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Mapping Secondary Forest Succession with Geographic Information Systems: A Case Study from Bulanıkdere, Kırklareli, Turkey

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Abstract: Developing forest management plans for sustaining the full range of forest values is a challenging task. One of the difficulties in this process is to set and achieve management objectives, and conservation targets. A sustainable forest management concept requires that a target forest structure (the composition and the configuration) be set before developing alternative management actions for the achievement of management objectives and the conservation targets. In this respect, developing and understanding vegetation succession play important roles in setting the target forest conditions. This study was conducted in the Bulanıkdere Forest planning unit (Kırklareli, Turkey) where the biodiversity-integrated multiple-use forest management planning process is conducted as part of the GEF project. The seral stages of secondary forest succession were determined according to Clements's succession theory by using 639 systematically distributed sample plots in the planning unit in 2003. The secondary forest succession was generated and mapped using a geographic information system (GIS) and remote sensing (RS), along with aerial photographs. The paired samples t-test was used to determine whether or not there were significant differences between estimated and calculated succession values. The difference was not statistically significant at a 95% confidence level. The results indicated that the forest has developed towards the climax stage. Around 70.1% of the area is in the competition stage, while the areas in the nudation, migration, and ecesis stages account for about 2.8%. Results show that anthropogenic disturbances and harvesting techniques have been the major causes of the succession. Under a selective harvesting regime, the trees left uncut or damaged would become the main components of the subsequent forest succession. The spatial database offers excellent opportunities to understand the vegetation dynamics and to help the forest manager in deciding future forest conditions for maintaining biodiversity.

Key Words: GIS, remote sensing, forest management planning, secondary forest succession

Coğrafi Bilgi Sistemleri Yardımıyla Sekonder Orman Süksesyonunun Haritalanması: Bulanıkdere, Kırklareli Örneği

Özet: Ormanların sahip olduğu tüm fonksiyonların/değerlerin sürdürülebilirliliğini sağlayacak şekilde orman amenajman planlarını geliştirmek önemli ve zor bir süreçtir. Bu süreçte karşılaşılan zorluklardan biri işletme amaçları ile koruma hedeflerini isabetli olarak belirlemektir. Sürdürülebilir orman planlama ve işletmeciliğinde, kompozisyon ve konfigürasyon açısından hedef orman kuruluşu, alternatif işletme faaliyetlerini belirlemek ve işletme amaçları ile koruma hedeflerini gerçekleştirmek için ortaya konmalıdır. Hedef orman kuruluşunun ortaya konmasında vejetasyondaki süksesyon aşamalarının belirlenmesi önemli rol oynamaktadır. Bu çalışma, biyolojik çeşitliliğin orman amenajman planlarına yansıtıldığı Kırklareli-Bulanıkdere planlama biriminde gerçekleştirilmiştir. Çalışma Dünya Bankası tarafından desteklenen GEF projesinin bir bölümüdür. Sekonder orman süksesyonu aşamaları, 2003 yılında sistematik olarak tespit edilen 639 örnekleme alanında alınan veriler kullanılarak Clements'in yaklaşımına göre belirlenmiştir. Bulanıkdere Planlama Biriminde, Coğrafi Bilgi Sistemi (CBS), Uzaktan Algılama (UA) ve Hava Fotoğrafları (HF) ile süksesyon aşamaları belirlenmiş ve haritaları oluşturulmuştur. Eşleştirilmiş t testi (Paired Samples t), gerçek süksesyon değerleri ile hesaplanan süksesyon değerleri arasında anlamlı bir fark olup olmadığını belirlemek için uygulanmıştır. Bu iki yöntem arasında istatistiksel olarak anlamlı bir fark olmadığı % 95 güven düzeyinde ortaya konulmuştur. Elde edilen sonuçlar ormanın klimaks aşamasına doğru gittiğini göstermektedir. Tüm alan süksesyon açısından değerlendirildiğinde, rekabet aşamasındaki alanın oranı % 70.1 iken başlangıç, göç ve yerleşme aşamasındaki alanların toplamı ise sadece % 2.8'dir. Bu sonuçlar alanda antropojenik etkinin varlığını ve farklı üretim tekniklerinin kullanıldığını ortaya koymaktadır. Kesilmeyen ya da zarar görmüş bireyler tek ağaç işletme şeklinde izleyen sekonder orman suksesyonu aşamalarının temel bileşenlerini oluşturabilir. Sayısal veri tabanları; vejetasyonda meydana gelen değişimleri anlamaya imkan sunmakta ve biyolojik çeşitliliğin devamını sağlayacak şekilde optimal karar vermede planlayıcılara yardımcı olmaktadır.

