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Determination of the priority areas for the rehabilitation of degraded forest lands

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Turkey has more than 21.67 million ha forest areas and 10.11 million ha of these forest areas are still degraded or highly degraded in 2012 year. These areas can only be transformed into a productive state with implementation of rehabilitation treatments. Determination of the priority of degraded forest areas for the rehabilitation is important issue and affected by many parameters in Turkey. Some important indicators such as slope, aspect, elevation, social pressure, roads near forest and tree species, were used to determine priority of forest rehabilitation areas by using Geographic Information Systems (GIS). In this study, we developed a spatial database including topographic parameters, forest stand type maps and stand type parameters, forest stratification, roads and settlement areas and its proximity tables with forest stands. Slope, aspect and elevation maps of the study area were created by employing a digital elevation model (DEM) produced from contour curves (10 m height accuracy). The study area is naturally covered by *Pinus brutia, Pinus nigra, Abies cilicica, Cedrus libani, Juniperus* spp., and *Quercus* spp., the most widely distributed species in the Mediterranean region. Total degraded forest areas consist of 2.880 sub compartments with 11.363 ha. Finally, we designed a priority map of the forest rehabilitation based on these sub compartments and other indicators by using GIS techniques. It is shown that 6364 ha of degraded forest areas has high priority index value (>=16 and =<19) and 1254 ha of degraded forest areas has very high priority values with higher than 19 priority index value.

Key words: Forest rehabilitation, Geographic Information Systems (GIS), forest management plans, Digital Elevation Model (DEM), priority areas, slope, aspect, proximity, degraded forest.

INTRODUCTION

Forest rehabilitation has always been a sophisticated issue based on not only wood production but also ecological and social services of forest areas in Turkey. Instead of forestry depending on only wood production, what is expected as a forestry concept to answer ecologic, economic and social functions in spoiled forest regions is to have maximum benefit from progress and growth energy of current stands, and to make forest areas efficient with rehabilitation requiring less work and costs by preserving current species in the region without

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spoiling the forest ecosystem.

In Turkey, conifers, broadleaved and mixed area in spoiled forest regions, whichhas no chance of being recovered by natural rejuvenation and silvicultural treatment, and the bare spaces in these forest regions are considered for rehabilitation.

In this perspective, forest rehabilitation practices have been applied to large areas and three different pytho-geographical regions (Euro-Siberian, Mediterranean and Irano-Turanian) for a long time (Ürgenç and Boydak, 1985; Saatçioğlu, 1961) in Turkey.

Rehabilitation treatments have been applied in 1453392 ha areas between 1998 and 2010 throughout Turkey (Çolak et al., 2010). By adding the treated area, 346902 ha, in 2010 and 345000 ha area objective for 2011, the total treated area is obtained as 2145394 ha (Anonymous, 2002). These treatment operations, purposely, make important contributions to decrease erosion rate, preserve the soil and manage it in a sustainable way, preserve water bodies, prevent sedimentation in dams, lakes and ponds and guarantee water and electricity generation, minimize floods and overflows, especially, minimize the negative effects of climate change and desertification.

The first forest management plans of Karaisali Forest Enterprise which includes the biggest dam basins and the major portion of Cukurova containing the most important agricultural areas of Turkey, has been designed in 1969. The spoiled forest areas have been decreased from 46851.9 ha area in 1969’s forest management plans to 15848 ha in the plans of 2012. Successful forestry applications and rehabilitations work in the last 10 years have been effective in this process. Thanks to these treatments, the spoiled forest areas have been decreased to 8642 ha in the last 10 years (Kadioğullari et al., 2013). Instead of these successful and convenient treatments, the parameters required setting priority order in the rehabilitation sites and which areas have the priority for the intervention are not clear and not considered, which is an important downside. In the abstract, area difference, rehabilitation and forestation effects on the products and services of forest ecosystem have been investigated in this study (Farley et al., 2005; Ilstedt et al., 2007; Chen et al., 2000; Andres and Ojeda, 2002; Şahin and Hall, 1996; Zinn et al., 2002; Louis Awanyo et al., 2011; Zhuang, 1997; Kadioğullari, 2013; Başkent and Kadioğullari, 2007; Kadioğullari et al., 2008; Sağlam et al., 2008).

