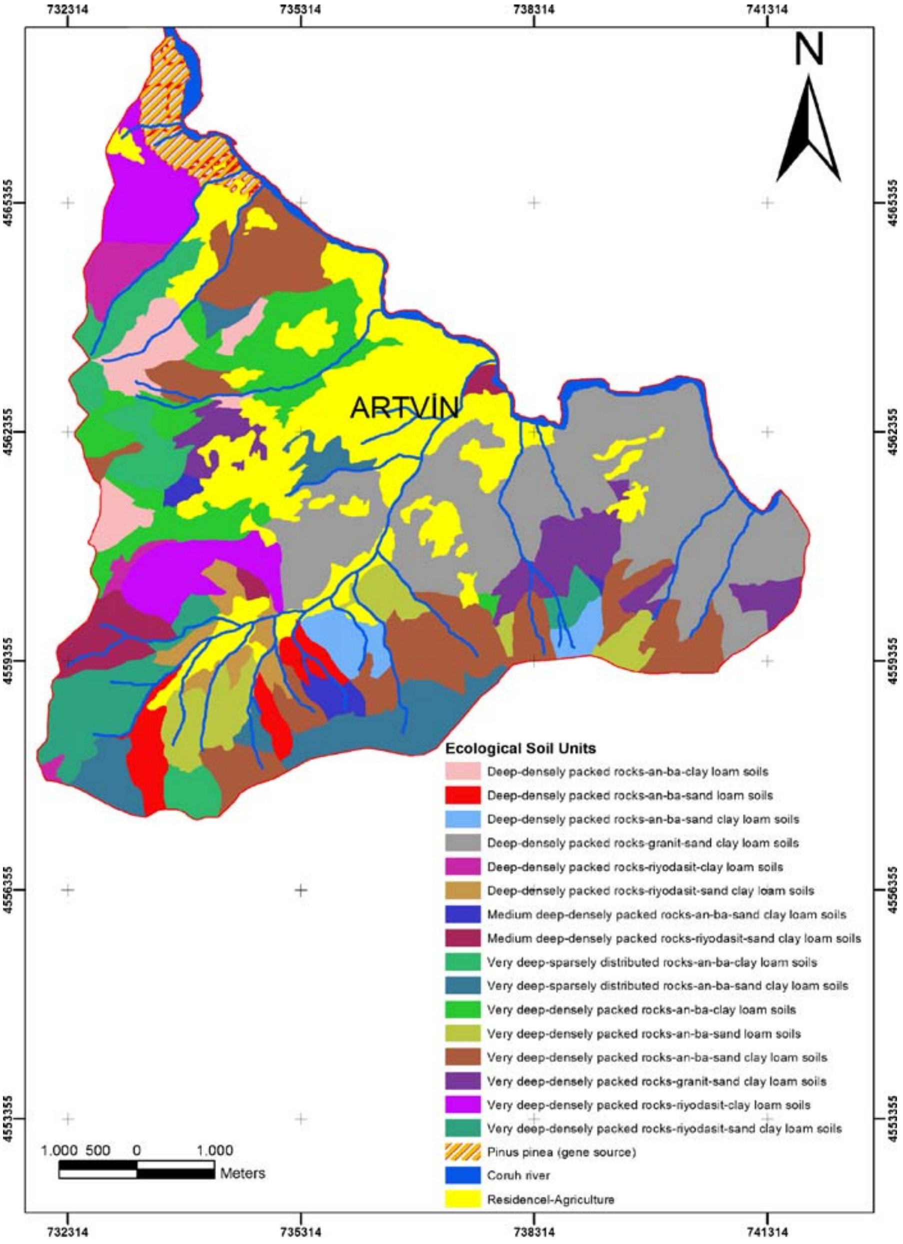


Fig. 3 The map of ecological soil units (an-ba: andesite-basalt)

Table 2 The attributes of some of ecological soil units and forest sites classification