Anahtar Sözcükler: CBS, Uzaktan Algılama, Orman Amenajman Planlaması, Sekonder Orman Süksesyonu

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Introduction

Succession is the process of species turnover, which leads to changes in vegetation cover and type (Usher, 1992). There are virtually no undisturbed forest areas in the world and most of Turkey's forest ecosystems have been dramatically altered by anthropogenic and natural disturbances. Secondary forest succession implies a change in either species composition or the structure of vegetation over time, which is the result of many disturbances, such as fire, insects, diseases, forestry activities, and urbanization (Turner et al., 1996; Wear et al., 1996; Cohen et al., 2002; Fernandez et al., 2004; Blatt et al., 2005; Uotila and Kouki, 2005). The ecological consequences of land abandonment, implying secondary successions, have been studied for several decades in many research fields (Elliott et al., 1997; Zhuang and Corlett, 1997; Kienast et al., 1999; Cain and Shelton, 2001; Harmer et al., 2001; Saïd, 2001; Ustin and Xiao, 2001; Kennard, 2002; Song and Woodcock, 2002; Sarmiento et al., 2003; Thomas et al., 2003; Bonet and Pausas, 2004; Fernández et al., 2004; Bischoff et al., 2005; Davis et al., 2005; Jia et al., 2005; Kubota et al., 2005; Moir et al., 2005; Wang et al., 2006). The importance of understanding secondary succession in abandoned systems is increasing (Risch et al., 2004). It is a process easily observed, but difficult to quantify (Blatt et al., 2005). Not many studies related to the mapping of succession in Turkey have been conducted in naturally regenerated forests (i.e. secondary forests), which have both ecological and socio-economic importance. Sufficient knowledge of the mechanisms, in addition to the rates and pathways of secondary succession, is crucial for understanding the response of vegetation to disturbance and the design strategies for ecosystem management and restoration (Sarmiento et al., 2003).

Biological resources are renewable as long as they are managed on a sustainable basis. Destruction caused by human activity is the greatest threat to plant communities and biodiversity (Mika, 2004). For instance, forests are cut and burned, grasslands are overgrazed, natural plant communities are cleared for agricultural purposes, crops are overwatered and polluted, and fertilizers, herbicides, and pesticides are applied in excessive doses. Urbanization, and water and air pollution, which accompany urbanization, threaten biological diversity (Menini, 1998).

Secondary forests differing in age vary in species composition. This variation has been related to changes in environmental conditions as succession proceeds, and to differences among species, in terms of their requirements and life histories (Finegan, 1984). Stand age may, therefore, explain the abundance of species. The traditional view of secondary forest succession (Clements, 1916) suggests that there will be a relationship between habitat quality and secondary forest age, depending on both the nature and duration of historical land use and the processes related to aggrading forest ecosystems.

When we admire nature in all its glory, we seldom ask, "why are these plant species here, how did they come to be here, how many species are growing together, what are the mutual relationships between them, is this plant community stable, or is it changing over time, and, does this plant community recover when disturbed?" Ecologists try to answer these challenging questions (Whittaker, 1975), and answering them is crucial for developing forest management plans to sustain the full range of forest values. It is, therefore, possible to observe the stabilization (or development of a stable climax) stage of secondary forest succession by considering plant sociological data. The Braun-Blanquet method (1964) describes characteristic and differential species of the associations and the structure of the community. If plant sociological studies are carried out or plant associations are determined in a forest area according to the Braun-Blanquet method, it is possible to decide whether or not the stand is in the climax stage (Terzioğlu, 2004).

Secondary forests provide a variety of forest products, and their management should allow for higher production levels. From a forest management perspective in Turkey, 80.2% of total forest area is managed for timber production and about 15.8% is allocated as conservation areas. Furthermore, a very small part of the total forest area (about 5%) is allocated for biodiversity conservation, including national parks, nature parks, nature conservation areas, nature monuments, seed stands, gene conservation forests, cloned seed orchards, and specially protected areas (Kaya and Raynal, 2001). On the other hand, about 91.6% of Turkish forests are natural forests, and the rest (8.4%) are plantation forests, which are mostly planted on degraded areas and open spaces of existing forests. The productive high forests are mainly composed of coniferous species at higher altitudes and deciduous species at lower altitudes. Among the coniferous species are pine, fir, spruce, juniper, and cedar, and among deciduous trees there are beech, oak, chestnut, hornbeam, and alder. Since 1937, 2 million ha of forest area have been planted, whereas 1.6 million ha of forest area have been burned.