This study aims to determine the priority of degraded forest areas for the rehabilitation in the Karaisali Forest Enterprise year of 2012 based on forest-stand-type maps by using a Geographic Information System (GIS). In this context, the objective of this study is to contribute to the understanding of the priority index of rehabilitation areas using topographic parameters with different class for the tree species, distance from settlement areas for social pressure and nearness of the roads in the Mediterranean forests of southeastern Turkey.

METHODS

Study area

The study area of Karaisali State Forest Enterprise included Çatalan, Kizildağ, Çukurova, Karaisali, Akarca and Hacili Forest Planning Units located in Adana Province in the Eastern Mediterranean Region of Turkey, UTM European 50 datum 36 zones 668970 to 716792 E, 4103218 to 4151137 N (GDF, 2012). The area consists of mountain forests, flat agricultural land and scattered settlements and highlands. The altitude varies between 20 and 2420 m (Figure 1) (Kadioğullari et al., 2013).

The region is naturally covered degraded forest by *Pinus brutia, Pinus nigra, Abies cilicica, Cedrus libani, Juniperus* spp*., and Quercus* spp*.* the most widely distributed species in the Mediterranean region. In this study, there are 11,363 ha degraded forest that consist of above species with 2,880 sub compartments (Number of patch; NP). According to stand-type maps, the forests in 2012 were mostly classified into BÇz (degraded *P. brutia*; calabrian pine), BÇz-E (degraded *P. brutia*-erosion), BÇz-T (degraded *P. brutia*-stony), BAr (degraded *Juniperus* spp.; juniper), BÇk (degraded *P. nigra*), BÇk-T (degraded *P. nigra*-stony), BG (degraded *Abies cilicica*; fir), BS (degraded *Cedrus libani*; cedar), BM (degraded *Quercus* spp*;* oak) degraded forest stand types with areas of 5848 ha (number of patch (NP) value is 1984), 311 ha (NP value is 167), 938 ha, 3398 ha (NP is 372), 108 ha, 69 ha, 32 ha, 145 ha and 511 ha (NP is 74) respectively.

Database development

In this study, stand parameter data of forest stand type were obtained from the Karaisali forest management plans carried out in 2012 (GDF, 2012). The forest-stand-type maps for 2012 were produced with digital collared infrared aerial photos and controlled field survey data. These plan maps merged and saved as a single database by using ArcInfo 10.0^{TM}. Settlement areas and degraded forest stand type were gathered using this database. Road maps of study area was gathered from management plans and controlled by ortho-photos created by using digital aerial photograph in the year of 2011 (Figure 2).

Topographic parameters such as slope, aspect and elevation were created by using a digital elevation model (DEM) produced from contour curves (10 m height accuracy). Slope maps produced from this data and average slope value was measured using area weighted methods based on per sub compartment. At the same time, elevation value was measured using area weighted methods based on per sub compartment. However, there are other aspect value of per sub compartment that are used to select dominant aspect value with covered area based on per sub compartment (Figure 2).

Determining of priority index

Priority index was determined by using same topographic parameters based on tree species except for elevation. The reason for this is that all the tree species were distributed in different stages of elevation and tree species grow best when elevation varies. Therefore, regardless of the tree species, for all stands slope, aspect, distance to the road, the distance from residential (settlement) area and stony-erosion according to the characteristics of the sub compartment basically used the same parameters.