Number	Ecological site units	Forest sites	Tree species	WHC (mm)	Horizon	Organic matter(%)	pH	Mean productivity	Mean altitude (m)
I	Quite deep-sparsely distributed rocks-andesite-basalt-sand clay loam	Moderate fresh	*Fagus orientalis*	89.40	Ah-Ael-Bts-BC-Cv	1.99–10.51	3.76–4.23	IV	1680
II	Medium deep-densely packed rocks andesite-basalt-sand clay loam	dry	*Fagus orientalis*	34.43	Ah-Ael-Bt-Cv	4.99–7.15	4.68–4.85	IV	1450
III	Deep –densely packed rocks andesite-basalt-sand clay loam	fresh	*Fagus orientalis*	64.74	Ah-Ael-Bts-BC-Cv	2.28–12.48	4.40–5.30	IV	1250
IV	Quite deep-densely packed rocks andesite-basalt-sand clay loam	Moderate fresh	*Fagus orientalis*	62.93	Ah-Ael-Bts-BC-Cv	2.32–4.99	4.87–5.46	III	1520
V	Medium deep-densely packed rocks dasit-sand clay loam	Moderate fresh	*Picea orientalis*	59.7	Ah-Ael-Bts-BC-Cv	0.44–9.61	4.84–5.06	III	1140
VI	Deep-densely packed rocks-dasit-sand clay loam	fresh	*Picea orientalis*	71.7	Ah-Ael-AB-Bst-BC-Cv	1.12–6.09	4.96–5.75	IV	1540
VII	Quite deep-densely packed rocks -dasit-sand clay loam	fresh	*Picea orientalis*	81.8	Ah-Ael-Bts-BC-Cv	2.50–6.68	4.77–5.35	III	1060
VIII	Deep-densely packed rocks -granit sand clay loam	fresh	*Picea orientalis*	58.32	Ah-Ael-Bts-BC-Cv	1.44–4.37	5.46–6.10	III	1210
IX	Qsuite deep-densely packed rocks-granit-sand clay loam	fresh	*Picea orientalis*	68.75	Ah-Ael-Bts-BC-Cv	1.82–6.71	5.05–6.65	IV	1620
X	Quite deep-sparsely distributed rocks-andesite-basalt-clay loam	Moderate fresh	*Picea orientalis*	107.0	Ah-Ael-Bts-BC-Cv	1.91–9.77	4.09–4.86	III	1590
XI	Deep-densely packed rocks-andesite-basalt-clay loam	fresh	*Picea orientalis*	45.16	Ah-Ael-Bts-BC-Cv	3.24–9.99	5.33–5.95	II	1400
XII	Quite deep-densely packed rocks-andesite-basalt-clay loam	fresh	*Picea orientalis*	78.10	Ah-Ael-Bts-BC-Cv	3.87–12.75	6.03–6.58	III	1385
XIII	Deep-densely packed rocks-dasit clay loam	Moderate fresh	*Picea orientalis*	41.46	Ah-Ael-Bts-BC-Cv	3.94–11.21	4.35–5.00	II	1640
XIV	Quite deep-densely packed rocks-dasit-clay loam	fresh	*Picea orientalis*	73.93	Ah-Ael-Bts-BC-Cv	1.24–3.64	4.62–6.25	III	1140
XV	Deep-densely packed rocks-andesite-basalt-sandy loam	fresh	*Picea orientalis*	40.10	Ah-Ael-Bts-BC-Cv	3.73–12.57	4.78–6.23	III	1425
XVI	Quite deep-densely packed rocks-andesite-basalt-sandy loam	fresh	*Fagus orientalis*	62.42	Ah-Ael-Bts-BC-Cv	2.01–8.27	4.69–4.94	III	1470