Forest management regulations, along with natural disturbances, are the primary driving forces behind the successional changes in plant ecology. The forests of Turkey have long been exploited to meet wood supply demands and to generate national income. By the 1960s forests were managed mostly with a single-tree selection silvicultural system, regardless of the biological characteristics of existing commercial trees previously indicated (Efendioğlu and Zık, 1993). For example, uneven-aged management practices were applied to forests composed solely of light-demanding trees (e.g., pine forests), even though those forests reflect single-layered, even-aged stand structures. Unregulated and anomalous forest structures were created across the country, leaving forest managers with a great dilemma (Köse and Başkent, 1996).

International agreements emerging from the United Nations Conference on Environment and Development in 1992 challenged forest managers to maintain biological diversity in forest ecosystems. Following this, most of the subsequent meetings or conferences necessitated, and even mandated, responsible organizations to focus on the conservation of biodiversity in the management of forest ecosystems. Yet, the successional patterns of Turkish forest vegetation are under-studied and under-documented, which is necessary for in situ conservation, making the determination and mapping of secondary forest succession in forest ecosystems vitally important.

Although knowledge about secondary forests has increased over the last few decades, information about their dynamics is still lacking (Pena-Claros, 2001). Therefore, succession is a process easily observed, but difficult to quantify (Blatt et al., 2005). Mapping of secondary forest succession needs to be developed with a collaborative effort between plant specialists and state-of-the-art technologies, such as GIS, RS, and GPS. There are a number of methods for determining secondary forest succession in forest ecosystems (Glenn-Lewin et al., 1992). Plant ecologists may interpret the succession trend of a community based on data from field surveys, i.e. the composition of succeeding trees under canopy is considered the future of the vegetation (Runkle, 1981; Lorimer et al., 1988).

High resolution satellite imaging should be used for mapping secondary forest succession due to its advantages. The spatial and spectral resolution of Landsat imagery provides means for mapping and monitoring land cover at landscape level; however, it does not provide for mapping and monitoring of a minor vegetation community or land cover type/stand type at stand level due to its low resolution. Thus, high resolution satellite imagery should be used either alone or with field survey data. The availability of high resolution satellite imaging, such as IKONOS, SPOT 5, and Quickbird, provides an opportunity to recognize ground features that were not previously observable.

Remotely sensed data has to be stored in a database and analyzed with GIS. GIS is designed for the collection, storage, and analysis of objects and phenomena when geographic location is an important characteristic or is critical to the analysis. GIS is a powerful system with versatile capabilities, such as spatial analysis, visualization, and spatial database management, which helps managers make the best decisions about natural resources and the management of these resources. GIS provides researchers with powerful automated tools for answering these questions. These tools make it much easier to analyze data for special studies and reports. In fact, new types of analysis that were not previously feasible are now possible. GIS can quickly search through map data, looking for features with certain characteristics or inspecting spatial relationships among features. GIS can automatically and quickly answer specified questions. The GIS technology supports entirely new applications, including vehicle navigation systems, decision support systems, ecosystem dynamics, and map and chart production systems (Aranoff, 1989; Date, 1999).

The objective of this study was to characterize, document, analyze, and understand the secondary forest succession so as to improve the management of forest ecosystems. The secondary forest succession was generated and mapped using a combination of 3 information technologies: GIS, RS, and GPS. Forest inventory sample plots distributed over the research area of 300 × 300 m were evaluated by experts and the succession was recorded with the numbers from 1 through 6, according to Clementsian theory. The secondary forest succession values (estimated) were determined as the arithmetic average of succession values in sample plots of the same stand types. The paired samples t-test was used to determine whether or not there were significant differences between estimated and calculated secondary forest succession. Results were evaluated in terms of biodiversity, forest management, and plant sociology.

