Biologia **65**/5: 843—852, 2010
Section Botany
DOI: 10.2478/s11756-010-0091-x

Monitoring forest plant biodiversity changes and developing conservation strategies: a study from Camili Biosphere Reserve Area in NE Turkey

Salih Terzioğlu[1]*, Emin Zeki Başkent[2], Fatih Sivrikaya[2], Günay Çakir[2], Ali Ihsan Kadioğullari[2], Şağdan Başkaya[3] & Sedat Keleş[2]

[1] *Department of Forest Botany, Faculty of Forestry, Karadeniz Technical University, 61080 Trabzon, Turkey; e-mail: sterzi@ktu.edu.tr*
[2] *Department of Forest Management, Faculty of Forestry, Karadeniz Technical University, 61080 Trabzon, Turkey*
[3] *Department of Wildlife and Forest Protection, Faculty of Forestry, Karadeniz Technical University, 61080 Trabzon, Turkey*

Abstract: This study was carried out in forestland of Camili Biosphere Reserve (CBR) area in NE Turkey. It was designed to evaluate the consequences of disturbances on changes in secondary forest succession from 1985 to 2005 for monitoring forest plant biodiversity changes and developing conservation strategies. The successional stages were mapped using Geographic Information System (GIS), Global Positioning System (GPS), aerial photos and high resolution satellite images (IKONOS). The results showed that stable stage decreased about 77.96% over the last 20-year time period. Although 701.6 ha conifer forests existed in competition and reaction stages in 1985, none existed in 2005. In overall, about 33.23% of the area decreased, 42.36% did not change and 24.41% increased in different seral stages. Consequently, 8.83% of the area decreased as a whole to indicate that the forest has been developing from stable to nudation stage, that is to say, retrogressive succession is going on in the area. Forest structure and its relationship with plant biodiversity along with its changes over time were determined using FRAGSTATS. We also investigated spatio-temporal configuration of six secondary forest successional stages and generated structural diversity measures. These measures revealed that the landscape has been fragmented, posing a danger to lose the important components of plant biodiversity. Sustainable management of such degraded forests is of crucial importance for plant biodiversity conservation. In conclusion, the study contributes to the development of a framework for effective conservation of plant biodiversity through plant biodiversity integrated Multiple Use Forest Management (MUFM) plans by using the successional stages and plant biodiversity changes.

Key words: biosphere reserve; forest management; FRAGSTATS; GIS; hotspots; plant biodiversity conservation; plant succession

Introduction

Conservation of plant biodiversity in forest ecosystems is a global issue, particularly where the traditional timber oriented forest management activities confront with conservation. Many large, sparsely populated countries require cost-effective monitoring of their inland ecosystems for sustainable management of natural resources, ensuring ecological integrity, reporting to international conventions and agreements (e.g. Earth Summit in Rio de Janeiro in 1992) which challenge forest managers to maintain biodiversity, conserve and restore the natural habitats in forest landscapes (Ejrnæs et al. 2003; Başkent et al. 2005a; Fraser et al. 2005). The traditional concept in Turkey has orchestrated over time to achieve the management objectives focused mainly on timber production, contrary to the concept of maintaining plant biodiversity in forest ecosystems. Increasing public awareness on the management of forest ecosystems focusing with economic, ecologic and socio-cultural aspects has been a major influence on forest management and there is an increasing interest in combining environmental and productive aspects of forest management (Bagnaresii et al. 2002). In many countries, lack of extensive natural areas is the main problem for conservation of biodiversity, and most nature reserves are of small size (Oppel 2005). One of the central tasks of conservation biology is to prioritize places on the basis of their biodiversity value and select those that have the highest priority (Abellán et al. 2005). As documented by many researchers, conservation as well as enhancement of biodiversity in such kind of natural areas has been one of the key objectives of forest management (Noss 1999; Simberloff 1999; Başkent & Yolasığmaz 1999; Başkent et al. 2005b). It is also emphasized that if a site is recorded as a reserve or protected area status, we should take into account the fact that it will undergo rapid evo-

* Corresponding author

lution due to the biological traits of the species (Saïd 2001).

The ability to determine how biodiversity is affected by landscape structure and habitat modification has become a major focus of landscape ecology and biological conservation (Maclean et al. 2006). The modern consensus between landscape ecologists, conservation biologists and, increasingly, forest managers asserts that habitat loss and forest fragmentation are the underlying cause of biodiversity loss (Forman 1995; Collinge 2001; Venema et al. 2005). Specifically, different species require different minimum areas to have a reasonable chance of survival (Diamond 1975) and some focal species or populations at risk are highly dependent on the existence and extent of specific habitats (Dale et al. 1999). For instance, a number of bird species have been found to be sensitive to forest core area (a function of patch size, shape and adjacent patch conditions) (Temple 1985).

Measuring forest biophysical characteristics aims at documenting forest integrity in structural, functional and species diversity aspects however; these measurements often depend on extensive and expensive fieldwork, encompassing a restricted study area (Freitas et al. 2005). Here remote sensing techniques provide a great opportunity to enable monitoring studies in a wide area at constant time periods (Wilkie & Finn 1996) and these studies must be cost-effective (Pax-Lenney et al. 2001; Song & Woodcock 2003; Fraser et al. 2005). Continuous use of information technologies such as Geographic Information System (GIS), Remote Sensing (RS), Global Positioning System (GPS), spatial statistics and other widely used computer programs along with the appropriate plant biodiversity database design are crucial for Multiple Use Forest Management (MUFM) (Başkent et al. 2005b).