WHC water holding capacity

The attributes of the ecological soil units were given in (Table 2). The water holding capacity of each horizon in soil profile was calculated using quantity of thin soil and horizon length. Later; the water holding capacity of soil profile was calculated as plus of water capacity holding of each horizon in soil profile. The quantity of water holding capacity of ecological soil series was calculated by taking into consideration physical soil depth of 100 cm (Kantarci 1980). Later, the following equation was used to calculate drought indices in study area (was used dates in Table 1).

$$\mathrm{Im} = 12 \times \mathrm{GET}/T_{\mathrm{om}} \tag{1}$$

Here, Im is drought indices, GET is real evapotranspiration (mm), T_{om} is total monthly max. temperature (°C), 12 is annual coefficient. As Eq. 1, monthly indices are calculated and then annual indices are determined by averaging of monthly

Table 3 The name of forest site classification and index values

İndex value	Forest site classification
<8	Very Dry (VD)
8–15	Dry (D)
15–23	Moderate Fresh (MF)
23–40	Fresh (F)
40–55	Humid (H)
>55	Hygric (Hy)

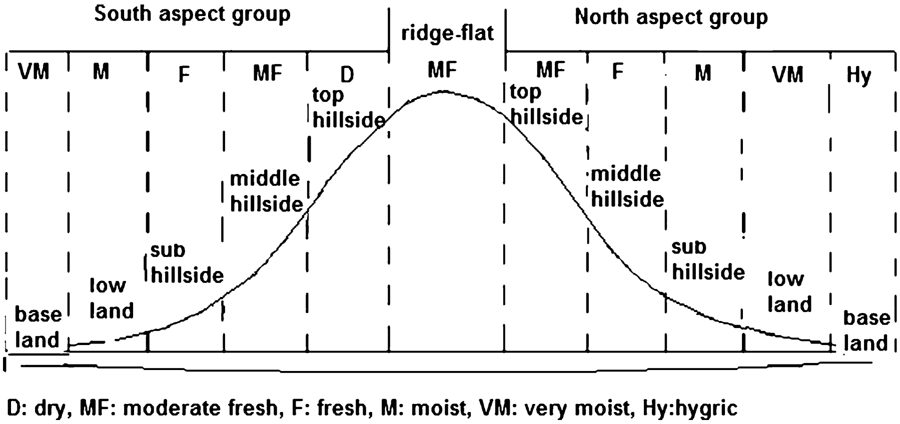
indices values. According to these indices values, forest sites are determined as Table 3 (Erinc 1984).

The index values calculated for the research area are between 15 and 23, indicating the moderate fresh base site. Since this classification does not take aspect, slope and altitude (the spatial factors) into consideration, the drought index values, thus the base site, calculated according to ridge flat were adjusted by the spatial factors. Therefore, the adjustment method developed by Kantarci (2000) (Fig. 4) for various base sites was used to determine forest sites across the forest landscape accordingly. For example, if the sample point is on the top hillside of south aspect, then the site is Dry according to the ridge-flat base site scheme. All the sample points are evaluated likewise and recorded in a database to delineate the forest sites across the research area using GIS (Fig. 4).

The scheme in Fig. 4 has been developed based on ecological understanding of forest sites. Basically, the north and south aspect groups differ from each other in terms of water economics. Since the areas in South aspect group and exposure get more straight and longtime sunbeam in Northern hemisphere and the areas are drier than those with similar ecological attributes (Cepel 1984). This fact can be clearly seen in steep, very steep and rugged areas (Fig. 4). For example, while an area, which is located in the North aspect group, top hillside and steep, very steep and rugged location, is classified as fresh forest site, the same area which is located in South aspect group is to be classified as dry site.