Study Area

The study area covers the entire Bulanıkdere planning unit, and is characterized by a flat terrain with an average slope of 12% and an altitude range of 0-380 m (Figure 1). It extends along Universal Transverse Mercator (UTM) ED 50 datum, zone 35, 570000-585000 E and 4626000-4642000 N in the northwestern Black Sea region of Turkey.

Of the 8506.34 ha total area, 7430.60 ha is forested and the rest is non-forested. The winters are mild and wet, and the summers are relatively cool and dry. Mean annual temperature of the study area is 8-15 °C, and mean annual precipitation is 962 mm. The main soil types are sandy clay loam, clay loam, and sandy loam (Stojchev et al., 1998). The major ecosystems of Bulanıkdere are sand dunes, sea water, lagoons (lakes), swamp, forest, and riparian. In 1991, the Nature Conservation Foundation (DHKD) reported that the Bulanıkdere Forest ecosystems are home to many birds and plants. Thus, the area was designated by DHKD as one of Turkey's important bird (especially for the black stork) and plant areas. For example, there are 11 rare plant species, including *Logfia minima, Centaurea arenaria, Jurinea kilaea*, and *Trifolium bocconei*, which can be found in the İğneada and Bulanıkdere Forest planning unit. Additionally, *Aurinia uechtritziana, Salvinia natans, Silene sangaria, Trapa natans*, and *Verbascum degenii*, which are also listed in the Bern Convention Categories (1979), have natural distribution in Bulanıkdere forests. The best example of ash, oak, and black or common alder forest communities in Turkey, which also dominate the forest