The ecological consequences of land abandonment (i.e., secondary successions) have been studied for several decades in many fields of research (Grau et al. 1997; Zhuang & Corlett 1997; Cain & Shelton 2001; Harmer et al. 2001; Song & Woodcock 2002; Ejrnæs et al. 2003; Kubot et al. 2005; Blatt et al. 2005). They all pointed out the importance of understanding secondary succession in the abandoned systems and also stressed that it is quite difficult to quantify though easily observed. Not many studies on succession, however, have been conducted on the naturally regenerated forests (i.e., secondary forests) which have both ecological and socio-economic importance for Turkey. Knowledge of the mechanisms, rates and pathways of secondary succession is crucial for understanding the response of the vegetation to disturbance and the design strategies for ecosystem management and restoration (Sarmiento et al. 2003). A major research challenge linking the communities of forest management and the conservation biology is the development of forest management strategies compatible with basic spatial ecology concepts, compatible with remotely sensed aspirations of the billions of people world-wide dependent on local ecosystems for their subsistence (WRI 2000; Venema et al. 2005).

So far it has been pointed out that plant biodiversity conservation is connected with both landscape composition and configuration. While it is relatively easy to characterize composition it is a bit difficult to measure and particularly relate landscape configuration to the status of plant biodiversity. Landscape configuration or structure relates to a mosaic of patches usually quantified by landscape metrics or measurements such as FRAGSTATS, a widely used landscape ecology software package (Urban et al. 1987; McGarigal & Marks 1994; Baskent & Jordan 1995). FRAGSTATS is a set of spatial statistics that were implemented by ecologists to describe the characteristics of landscapes and components of those landscapes (Raines 2002). As such a need arises to characterize both components and spatial configuration of forest landscape for effective conservation of plant biodiversity. In this respect, Camili region in Artvin Province of Turkey is highly critical area as included within Conservation International's 25 World Biodiversity Hotspots (biologically the richest and the most endangered terrestrial ecoregions) and is as one of the 200 priority ecoregions on the Earth (classified as temperate forests of the Caucasus) (WWF and IUCN 1994). Furthermore, the area was designated as Biosphere Reserve which is the only one in Turkey (UNESCO 2005) and the study area includes two Nature Conservation Areas (Efeler & Gorgit) designated in 1998 by the Turkish Parliament.

The main objective of this study is to document and monitor 20–year changes in secondary forest succession, affected by natural disturbance such as windbreaks and insect outbreaks, and human-caused disturbance in the study area from 1985 to 2005 using up-to-date information technologies such as GIS, RS and database management systems. The study also aims to characterize and monitor plant biodiversity changes using FRAGSTATS, determine the reasons result in secondary forest successional changes, and investigate the causative basis for secondary forest development over time to contribute the development of a framework for effective conservation of plant biodiversity through MUFM plan.

Material and methods

Study site

In the UNESCO-MAB program Camili was recognized as a Biosphere Reserve to ensure the protection, maintenance and development of this high steep mountain landscape in 2005 (UNESCO 2005). The study area is located in the mountain ranges of Artvin city in the northeastern corner and Georgian border of Turkey, UTM European 50 datum 37. zone 736000–757000 E, 4581000–4602000 N, Camili Biosphere Reserve (CBR) is the only one in Turkey with 21990 ha of area. The study area consists of primarily forests and settlement areas except for alpine region of CBR. The altitude ranges from 360 m to 2000 m a.s.l (Fig. 1). During the summer period study area are often shrouded by fog, winters are mild and wet and the average annual precipitation

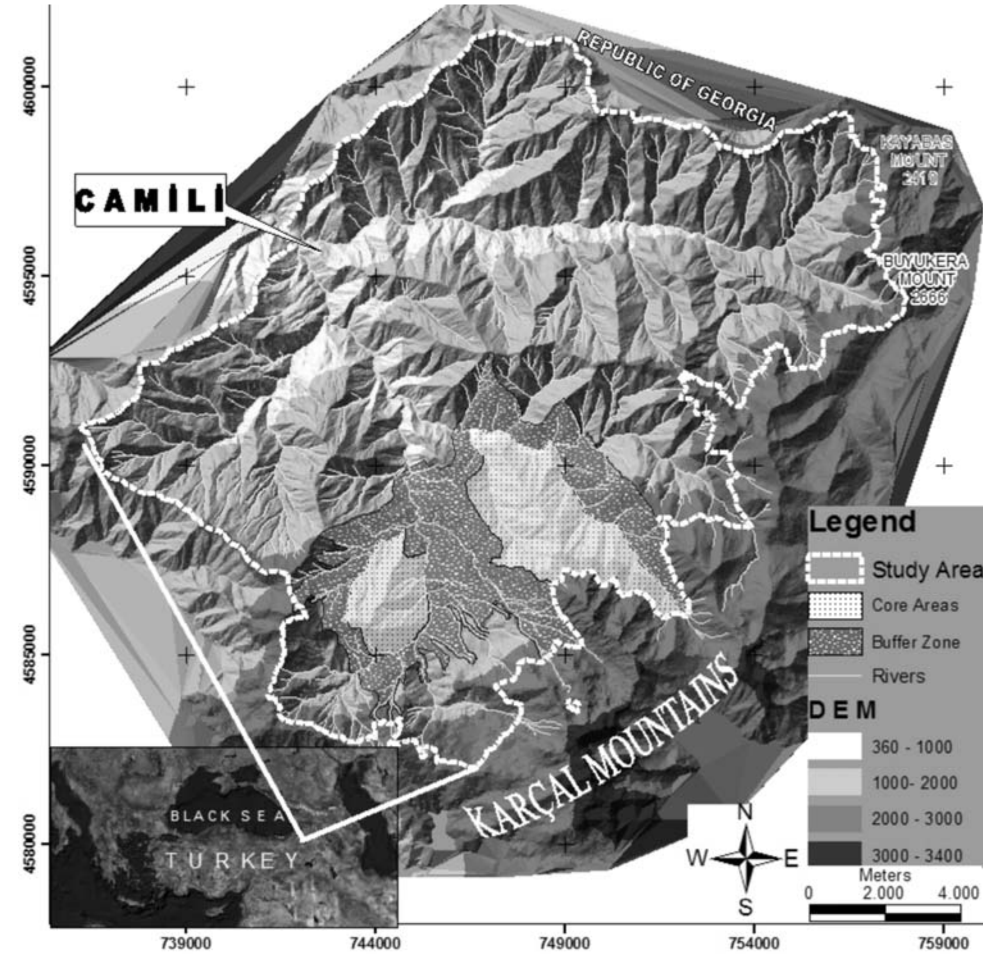

Fig. 1. Map of the study area indicated with dotted line.

is 705 mm with an average temperature of 11.9 °C. Local residents are scattered in lower lands in almost all seasons except in summer where they move to upper lands or to plateau higher altitudes of the area.