Index of stony-erosion was classified into three, while other

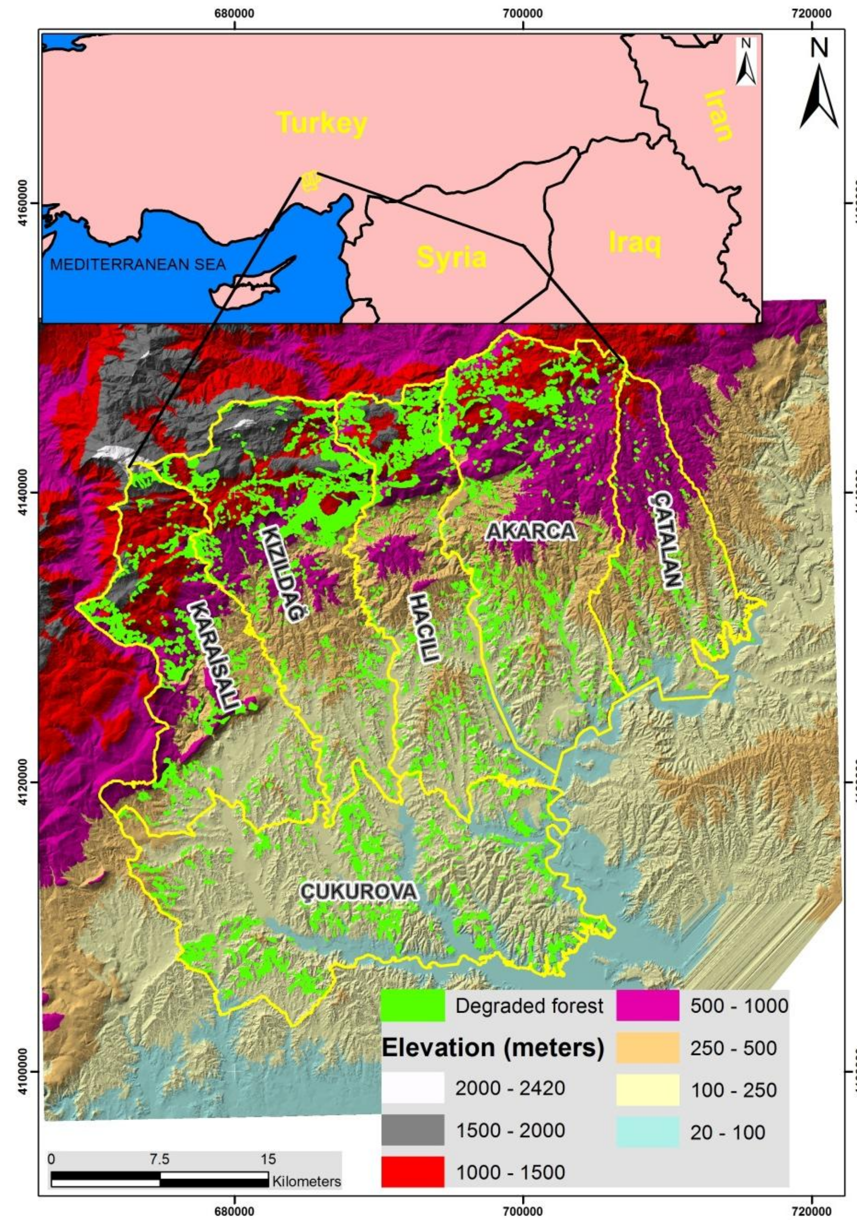

Figure 1. Study area.

indexes were classified into four. All sub compartments were classified into three for erosion-stony index; stony, erosion and normal stand with index of 1, 2 and 3. According to slope index, all sub compartments were classified into four for slope (%; percent) using area weighted method; <20%, 20-40%, 40-60% and >60% with index of 4, 3, 2 and 1. Furthermore, for other parameters such as distance to road index, all sub compartments were classified into four; 0 m, 0.1-250 m, 251-500 m and >500 meter with index of 4, 3, 2 and 1. For parameters as distance from settlement areas, all sub compartments were classified into four; <500 m, 501-1000 m, 1001-1500 m and >1500 m with index of 1, 2, 3 and 4. For other main aspect parameters, all sub compartments were classified into four; north, east, west and south aspects with index of 4, 3, 2 and 1. Lastly, all the tree species were distributed in different stages of elevation and classified into four based on elevation. For the *Pinus brutia* (calabrian pine; Çz) and *Quercus* (Oak; M) species for all sub compartments were classified into four; <500 m, 501-1000 m, 1001-1500 m and >1500 m with index of 4, 3, 2 and 1, respectively. For the *Pinus nigra* (Çk), *Abies cilicica* (G) and *Cedrus libani* (S) species for all sub compartments were classified into four; 900-1250 m, 1250-1500 m, 1500-1750 m and >1750 m with index of 4, 3, 2 and 1, respectively. For the last species as *Juniperus sps*, (Ar) for all sub compartments were classified into four; 250-750 m, 750-1250 m, 1250-1750 m and >1750 m with index of 4, 3, 2 and 1, respectively. To end this calculated priority index for each sub compartment, total priority index is determined by summing these six indexes. This index value for each sub compartment is changed from 6 to 23. To better understand the spatial distribution of priority index, it is classified into four classes as, <=10, 11-15, 16-19 and>=20 (Figure 3).