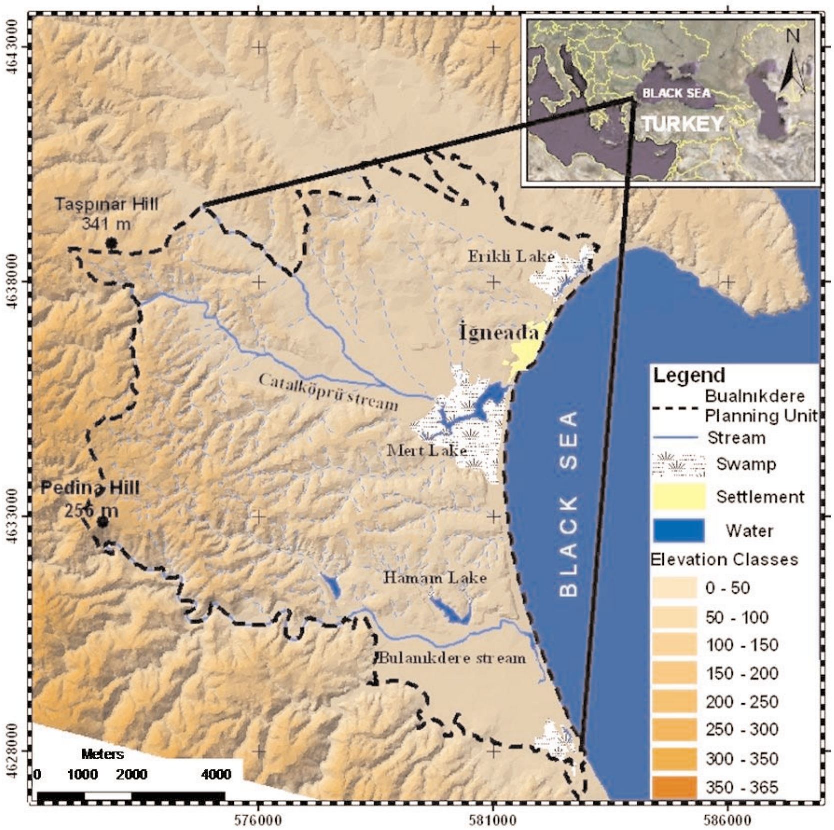


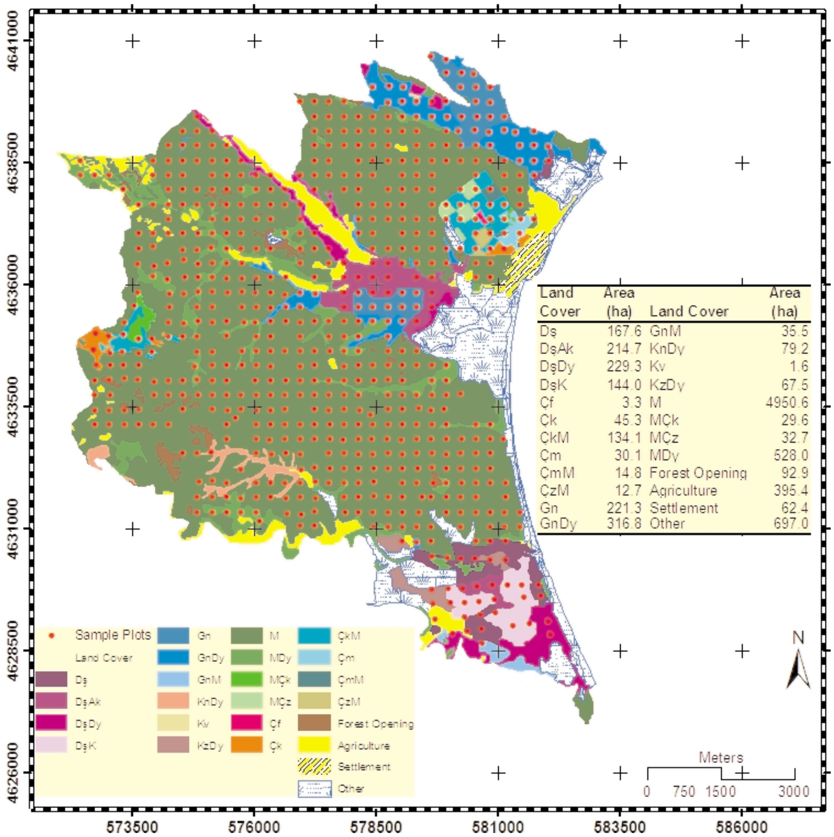
Figure 1. The study area with digital elevation model.

species in the Bulanıkdere lagoons, can be found here. In moist areas, black or common alder (*Alnus glutinosa* subsp. *barbata*) and ash (*Fraxinus angustifolia* subsp. *oxycarpa*) dominate, while *Quercus robur* and other oak species (such as *Q. frainetto, Q. cerris* var. *cerris, Q. hartwissiana*, and *Q. paetraea* subsp. *petraea*) are the major tree species in relatively dry areas (Başkent et al., 2004).

Methods

Database Development

The spatial database, developed as part of this study, consisted of a forest stand type map and a secondary forest succession map, along with the attribute data. The stand map was derived from remotely sensed data (1:15,000 average scale color infrared aerial photographs in 2002 and a 1-m resolution IKONOS image in 2003) and a field survey, and was used to create the secondary forest succession map. Remotely sensed data of the study area were obtained from the General Directorate of Forestry. Image processing and spatial analysis were carried out using ERDAS Imagine™ 8.6 image processing software and ArcGIS 8.3. Statistical procedures were used to design sample points to conduct the ground forest survey. GIS, RS, GPS, and the database management system were collaboratively used to establish a spatial forest information system necessary for mapping and monitoring secondary forest succession, as well as for developing forest management plans. In the field survey, circular sample plots, generated as point coverage, were distributed over the forest landscape using 300 × 300 m intervals (Figure 2). Species mix, understorey vegetation, development stage, crown closure, site index, damage or any indication of damage to trees or stands were measured in each sample plot. Sample plots were spatially located using a hand held GPS (Garmin eTrex Summit) with ± 5 m ground accuracy



Land Cover	Area (ha)	Land Cover	Area (ha)
Dş	167.6	GnM	35.5
DşAk	214.7	KnDy	79.2
DşDy	229.3	Kv	1.6
DşK	144.0	KzDy	67.5
Çf	3.3	M	4950.6
Çk	45.3	MÇk	29.6
ÇkM	134.1	MÇz	32.7
Çm	30.1	MDy	528.0
ÇmM	14.8	Forest Opening	92.9
ÇzM	12.7	Agriculture	395.4
Gn	221.3	Settlement	62.4
GnDy	316.8	Other	697.0

Figure 2. Land cover and distribution of sample plots in the Bulanıkdere Forest planning unit.

under forest cover. The spatial database consisted of stand type, crown closure, forest development stages based on the diameter of breast height (dbh), age classes, and successional stages. After the field survey, satellite images were rectified for their inherent geometric errors using 1:25,000 topographic maps instead of GPS coordinates in the UTM coordinate system (ED 50 datum). The forest stand type map made in 2003 was derived from previously interpreted aerial photographs, new high-resolution satellite images, and the field survey. The stand type map was later digitized and processed using Arc/Info 8.3 GIS, with a maximum root mean square (RMS) error < 10 m on the ground, and then the spatial database was created. Given the initial spatial database, spatial analyses, such as overlay, reclassification, and spatial query functions of GIS, were used to derive the secondary forest succession maps in 2003. The created maps, along with their attribute data, were all added to the spatial database.