The CBR is one of the plant biodiversity rich areas in Turkey accommodating many ancient, rare, endangered and endemic plant species (Başkent et al. 2004). The study area is primarily surrounded by Karçal Mountains that is an important plant area (IPA) designated by WWF in 2003 with 77 endemic and 43 rare plant taxa (Özhatay et al. 2003). As well, the study area is included by the regions' last pristine and natural mixed forests. Naturally, the region is seen to be covered by *Picea orientalis* L., *Fagus orientalis* Lipsky, *Castanea sativa* Miller, *Tilia rubra* DC. subsp. *caucasica* (Rupr.) V. Engler, *Abies nordmanniana* (Stev.) Spach subsp. *nordmanniana*, *Alnus glutinosa* (L.) Gaertner subsp. *barbata* (C. A. Meyer) Yalt., *Carpinus betulus* L., *Acer cappadocicum* Gleditsch var. *stenocarpum*Yalt. (endemic), *Quercus petraea* (Mattuschka) Lieb. subsp. *iberica* (Steven ex Bieb.) Krassiln. and *Q. hartwissiana* Stev. The woody understory of this unique forest site is predominantly *Ericaceae* members – together with IUCN threat categories – (*Rhododendron smirnowii* Trautv., endemic, EN), *R. ungernii* Trautv. (rare, VU), *R. caucasicum* Pall., *R. ponticum* L., *R. luteum* Sweet, *Epigaea gaultherioides* (Boiss. & Bal.) Takht. (rare, VU), *Vaccinium arctostaphylos* L. (in Bern list), *V. myrtillus* L. and *V. uliginosum* L. and the other endemics (*Lonicera caucasica* Pallas subsp. *orientalis* (Lam.) Chamb. & Long (LR), *Euonymus latifolius* (L.) Mill. subsp. *cauconis* Coode & Cullen (LR)), relicts (*Quercus pontica* C.Koch. (VU), *Betula medwediewii* Reg.) and rare taxa *Osmanthus decorus* (Boiss. & Balansa) Kasaplıgil (VU), *Salix caucasica* Andersson (VU)).

From plant geographical point of view, study area is located in Colchis sector of Euxine province of Euro-Siberian region.

An international project, supported by Global Environment Facility (GEF) through World Bank, has been conducted in Camili to integrate biodiversity into forest management plans with two other similar sites in Turkey (Başkent et al. 2004). A pioneer biodiversity integrated MUFM plan in Turkey was prepared for the region and has been in effect for a year (Anonymous 2005). The plan has called for an immediate consideration and monitoring of biodiversity as well as public participation in conducting forest management plans.

Database development

The spatial database, developed as part of this study, consisted of forest cover type map and secondary forest succession map. Both maps were derived from the remote sensing data (1/15000 color infrared aerial photographs in 2003 and with 1 m resolution of IKONOS images in 2004) and field survey in 2004. IKONOS images were obtained from the General Directorate of Turkish Forestry and the forest stand map was derived from interpreting aerial photographs, high resolution satellite images and field survey. Statistical procedures accommodated the design of sample points to conduct the field survey and used information technologies such as GIS, RS, GPS and database management system to establish spatial forest information system necessary for mapping and monitoring secondary forest succession. Circular sample plots were generated and distributed over the forest with 300 by 300 m intervals and located with GPS. The spatial database included stand type, crown closure, forest development stages determined based on the diameter of breast height (DBH), age classes and successional stages. Forest cover type map was later digitized and processed using Arc/Info 8.3 GIS with a maximum root mean square (RMS) error under 10 m. Given the initial spatial database, the secondary forest succession obtained from field survey was added to the database to drive the secondary forest succession map in 2004. Forest stand type map of 1985, obtained from the General Directorate of Turkish Forestry, was digitized and processed using Arc/Info (RMS < 15 m) and the spatial database was established. The secondary forest succession values determined in 2004 was added to the database of 1985 dated stand type map. The stand type map of 1985 was then reclassified according to succession values and the forest succession map in 2004 was generated.

Both landscape and class level spatial statistics for each patch and class (based on seral stages) were calculated using FRAGSTATS. As known, these metrics are proxy or indirect measurements of plant biodiversity in a landscape that quantify both composition and spatial configuration of patches. Diversity measures have been used extensively in a variety of ecological applications and gained popularity as measures of plant and also animal species diversity. Among several ones, FRAGSTATS computes three diversity indices, accommodating for both richness and evenness. Richness refers to the number of patch types present while evenness refers to the distribution of area among different types. Richness and evenness generally refer to the compositional and structural components of diversity. For computing diversity by FRAGSTATS, secondary forest succession stages were assumed to be patch types such as nudation, migration, ecesis, competition, reaction and stabilization (class). According to Clements theory, seral stages or secondary succession stages were used as classes in computation with FRAGSTATS.