The study showed that there are five different forest sites; dry, moderate fresh, fresh, humid and hygric, generated and mapped with GIS. Dry forest site is water deficit that can create droughtness. The site is very steep and on south aspect hillside. Water in the soil is at a low level, not enough to meet the need of forest trees over the growing period. However, soils of these forest sites can provide the need of plants by storing a part of seasonal rain due to deepness of the soil and less stony feature. In moderate fresh site, water deficit can occur or reach a level to cause droughtness in low rainy years. Even though this site is at a margin of drought in water holding capacity, it is at steep slope on North aspect hillside. Because of local spatial factors, the site is not taking water leakage from neighboring site. In fresh forest site, after rains, because soil is full of water, water level at field capacity is held and spare of water has flown. In fresh forest site, available water in soil is in adequate amount over an important part of growing period. In humid forest site, if the moderate fresh and fresh forest site can get reinforcement of water from sub hillside, water collection line, valley and base become "humid." The pores of soil are fully generated by water. The hygric forest site is generally situated in near stream and a

Fig. 4 Forest site units with steep, very steep and rugged



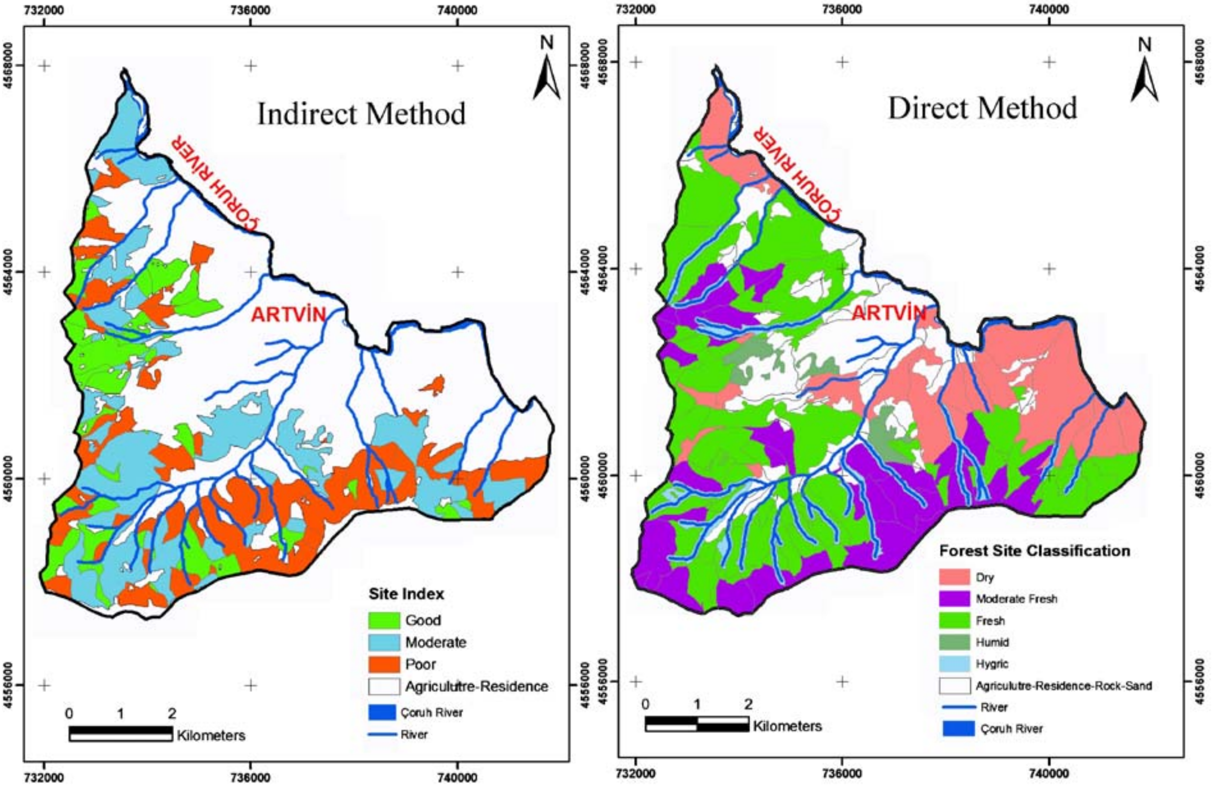


Fig. 5 Spatial distribution of forest sites; determined by both direct and indirect methods

place which has height groundwater. Because of decreasing the temperature of soil, these sites are not suitable for roots.