Determining Secondary Forest Succession

There are a number of theories used for determining secondary forest succession (Davis, 1899; Clements, 1916; Gleason, 1926; Clements, 1936; Watt, 1947; Odum, 1969; Pickett, 1976; Kojima, 1981). In this study, secondary forest successional stages were determined according to Clementsian theory. Clements (1916, 1936) developed a scheme of process sets of interacting mechanisms that drive succession: 1-nudation (or disturbance); 2-migration; 3-ecesis (or establishment); 4-competition (or interaction); 5-reaction (or modification of the site by the organisms); 6-stabilization (or development of a stable climax). Furthermore, a zero (0) successional value is added to represent unknown plant species in water, dam, and rocky areas.

In the field survey of 2003, observations and measurements were carried out in each sample plot (Figure 2). The sample plots were evaluated by both plant specialists and trained forest managers on the planning team, and succession was recorded with the numbers 1-6, according to Clementsian theory. Therefore, the secondary forest succession value for each plot was determined. After completing the field survey and finalizing the forest stand type map, secondary forest succession values in the sample plots were used to generate secondary forest succession values (calculated) for each forest stand type according to tree species, crown closure, and development stage. Furthermore, the data from field studies were compared to IKONOS images to further ascertain the successional stages. In addition, the secondary forest succession values were determined as the arithmetic average of succession values in sample plots of the same stand types. Statistical analysis was used to determine if there were any differences between the estimated and calculated forest secondary succession values. The normality of secondary forest succession values was tested with the Kolmogorov-Smirnov one-sample test and normality of variance for secondary forest succession was tested with Levene's test. The paired samples t-test was used to determine whether or not there were significant differences between the methods for determining secondary forest succession. Given the assigned successional values for each stand type, the secondary forest succession map of 2003 was prepared.

Results and Discussion

Conserving and monitoring diversity in forest ecosystems during seral stages is an important forest ecology task that requires determining the changes in biomass and diversity with succession (Figure 3). As such, the results relating to the successional stages in the research area were evaluated according to this presumption.

The rates of secondary forest succession stages of the study area in 2003 are shown in Table 1 and the

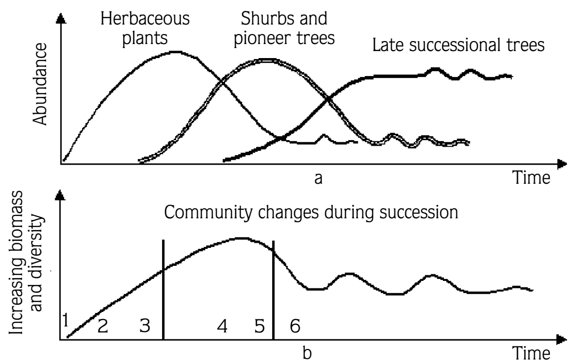


Figure 3. The changes in biomass and diversity with succession (Modified from Botkin and Keller, 1995).