A patch refers to the adjacent or contiguous areas that have the same stand structure according to a set of defined criteria. Patches were a group of stands belonging to the same successional stage. The adjacent or contiguous stands with the same successional stages were spatially clumped into a patch using the reclassification function of GIS. The computed metrics are;1. Shannon's diversity index (SHDI ≥ 0); 2. Simpson's diversity index ($0 \leq$ SIDI <1); 3. Modified Simpson's diversity index based on Pilelou's (1975) modification of Simpson's diversity index (MSIDI ≥ 0); 4. Shannon's evenness index ($0 \leq$ SHEI ≤ 1); 5. Simpson's evenness index ($0 \leq$ SIEI ≤ 1) and 6. Modified Simpson's evenness index ($0 \leq$ MSIEI ≤ 1).

Determining plant succession

There are a number of approaches used to determine secondary forest succession (Clements 1916; Clements 1936; Davis 1999; Gleason 1926; Watt 1947; Odum 1969; Pickett 1976; Kojima 1981; Pojar et al. 1987). In the present study, secondary forest successional stages were determined according to Clementsian theory. Clements (1916 and 1936) developed a scheme of processes 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). Additionally, 0 value is used to depict water, dam and rocky areas indicating no plant species.

In field survey of 2004, observations and measurements were carried out in each circular sample plot. Forest inventory sample plots were distributed over the research area by 300×300 m intervals in productive forest and evaluated by the experts. The sample plots were taken as 400, 600 and 800 m^2 according to crown closure. Experts generally focused on tree layer in sample plots. The succession in sample plots was recorded with the numbers from 1 through 6, according to Clementsian theory. Therefore, secondary forest succession value for each plot was determined. After completing the field survey and finalizing forest stand type map, secondary forest succession values in sample plots were used to generate secondary forest succession values for each forest stand type according to tree species, crown closure and the development stages. Also, the data from field studies were checked with IKONOS images and aerial photos to further ascertain the successional stages. Given the assigned successional values for each stand, the secondary forest succession map was generated.

The spatial configuration of landscape structure is important as it has important implications to the design and management of forest resources (Baskent et. al. 2000). We used limited number of metrics as proxy to quantify and spatially analyze the changes in spatial structure as demonstrated by Baskent & Jordan (1995a,b) and McGarigal & Marks (1995). Quantification and comparison of the spatial configuration of forest fragments were conducted based on the following set of key landscape metrics selected after reviewing recent studies (Franklin, 2001; Armenteras et al., 2003; Millington et al., 2003; Turner et al., 2003): (a) CA; (b) NP; (c) MPS; (d) PERCLAND; (e) LPI; (f) PD; (g) PSCV; and (h) AWMSI. Brief definitions for the selected metrics are shown below Table 3.

Results and discussion

Conserving plant biodiversity in forest ecosystems is an important task of ecology that requires determining the changes in diversity with secondary forest succession. As such, the results relating to the successional stages in the research area are evaluated according to this presumption.

Monitoring 20-year changes

Succession is a compositional change, usually evident from a few decades to a few centuries (Glenn-Lewin et al. 1992). Over two decades, secondary forest successions of CBR were determined and mapped in 1985 and 2005 (Fig. 2). The results indicated that the forest is developing retrospectively (i.e., back towards the nudation stage). Especially the conifer forest, in its optimum zone, is mainly under detrimental effect of insects without any stable stage in this period. The results showed that stable stage in general, however, declined from 4931.1 ha to 1086.7 ha (77.96%) over the last 20-year time period (Table 1). Totally, 7308.5 ha (33.23%) area decreased, 9314.8 ha (42.36%) stayed unchanged and 5366.7 ha (24.41%) increased in different stages. In

Table 1. Areas of seral stages that were converted from each succession unit in 1985 to each succession unit in 2005.

		2005 year secondary forest succession						
	Seral stages	1	2	3	4	5	6	Total area in 1985
1985 year secondary forest succession	1	934.8	23.9	1.1	378.6	–	–	1338.4
	2	2.8*	187.4	41.7	429.4	–		661.3
	3	–	308.9*	1708.7	577.9	222.3		2817.8
	4	141.9*	786.3*	540.1*	4109.8	3228.1	279.6	9085.8
	5	78.4*	51.1*	51.0*	1039.9*	1751.1	184.1	3155.6
	6	34.7*	82.8*	25.7*	1034.6*	3130.3*	623.0	4931.1
Total area in 2005		1192.6	1440.4	2368.3	7570.2	8331.8	1086.7	21990.0

Table 2. Forest vegetation classification of CBR.

Classification unit	Formation	Representing plant association
I.B.3d(2)	Cold deciduous alluvial forest (regularly flooded)	*Oplismeno undulatifolii-Alnetum barbatae*
I.B.3a	Temperate lowland and submontane broad-leaved cold-deciduous forest	*Fago orientalis-Castaneetum sativae*
I.B.2b	Cold-deciduous broad-leaved forest with evergreen needle-leaved trees	*Piceo orientalis-Fagetum orientalis*
I.A.10c	Evergreen needle-leaved forest with conical crowns	*Sedo stoloniferi-Piceetum orientalis*

the study area, 7308.5 ha (33.24%, sum of the numbers indicated with "*" in Table 1) decreased and 5366.7 ha (24.41%) increased as a whole. Consequently, total 1941.8 ha (8.83%) decreased indicating that the forest has been developing from stable to nudation stage; that is to say retrogressive succession is ongoing in the area (Table 1).

Quantifying landscape structure

As indicated in Table 2, there are four main types of forest formations according to vegetation classification of UNESCO (1973) together with the plant associations according to Braun-Blanquet (1964).

To quantify and understand the spatial configuration of patches (i.e., successional units), Diamond (1975) suggested and illustrated some geometric design principles towards interpreting the meaning or function of reserves in saving species (Fig. 3). For example, larger areas are generally richer because there is generally greater heterogeneity over larger areas than over comparable smaller areas (Diamond 1975; McGarigal & Marks 1994). If it is not possible to have one large reserve in an area with homogeneous habitat, then individual reserves should be as large as possible and located near each other to maximize the potential for dispersion. In the same vein, reserves should be placed equidistant from each other rather than linearly, and, whenever possible, should be connected by corridors of the same habitat (Diamond 1975).