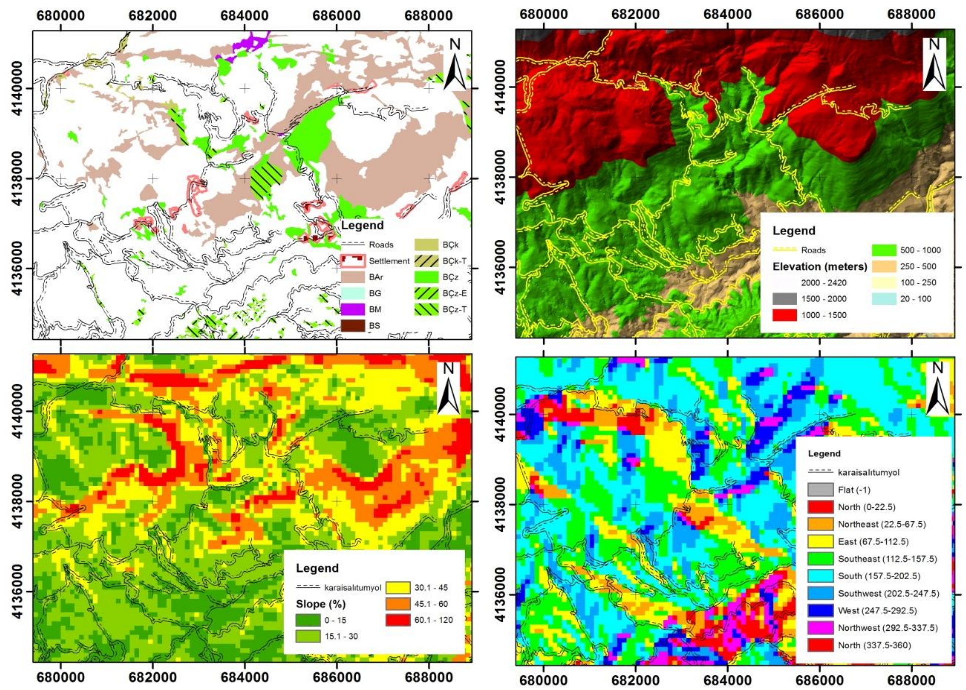

Figure 2. Database development of study area.

Table 1. Priority index of rehabilitations areas based on degraded stand types.

Stand type		BÇk	BÇk-T	BAr	BÇz	BÇz-E	BÇz-T	BG	BM	BS	Total
Priority index	**Priority group**					**Area (ha)**					
10	Low			5.1							5.1
11				24.2	16.0		93.9			3.8	137.9
12			42.7	97.1	26.5		176.8			8.0	351.1
13	Medium		11.4	496.7	93.3		215.3	2.5		5.0	824.2
14		2.3	2.5	603.7	377.4	11.1	81.5	11.1	14.6	25.9	1130.1
15		23.2	3.8	653.2	330.4	9.8	153.0		88.8	31.4	1293.5
16		30.5	6.5	602.2	818.6	58.7	98.7		49.4	23.5	1688.1
17	High	18.2		429.4	977.4	92.4	54.4	16.6	158.2	34.0	1780.5
18		24.8	2.4	282.8	1168.1	80.9	49.0	2.1	29.3	3.5	1643.1
19		8.8		101.1	1060.6	37.7	15.6		31.7		1255.5
20		0.8		84.0	558.6	18.5			108.7	10.2	780.9
21	Very high			19.1	326.7	2.1			29.4		377.3
22					93.4	0.5			1.3		95.2
23					1.3						1.3
Total		**108.7**	**69.4**	**3398.4**	**5848.5**	**311.6**	**938.2**	**32.2**	**511.5**	**145.4**	**11363.9**