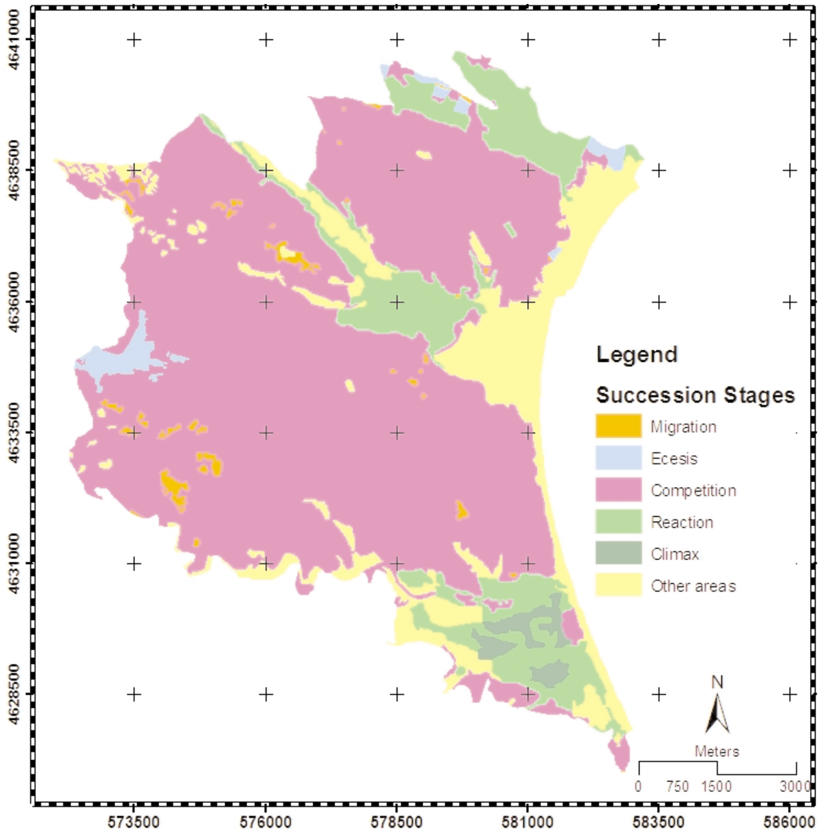


Figure 4. Secondary forest succession in the Bulanıkdere Forest planning unit.

succession map is given in Figure 4. Of the total forest study area, seral stages 4 (competition) and 5 (reaction) of secondary forest succession accounted for a total of 82.3%, whereas stages 1, 2, and 3 accounted for only 2.8%. These results indicate that the biodiversity of the study area is high because of the great species richness and evenness at the present time. Towards seral stage 6 (stabilization), diversity will decrease and reach a stable climax (late successional stage) (Figure 3). The total forest area in seral stage 6 (1.4%) was smaller than expected and appeared mainly in alluvial forest (Figures 1 and 4).

Secondary forest succession values were determined as the arithmetic average of succession values in sample plots of the same stand types. There were 639 sample plots in which 374 secondary forest succession values were correctly determined (Table 2).

Because of an inadequate number of experts in the field of biodiversity that have sufficient technical capacity to use GIS, RS, and GPS technologies, monitoring secondary successional changes in Turkey's forests has become difficult and complex. This study, however, is the first to extensively map secondary forest succession in

Table 1. Secondary forest succession values in the Bulanıkdere Forest planning unit.

Succession stages	Area (ha)	Area %
1	0.0	0.0
2	92.9	1.1
3	140.7	1.7
4	5965.8	70.1
5	1036.3	12.2
6	115.8	1.4
Other areas	1154.8	13.5
Total	8506.34	100.00

Table 2. Estimated and calculated secondary forest succession values for each stand-type level.

Stand Type(*)	Succession Stages and # of Samples						Succession Stages	
	1	2	3	4	5	6	Estimated	Calculated
Çkb3			4				3	3
Çfc3					1		5	5
Çkc3				4	1		4	4
ÇkMb3			6				3	3
ÇkMbc3				5	2		4	4
Çmc3				2			4	4
ÇmMc3				1			4	4
ÇzMbc3				1			4	4
DşAkc3				1			4	4
DşAkDycd3			1	2	10		5	5
DşAkKad3						1	6	6
Dşbc3				2			4	4
Dşc3				2	1		4	4
Dşcd2					1		5	5
Dşcd3					1		5	5
DşDybc3				3	2		4	4
DşGnMbc3				1			4	4
DşKad3					1	2	6	6
DşMAkcd3					4	1	5	5
Gnbc3				2	1		4	4
Gncd3				2	18	2	5	5
GnDşAkbc3				1	1		5	4
GnDşDycd3					7	4	5	5
GnDycd3					8	4	5	5
GnIhDybc3				3	1		4	4
GnKvbc3				1			4	4
GnMbc3			1	2			4	4
GnMDybc3				2	1		4	4
KnMGnDybc3			1	3			4	4
KzDşKacd3					1		5	5
Mab3			2	4	2		4	4
Mb2			5	16	7		4	4
Mb3			50	185	121		4	4
Mbc3			11	27	20		4	4
Mc2				2	1		4	4
MÇkb3			4	2			3	3
MÇzb3				1			4	4
MDşDyb3			2	1			3	4
MGnc3			5	3			3	4
MGnDybc2				3			4	4
MGnDybc3			2	21	8		4	4
MIhGnbc3			3	1			3	4
MIhGnc3				1			4	4

(*) The symbols are described in forest management guidelines developed by the General Directorate of Forestry in Turkey

Turkey by integrating appropriate information technologies.