Spatial structure of forest landscape (i.e., spatial configuration) was quantified with a number of landscape metrics (Table 3) using FRAGSTATS that helped perform spatial analyses. Change of spatial structure of secondary forest succession in CBR was quantified between 1985 and 2005. A quick look with the computed diversity indices (SHDI, SIDI, MSIDI, SHEI, SIEI and MSIEI) in 1985 and 2005 indicated that richness (the compositional components of diversity) and evenness (relative representation of structural components of diversity) decreased in line with retrogressive succession

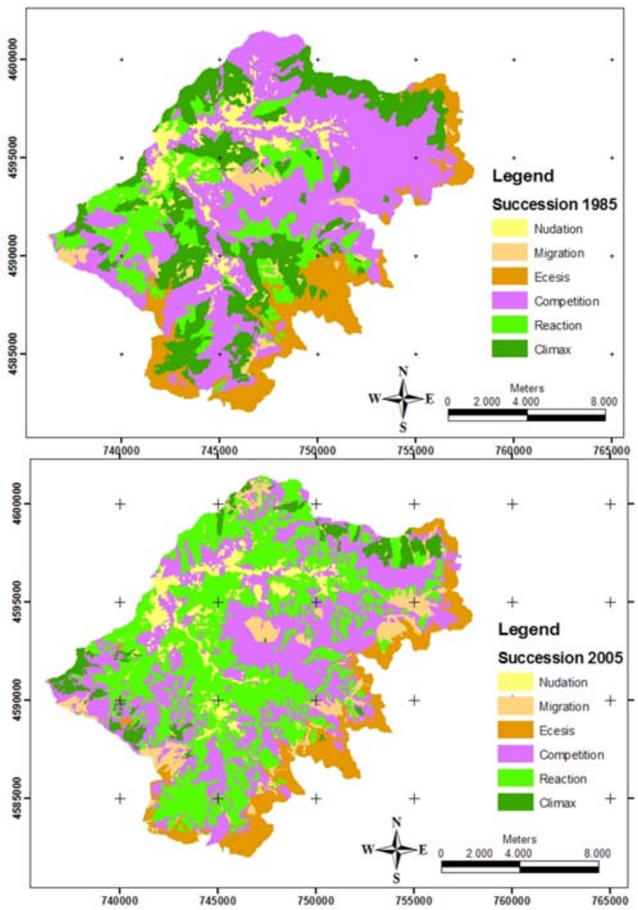

Fig. 2. Maps showing the changes of secondary forest successional stages from 1985 to 2005.

Table 3. The landscape metrics used to detect the spatial changes of CBR in 1985 and 2005.

Seral stages	CA		NP		MPS		PERCLAND		LPI		PD		PSCV		AWMSI	
	1985	2005	1985	2005	1985	2005	1985	2005	1985	2005	1985	2005	1985	2005	1985	2005
1	1338.39	1192.64	137	96	9.77	12.42	6.09	5.42	1.55	1.01	0.62	0.44	395.84	269.44	3.52	3.12
2	661.38	1440.46	47	113	14.07	12.75	3.01	6.55	0.91	0.90	0.21	0.51	240.41	276.81	2.30	2.79
3	2817.69	2368.31	13	11	216.75	215.30	12.81	10.77	7.69	3.34	0.06	0.05	217.73	103.80	4.38	3.77
4	9085.85	7570.26	37	130	245.56	58.23	41.32	34.43	24.49	11.83	0.17	0.59	367.16	471.71	5.97	8.43
5	3155.69	8331.60	39	153	80.92	54.45	14.35	37.89	4.73	15.90	0.18	0.70	214.18	583.83	3.37	8.03
6	4931.02	1086.75	34	42	145.03	25.88	22.42	4.94	4.90	0.92	0.15	0.19	178.88	153.59	3.41	2.27
Total	21990.02	21990.02	307	545	71.63	40.35	100.00	100.00	24.49	15.90	1.40	2.48	490.78	546.86	4.56	6.82

SHDI		SIDI		MSIDI		SHEI		SIEI		MSIEI	
1985	2005	1985	2005	1985	2005	1985	2005	1985	2005	1985	2005
1.52	1.46	0.74	0.72	1.34	1.26	0.85	0.81	0.88	0.86	0.75	0.70

CA – Class area (ha); NP – Number of patches (#); MPS – Mean patch size (ha); PERCLAND – Percent of landscape (%); LPI – Largest patch index (%); PD – Patch density ((#/100 ha); PSCV – Patch size coefficient of variation (%); AWMSI – Area-weighted mean shape index; SHDI – Shannon's diversity index; SIDI – Simpson's diversity index; MSIDI – Modified Simpson's diversity index; SHEI – Shannon's evenness index; SIEI – Simpson's evenness index; MSIEI Modified Simpson's evenness index

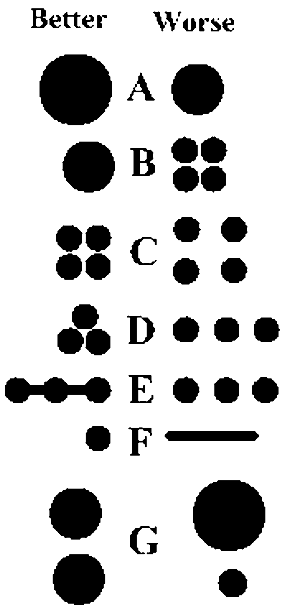

Fig. 3. Diamond's suggested geometric design principles for nature reserves.
Diamond's suggested geometric design principles for nature reserves. Principle A – large is better than small habitat of the same shape; principle B – contiguous is better than dispersed habitat of the same size; principle C – compact is better than dispersed habitat of the same size; principle D – compact is better than unconnected corridor habitat; principle E – connected corridors are better than unconnected corridors; principle F – compact is better than linear habitat of the same size; principle G – dispersed habitat of the similar size is better than dispersed habitat of varying sizes (modified from Diamond 1975).

occurred in the CBR according to FRAGSTATS results.