RESULTS

According to the priority index of rehabilitation are asbased on degraded forest stand type map in the 2012, there are four classes: low (index value =<10), medium (10< index value <16), high (16<= index value =<19), and very high (index value>=20) priority classes (Table 1, Figure 3). Priority index class was generally concentrated into high class (6367.2 ha, NP value is 1911 (sub compartment), very high value class (1254.7 ha, NP is 481) and medium class (3736.8 ha, NP value is 487) (Table 1, Figures 3 and 4). The low class has very low

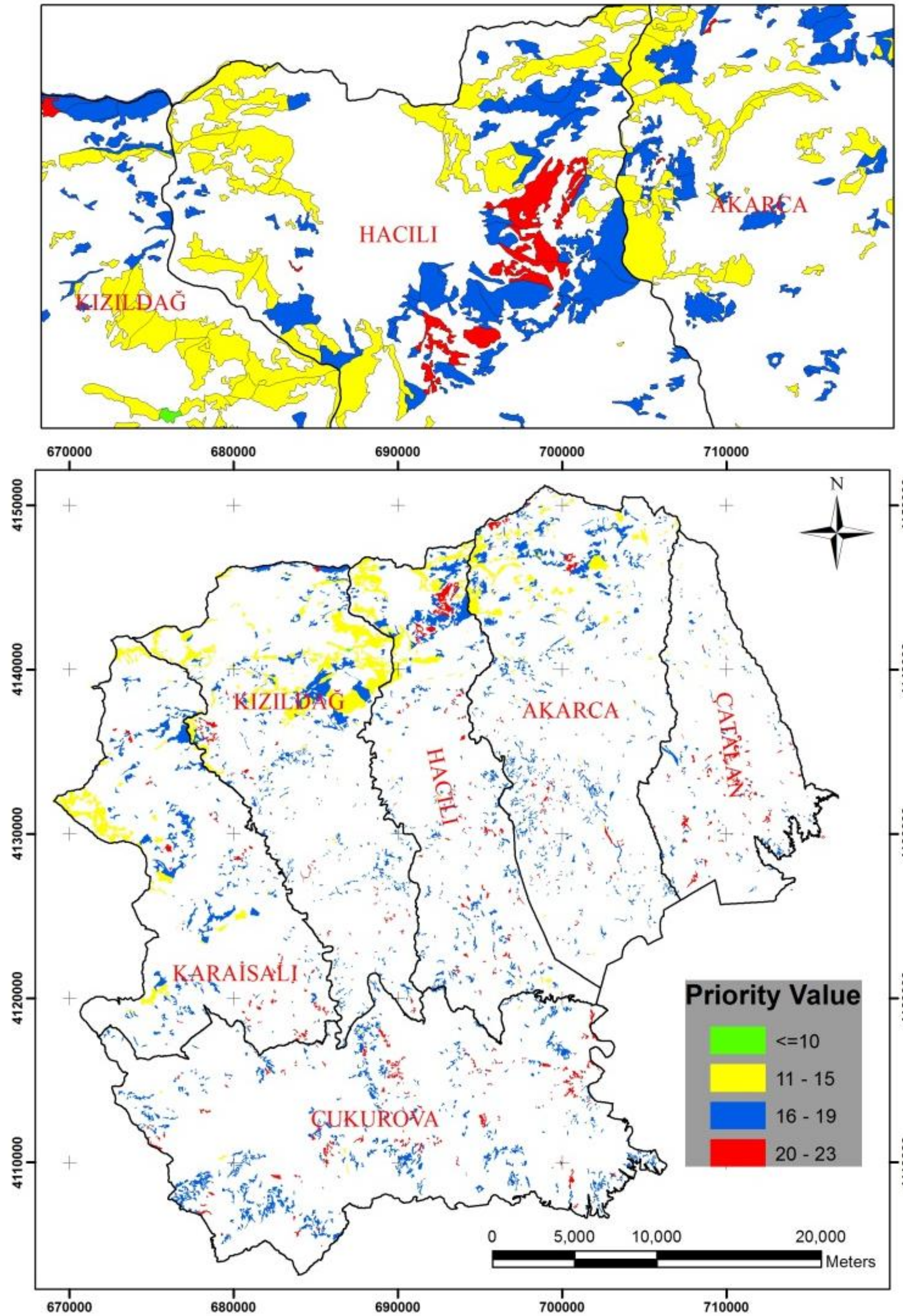

Figure 3. Priority maps of rehabilitations area.