Indirect methods

The assessment of site productivity in a forest area is fundamental to a good resource management. Accurate and reliable evaluation of site quality is necessary for forest resource management, in making cost-effective decisions about silviculturel investment (Corona et al. 1998; Kayahara et al. 1998). In this study, site index (SI) was used to determine forest sites. This method attempt to select a few easily measured properties of the vegetation or the land, which will represent all factors important to the growth of a particular species on a given site. The direct method depends on the relationship between average height and age. Basic data for this relationship was obtained from each sample plot. In each sample plot, height and age measurements were taken on dominant and co-dominant trees. Heights were measured with Blume-Leiss 0.1 mm precision. SI has been estimated through stand age and top height (average height of 100 dominant and co-dominant trees per hectare) with no obvious evidence of growth abnormalities and damages. SI, of all the indirect measures that have been investigated, the rate of tree height growth appears the most practical, consistent, and useful indicator of forest site. It is not a perfect measure by any means, but it remains the standard to which other measures, such as soil properties, are compared.

Trees from stands of a particular species or species group having a full canopy of normally developed crowns were measured for age and height. According to the method, first of all, the guiding curves are used to generate anamorphic SI equations. Then other curves are generated by first fitting an average height-over-age guide curve to these data and then constructing a series of higher or lower curves with the same shape as the guide curve. Such a process is called anamorphic curving. Given this procedure, the SI curves developed by (Akalp 1978) for *P. orientalis* and (Carus 1998) for *F. orientalis* were used. The site productivity was grouped into low=IV, V; medium=

III and good=I, II sites. The SI map was created using GIS functions (Fig. 5). Here, the SI value calculated for each sample plot was recorded to the location of the associated sample plot. Then, using the spatial analysis functions (proximity, nearest neighborhood) of GIS the borders of the sites were delineated. Later, using the reclassification functions (eliminate) of GIS, the geographically adjacent (contiguous) sample plots with the same SI values were clumped resulting in a map showing the forest SI values across the research area. Moreover, the flow chart show the relating of direct and indirect method was given (Fig. 6).

Results and discussion

The study showed that 16 ecological soil units and five forest site classifications were identified and mapped by using GIS. The forest sites were identified with site attributes, landscape attributes such as altitude, aspect, slope, hillside; climate attributes such as temperature and precipitations; water holding capacity of soil depending on soil reaction, organic matter, steepness, stones of soils. As already known a forestation, silviculturel prescriptions and thus forest management decisions along with land use planning are based on sound site information to design appropriate actions for implementation on the ground (Altun et al. 2002). Forest sites are not classified for solo forest management purposes. Site-classification systems can and should be used as a strategic tool in forest research planning for the extrapolation of research results, as well as the application of empirical and/or process-based models to actual forestland areas (Louw and Scholes 2002). A number of site studies focusing on site factors with modern techniques, have been conducted in South Africa including some of the most important pine and