In CBR, the spatial analysis of the landscape pattern showed that the total number of patches increased from 307 to 545, MPS decreased from 71.63 ha to 40.35 ha and patch density increased from 1.40 to 2.48 during 20–year period. Accordingly, LPI value decreased from 24.49% to 15.90%, and PSCV increased from 490.78 to 546.86, clearly indicating an increased variation of patch sizes. Similarly, AWMSI value increased from 4.56 to 6.82 indicating a more cornered shape with edgy environment. All these changes clearly indicate that the forest landscape has been gradually fragmented (A and B worse), patches are more edgy (F worse), PSCV value increased (G worse), PD value increased (C better), thus subjected to susceptibility of the area to further abrupt changes in the future.

When the successional stages as class are spatial analyzed in detail, area in climax stage sharply decreased with about 4 000 ha (from 22.42% to 4.94% of landscape). The number of patches increased from 34 to 42 and the MPS and LPI value decreased indicating a worse spatial structure (A and B worse). However, the shape value decreased from 3.41 to 2.27, the patch sizes varied less (G better) and patch density increased with a decrease of interpatch distances (C better).

Fifth secondary succession class area increased almost 5200 ha (from 14.35% to 37.89% of landscape). While NP and LPI increased, MPS value decreased indicating an increased fragmentation (B worse). Patch density increased with a more closely related patch (C better). However, the shape of the seral stage was more irregular (AWMSI increased from 3.37 to 8.03, F worse) and the patch sizes distinguishably varied from each other (G worse).

Fourth secondary succession class area decreased almost 1500 ha (from 41.32% to 34.43% of landscape). While NP increased, MPS and LPI value decreased indicating a fragmented structure (A and B worse). However, the shape of the seral stage was more irregular (AWMSI increased from 5.97 to 8.43, F worse) and the patch sizes distinguishably varied from each other (G worse). Patch density increased with a decrease of interpatch distances (C better).

Table 4. Conservation targets and threats to biodiversity in CBR.

No	Conservation Target	Threats to Biodiversity
1	Protection and restoration of old growth forests	– Degradation, fragmentation and loss of habitats
2	Protection of conifer forest	– Insect outbreaks, illegal and/or clear-cutting
3	Protection of alpine zone and improvement of rangeland for animal grazing	– Degradation, fragmentation and loss of habitats – Heavy grazing, roads, erosion and tourism
4	Production and protection of pure natural Caucasian Bee clones	– Genetic pollution, and degradation of genetic structure, production of other bees in the adjacent areas
5	Protection of habitats and establishment of connectivity (habitat corridors) among nature conservation areas	– Fragmentation and loss of habitats and corridors – Deforestation, haphazard road construction
7	Protection of heritage or traditional lifestyle-culture including local architecture	– Ruining the traditional architecture – Degeneration of cultural structure, tourism – Building concrete buildings
8	Provision for ecotourism with the local people	– Lack of education, new concrete buildings – Conflict of interest
9	Encouragement for organic agriculture (maize, bean, honey, parent bee, colonies, hazelnut, medicinal and aromatic plants)	– Use of pesticide and herbicide – Desire to increase the production – Other human activities
10	Protection of threatened plant species	– Degradation, fragmentation and loss of habitats – Alien species such as *Corylus maxima, Ailanthus altissima, Robinia pseudoacacia* and *Conyza albida* – Heavy grazing – Uncontrolled tourism – Collecting of threatened plant species

Third secondary succession class area decreased almost 450 ha (from 12.81% to 10.77% of landscape). Contrary to other stages, number of patches and MPS decreased showing a less fragmented structure (B better). However, the shape value decreased from 4.38 to 3.77, the patch sizes varied less (G better) and patch density increased with a decrease of interpatch distances (C better).

Second secondary succession class areas increased almost 780 ha (from 3.00% to 6.55% of landscape). While NP increased from 47 to 113, MPS value decreased from 14.07 ha to 12.75 ha with a more fragmented structure (B worse). However, the shape of the seral stage was more irregular (F worse) and the patch sizes did considerably varied from each other (G better). Patch density increased with a decrease patch size and distance of patch from each other (C better).

First secondary succession class areas decreased slightly (0.67%). While NP decreased from 137 to 96, MPS value increased from 9.77 ha to 12.42 ha indicating a less fragmented structure (B better). However, more regular shape of the patches was created (F better) and the patch sizes did considerably varied from each other (G better). Patch density increased with an increase patch size and distance of patch from each other (C worse).

Conservation targets and threats to plant biodiversity in CBR

Based on the brief information of plant biodiversity in Camili, it is important to develop conservation targets and reveal the threats to each conservation target for an effective conservation program in forest management plans. The conservation targets and the principal threats for each conservation target in CBR are listed in Table 4. The secondary forest succession maps and the results of the landscape metrics clearly showed that forest fragmentation increased in CBR, the principle threat to plant biodiversity. Secondly, the competitive superiority of exotic plant species in novel habitats makes invasive species one of the largest threats to plant biodiversity (Mooney & Cleland 2001) and so many naturalized plant taxa were recorded from the region (Terzioğlu & Anşin 2001). Protected by beekeepers, members of *Robinia pseudoacacia* L. have been reproduced day by day together with planted *Corylus maxima* Mill. for hazelnut production.