Estimated and calculated secondary forest succession values in stand type level are given in Table 2. Evaluated at stand type level, 39 secondary forest succession values (91%) for stand type were correctly determined. Calculated succession values and estimated succession values were evaluated statistically. The normality of data was first tested by the Kolmogorov-Smirnov one-sample test and it was concluded that the distributions were normal. The normality of variance for secondary forest succession was tested with Levene's test and the distributions were normal. Thus, the paired samples t-test was applied and showed that the methods used to determine secondary forest succession were not statistically different at a 95% confidence level ($P < 0.05$). In other words, estimated and calculated succession values were statistically the same. The results stressed that determining secondary forest succession by trained forest management teams is valuable.

Succession is a process whereby the biotic components of the ecosystem affect the physical structure sufficiently to create a change. Successional stages can be interrupted, maintained, or forwarded to another stage by natural and/or man made causes, including fire, insect outbreaks, diseases, forestry activities, and urbanization (Turner et al., 1996; Wear et al., 1996; Cohen et al., 2002; Fernandez et al., 2004; Blatt et al., 2005). The Bulanıkdere Forest planning unit is situated in a region highly resistant to fire and insects, due to natural and ecological conditions, such as a high level of species mix, with deciduous species; therefore, forest fires and insect outbreaks have not occurred since the initiation of the forest ecosystem, and thus have had no effect on successional change. As for anthropogenic disturbances, different harvesting techniques have been used in a large spectrum of forest-cover types. Under a selective harvesting regime, the trees left uncut or damaged would become the main components of the subsequent forest. Harvesting techniques, which involve *clear-cutting* of a forest type (substantial or total removal of the tree canopy), have far-reaching impacts upon the successional vegetation. With the removal of all trees, herbaceous vegetation inevitably invades a forest area, often choking out the shade-tolerant ground-cover vegetation and tree seedlings that remain. The best examples of ash, oak, and black or common alder forest community types in Turkey, which also dominate the forest species in the Bulanıkdere lagoons, can be found here. Approximately 45% of the forest area in the planning unit is dominated by stands of various oak species.

In the Bulanıkdere Forest planning unit, until 1990, the harvest schedule was prepared to generate maximum wood production. After that time, intensive fiber and fuel wood production have been interrupted in the forests around the city of İğneada. However, unusual harvesting activities have been carried out in the area as a result of newly designated nature conservation areas since 1991. Currently, there are various conservation programs, such as a nature conservation area (1345.0 ha), a wildlife conservation area (5399.0 ha), and natural areas that include some important ecosystems in the area. In 1991, the Nature Conservation Foundation (DHKD) reported that the Bulanıkdere Forest ecosystems are home to many birds and plants; thusly, the area was designated by DHKD as one of Turkey's important bird (especially for the black stork) and plant areas (Başkent et al., 2004).

Knowledge of natural disturbance regimes and succession dynamics is essential for maintaining regional biodiversity, as well as for developing appropriate silvicultural actions for sustainable forest management plans. Many researchers have pointed out that conservation and enhancement of biodiversity are the key objectives of forest management (Başkent and Yolasığmaz, 1999; Bunnell and Huggard, 1999; Lindenmayer, 1999; Noss, 1999; Simberloff, 1999; Başkent et al., 2005). Also of importance is the maintenance of natural forest structure; therefore, before developing a biodiversity integrated forest management plan, it is most important to document and understand the vegetation dynamics through forest succession. Moreover, understanding forest succession allows managers to determine the target structure, either for stands or forests, for developing sustainable forest management plans.

Conclusions

Understanding secondary forest succession is very important in preparing appropriate forest management prescriptions. When a current stand is naturally regenerated following a harvest, it is important to know what successional stage these species typically will occupy in the future, and what type of harvest will generate the desired conditions for a new stand establishment. Effective forest management activities can only be designed and implemented when a target stand structure is recognized and a target forest landscape structure or pattern is known. Revealing and understanding secondary forest succession, as carried out in this study, will help forest managers to better define the target pattern/structure relevant to the natural development and management of forest ecosystems. The method developed as part of this study for determining secondary forest successional stages based on forest stand types is simple, practical, and easy to use.

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