Fig. 6 The flow chart of forest site classification process

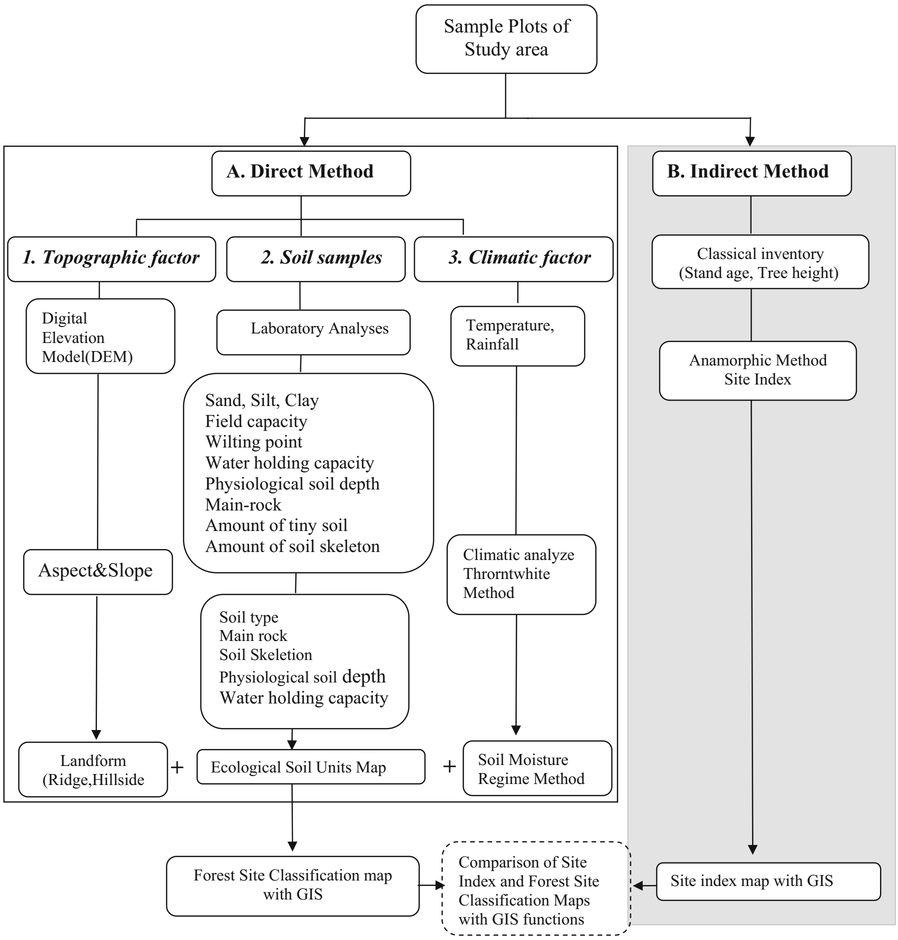


Table 4 Distribution of forest sites determined by three methods of direct and indirect

Direct method		Indirect method
Forest sites	Area (ha)	Site index[a]
Dry	937.58	15% III (139.59 ha) 2% IV (22.49 ha) 1% V (7.83 ha) 767.67 ha (82%) not determined by indirect method
Moderate Fresh	931.90	4% I (38.79 ha) 12% II (114.05 ha) 27% III (251.47 ha) 25% IV (233.62 ha) 15% V (139.27 ha) 154.70 ha (17%) not determined by indirect method
Fresh	1,797.71	2% I (48.72 ha) 14% II (248.44 ha) 30% III (546.34 ha) 18% IV (322.26 ha) 7% V (126.73 ha) 505.22 ha (28%) not determined by indirect method
Humid	80.48	5% II (4.03 ha) 74% III (59.85 ha) 21% IV (16.60 ha)
Hygric	356.55	6% I (22.60 ha) 8% II (29.36 ha) 28% III (98.84 ha) 27% IV (94.60 ha) 8% V (29.55 ha) 81.60 ha (23%) not determined by indirect method
Residence–Agriculture	1,007.88	1,007.88
Total	5,112.1	5,112.1

[a] SI: I and II (good site), SI: III (moderate site) and SI: IV and V (poor site)

eucalyptus species. Water and nutrient interactions are found to be key factors in determining forest productivity. The moisture balance of a particular site is commonly expressed by variables such as mean annual or driest quarter precipitation, slope shape, aspect, terrain unit, slope curvature, soil texture, effective soil depth, stone content and even soil classification. Soil nutritional aspects, on the other hand, can be linked to variables such as underlying geology, topsoil cation levels, soil pH and organic matter. In this study, especially; water holding capacity, soil depth, soil rock and soil type was found to be important in the distinguishing of forest sites.