Due to its remote location and close proximity to the international border, CBR has not been logged nor developed for natural or ecotourism. However, unless an effective biodiversity conservation program is carefully integrated within the context of forest management plan or a conservation and rural development program, current plans to harvest timber and construct roads, and to encourage tourism, may constitute an imminent threat to the plant biodiversity and ecological integrity of this important site. Developing strategies to achieve conservation targets and lessen or eliminate the threats, the followings measurements should be taken into consideration:

– Restoration is an indispensable action that should be systematically designed and included in the upcoming forest management plans in Camili, particularly in the fragmented areas,

– An appropriate grazing plan is necessary to prepare and conduct for organized livestock raising in the range land as the biodiversity exists in the transition zones from alpine vegetation to timberlines,

– The network of access roads should carefully be decided by the consensus of the local people.

– Design and conduct coordinated and effective biologic and biotechnical protection plans,

– Develop effective education, training and awareness programs for ecotourism plans and activities to encourage and improve ecotourism. A sound and effective self or auto-control mechanism is desirable to control the activities in the areas. Also, a guideline for visitors needs to be developed to standardize the common actions in the region,

– Develop planned production of pure natural parent bee clones in Camili for pollination,

– Environmental and residential plans are necessary to protect traditional architecture,

– Designate whole watershed as an organic agriculture zone for walnut, hazelnut, cherry, corn, cabbage, and beans like crops and help villages to market these by collaboration of Provincial Agriculture Directorate in Artvin.

Forest management planning and plant biodiversity conservation

The conceptual framework of management generally shapes around the characterization of forest ecosystems, development of management strategies and establishment of management outputs. Specifically, forest resources are quantified to describe the current status of forest structure, planning alternatives are designed to lay out appropriate management prescriptions or actions based on constraints and planning outputs are defined to assess the relative achievement of management objectives to the set targets. Within the concept, management actions should be based on a sound understanding of ecological principles and of the goals established for a forest. Any forest management actions or regulations will change the status of forest ecosystems including forest plant biodiversity thus designing appropriate management actions (i.e., silvicultural prescriptions) to protect and monitor plant biodiversity is crucial. To harmonize the balance between conservation and wood based production is a challenge and must be pursued on a sustainable basis. Here, MUFM is an alternative approach designed to integrate primarily the plant biodiversity conservation into forest management plans. The planning approach focuses on the maintenance of plant biodiversity, productivity, regeneration capacity, vitality and their potential to satisfy ecological, economic and socio-cultural values without jeopardizing the long term stability of forest ecosystems.

The process of plant biodiversity integrated MUFM concept provides new insights in a number of respects. First, MUFM concept utilizes new forest ecosystem inventory process that takes plant biodiversity and other forest values into account. Second, the concept incorporates participation of non-governmental organizations (NGO) and local people along with various institutions crucial in preparing on-the-ground forest management plan. Third, it utilizes various up-to-date information technologies such as GIS, RS, GPS and database management system to establish spatial forest information system necessary for plant biodiversity incorporation. Fourth, management actions are decided based on general consensus reached in a number of various meetings with the major stakeholders. Fifth, management objectives and conservation target are formulated based on both public demand and potential forest values. Finally, forest utilization rates including time and location of silvicultural prescriptions—harvest schedule—are decided with the conservation of plant biodiversity in mind. These improvements provide unique opportunities to integrate plant biodiversity conservation into forest management plans.

Given the framework, a plant biodiversity integrated forest management plan in CBR and across many jurisdictions can be prepared and implemented based on the sequential process of the following activities.

– Conducting ecosystem inventory (i.e., plant biodiversity, forest resources, site condition, capacity, recreation) and creating spatial data base with GIS

– Identifying and finalizing forest values leading to pre-stratification of forest landscape

– Developing the functional relationships between forest structure and plant biodiversity

– Setting forest management objectives and conservation targets as forest outputs

– Awareness and the effective participation of stakeholders

– Developing silvicultural prescriptions as management actions for each conservation target or management objective

– Determining a best management alternative through a decision making technique

– Preparing action plan for each objective (i.e., harvest schedule and grazing plan) and writing the management plan

Conservationists, forest managers and developers would all benefit from the provision of a tool for identifying priority sites as well as development of a comprehensive framework for plant biodiversity conservation in forest ecosystems. As one of the priority sites of Turkey, the forest of CBR is a biologically important ecosystem that has undergone extensive alteration over the past 50 years. Biosphere reserves are protected areas with the following aims: i) protection of the environment/habitat of specific species, ii) promotion of scientific research and environmental education, and iii) improvement of social and economic status of local people to ensure sustainable use of natural resources under traditional patterns of land use. In fact, each biosphere reserve consists of a core area, a strict conservation importance, and a buffer zone. Core areas are strictly protected (no management actions prescribed unless special use is permitted by the scientific authority) and only scientific research and monitoring are allowed. In the buffer zone, natural resource use is generally permitted for subsistence uses and economic gain through exploitation of natural resources is prohibited (Rao et al. 2003). The core area of CBR consists of two natural reserves which cover approximately 1405 ha (6%). Natural reserves have been widely adopted to protect biodiversity/ecodiversity over the world.

In conclusion, secondary forest succession in CBR is retrospectively developing and has been altered dramatically by anthropogenic and insect disturbances, ending up with a potential cause of habitat degradation. Specifically, the proxy landscape metrics indicated that the forest structure is generally fragmented that pose a potential danger for habitat loss and the loss of plant biodiversity. Thus, reevaluating and visiting the efficiency of current natural reserves and implementing the MUFM plans are critical to biological conservation of the ecosystems in the world, particularly in CBR of Artvin, Turkey.

Acknowledgements

We would like to extend our thanks for many foresters working in the General Directorate of Forestry in Turkey for their valuable time and contribution, and specifically to the two forest management team leaders, Kemal Can and Caner Akgül, and their staff members assigned to prepare forest management plans in Camili.

References

Abellán P., Sánchez-Fernández D., Velasco J. & Millán A. 2005. Conservation of freshwater diversity: a comparison of different area selection methods. Biodivers. Conserv. **14:** 3457–3474.