priority areas of 5.1 ha. These results showed that, degraded forest areas have different priority index values and these values may help the plan makers decide which areas have the priority for rehabilitation in the first

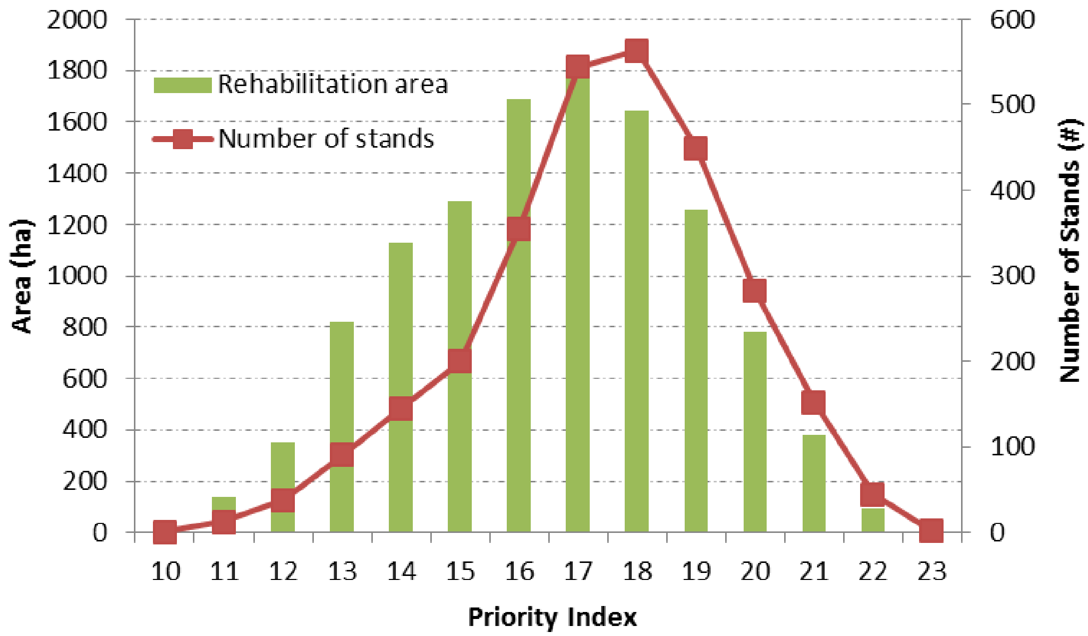

Figure 4. The distribution of the number of sub compartment of rehabilitations area.

forest management planning period.

DISCUSSION

This study was a determination of the priority of degraded forest areas for rehabilitation in the Karaisali Forest Enterprise by using a Geographic Information System (GIS). This study analyzed priority index of rehabilitation by using topographic parameters with different class for the tree species, distance from settlement areas for social pressure and closeness of the roads based on degraded forest stand type maps of the year 2012 in the Mediterranean forests of southeastern Turkey. The results of priority class in the study area show that the high priority areas have bigger areas than other classes and the same stand type has different priority index based on other parameters. At the same time, user change the parameters used for determined priority index of each degraded forest stand type which may be useful for planning other study areas.

Conclusions

Determined priority index for rehabilitation areas and mapping by using GIS for the planning of sustainable forest resources have become increasingly important during the preparation of Ecosystem Based Multi Objective (ETÇAP) forest management plans. This study examined the priority index by using only a number of topographic parameters in Karaisali Forest Enterprise, but for the following studies, adjacency/proximity parameters and opening size parameters should be used for determining the priority index for each degraded forest stands in order to prevent area of forest ecosystems from turning into monotonous block and fragmented areas.

Conflict of Interest

The authors have not declared any conflict of interest.

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