The direct method identified forest sites as dry, moderate fresh, fresh, humid and hygric and indirect method as good, medium and poor. Some important differences between the methods were identified. The forest sites determined with indirect method indicate that area for site indexes I and II is 505.99 ha, III 1,095.79 ha and for sites IV and V 992.95 ha, and other areas 2,517.07 ha. However, forest sites determined with direct method relate to dry site of 937.58 ha, moderate fresh site of 931.90 ha, fresh site of 1,797.71 ha, humid site of 80.48 ha and hygric site of 356.55 ha (Table 4). Non-forest areas such as treeless and degraded areas (1,509.19 ha) were not determined by indirect method. However, most of those areas can be evaluated and their productivity can be determined with direct method as opposed to the indirect method that was unable to determine the site class for those open areas.

Table 4 shows that the study area was classified into good, moderate and poor sites with indirect method. Then, the results of direct method were distributed over the study area for compassion to other method by using GIS function. First of all, the comparison shows that direct method classified 937.58 ha of area as dry site, 931.90 ha moderate fresh site, 1,797.71 ha fresh, 80.48 ha humid site and 356.55 ha hygric site; indirect method classified 505.99 ha as good site, 1,095.79 ha moderate site, 992.95 ha poor site and 1,509.19 ha areas other areas. Obviously, the indirect method failed to identify the site productivity of 1,509.19 ha open areas. Second, of 992.95 ha poor site determined by indirect method, nearly 962.63 ha (97%) was in fact in moderate fresh, fresh, humid and hygric site which shows a significant misrepresentation of sites. Similarly, of 1,095.79 ha moderate sites, nearly 298.28 ha (27%) was in fact in dry, humid and hygric site which also shows a significant misrepresentation of sites. Furthermore, of 505.99 ha good sites, nearly 450.4 ha (89%) was in fact in moderate fresh and fresh site which also shows a significant misrepresentation of sites.

Conclusions

As a result of this study; there are very important differences between direct and indirect methods used to distinguish forest sites in Turkey. Because of these meaningful differences, the estimation of the productivity of Turkish forests with indirect method used so far is not quite appropriate. First of all, the forest sites of bare lands including treeless areas and afforestation areas (1,509.19 ha^{-1}), as seen in Table 4, was not determined by indirect methods, whereas determined by direct methods. Moreover, there were some differences in the real productivity of the areas distinguished by indirect and direct methods. For example, while 962, 63 ha areas must be in good sites according to direct method, these areas appear to take place in poor sites. Thus, any treatment prescriptions scheduled (or even applied) within management strategies would certainly be inappropriate for those sites, potentially causing to create degraded forest. Therefore, forest site classification has been seen one of the major problems of Turkish forestry for a long time giving the fact that researchers have tried to develop a classification system superior to site index, but no alternative approach has gained the widespread acceptance of site index. Similarly, one of the important national problems in Turkey is the degradation of soil richness. As known, the soil has to be protected and enriched before it serves to the growth and development of many of the products. The value of soil depends on its size and characteristics. The unit value relates its location and site quality. Here, forest management activities are necessary to supply the needs of the society and control or regulate the forest conditions over which many values reside. In most cases, through, alterations of physical soil properties are extensive. The effects in reducing productivity are well-documented. Chemical and biological soil properties are also modified by management activities, but the effects on productivity are not well-documented, (i.e., influence is not clear). Historical evidences show that forest ecosystems are dynamic and resilient. Assessment of the consequences of changes in properties must recognize that shifts in preferred species should not be equated with changes in productivity, and that short term effects, measured by the length of most experiment or observations, may not be indicative of long-term effects. In conclusion, worldwide, forestry progresses into an era of managing forests for both commodity production and services. The need for efficient multi-objective planning, decision making and environmental accountability necessitates the development of an efficient site classification method to apply.

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[1] Treeless area = (residential area + agriculture area + treeless area) − (agriculture + residential) = 1,509.19 ha

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