Anonymous 2005. Artvin forest regional directorate, Borçka Forest Enterprise, Management plan of Camili Forest Planning Unit Between 2005–2014.

Bagnaresii U., Giannini R., Grassi G., Minotta G., Paffetti D., Pini-Prato E., Proietti E. & Placidi A.M. 2002. Stand Structure and biodiversity in mixed, uneven-aged coniferous forests in the eastern Alps. Forestry **75 (4):** 357–364.

Başkent E.Z., Köse S., Kaya Z., Altun L., Terzioğlu S. & Başkaya Ş. 2004. Technical Assistance for Development of Strategy Process Design for Effective Incorporation of Biodiversity Conservation into Forest Management Plans in Turkey. Republic of Turkey Biodiversity and Natural Resources Management Project. Grant No: TF-023556–TU. Final report (unpublished). 73 pp.

Başkent E.Z., Köse S., Altun L., Terzioğlu S. & Başkaya Ş. 2005a. Biyolojik Çeşitliliğin Orman Amenajman Planlarıyla Bütünleştirilmesi: GEF Projesi Yansımaları–I (Tasarım), Orman Mühendisliği Dergisi **4,5,6:** 31–37.

Başkent E.Z., Köse S., Altun L., Terzioğlu S. & Başkaya Ş. 2005b. Biyolojik Çeşitliliğin Orman Amenajman Planlarıyla Bütünleştirilmesi: GEF Projesi Yansımaları–II (Yaygınlaştırma Stratejileri). Orman Mühendisliği Dergisi **7,8,9**: 27–33.

Başkent E.Z. & Yolasığmaz H.A. 1999. Forest landscape (ecosystems) management revisited. Environ. Manag. **24(4):** 437–448.

Başkent E.Z. & Jordan J.A. 1995. Characterizing spatial structure of forest landscapes: a hierarchical approach. Can. J. Forest Res. **25(11):** 1830–1849.

Blatt S.E., Crowder A. & Harmsen R. 2005. Secondary succession in two South-eastern Ontario old-fields. Plant Ecology **177:** 25–41.

Braun-Blanquet J. 1964. Pflanzensoziologie. Grundzüge der vegetationskunde, 3rd edn. Springer, Wien, New York, 865 pp.

Cain M.D. & Sheton M.G. 2001. Secondary Forest Succession following reproduction cutting on the Upper Coastal Plain of southeastern Arkansas, USA. Forest Ecol. Manag. **146:** 223–238.

Clements F.E. 1916. Plant Succession. Carnegie Institute Washington Publication. 242. Washington. D.C.

Clements F.E. 1936. Nature and structure of climax. J. Ecol. **24:** 252–284.

Collinge S.K. 2001. Spatial ecology and biological conservation. Biol. Conserv. **100:** 1–2.

Dale V.H., King A.W., Mann L.K., Washington R.A. & McCord R.A. 1999. Assessing land-use impacts on natural resources. Environ. Manag. **22(2):** 203–211.

Davis W.W. 1999. The geographical cycle. Geograph. J. **14:** 481–504.

Diamond J.M. 1975. The island dilemma: Lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. **7(2):** 129–146.

Ejrnæs R. Hansen D.N. & Aude E. 2003. Changing course of secondary succession in abandoned sandy fields. Biol. Conserv. **109:** 343–350.

Forman R.T.T. 1995. Some general principles of landscape and regional ecology. Landsc. Ecol. **10 (3):** 133–142.

Franklin S.E., Connery D.R. & Williams J.A. 1994. Classification of alpine vegetation using Landsat thematic mapper, SPOT HRV, and DEM data. Can. J. Remote Sens. **20:** 49–56.

Fraser R.H., Abuelgasim T.A. & Latifovic R. 2005. A method for detecting large-scale forest cover change using coarse spatial resolution imagery. Remote Sens. Environ. **95:** 414–427.

Freitas S.R., Mello M.C.S. & Cruz C.B.M. 2005. Relationships between forest structure and vegetation indices in Atlantic Rainforest. Forest Ecol. Manag. **218:** 53–362.

Gleason H.A. 1926. The individualistic concept of plant association. Bulletin of the Torrey Botanical Club **53:** 79–89.

Glenn-Lewin D.C., Peet R.K. & Veblen T.T. 1992. Plant Succession– Theory and Prediction. Chapman & Hall, London, 352 pp.

Grau H.R., Arturi H.F., Brown A.D. & Acefiolaza P.G. 1997. Floristic and structural patterns along a chronosequence of secondary forest succession in Argentinean subtropical montane forests. Forest Ecol. Manag. **95:** 161–171.

Harmer R., Peterken P., Kerr G. & Poulton P. 2001. Vegetation changes during 100 years of development of two secondary woodlands on abandoned arable land. Biol. Conserv. **101:** 291–304.

Hoffmeister T.S., Vet L.E.M., Biere A., Holsinger K. & Filser J. 2005. Ecological and evolutionary consequences of biological invasion and habitat fragmentation. Ecosystems **8:** 657–667.

Kojima S. 1981. Biogeoclimatic ecosystem classification and its practical use in forestry. J. College of Liberal Arts **14 (1):** 41–75.

Maclean I.M.D., Hassal M., Boar R.R. & Lake I.R. 2006. Effects of disturbance and habitat loss on papyrus-dwelling passerines. Biol. Conserv. **131:** 349–358.

McGarigal K. & Marks B.J. 1994. Fragstats: Spatial pattern analysis program for quantifying landscape structure. Technical report, version: 2, Forest Science Department, Oregon State University, 141 pp.

Mooney H.A. & Cleland E.E. 2001. The evolutionary impact of invasive species. Proc. Nat. Acad. Sci. USA **98:** 5446–51.

Nagendra H. & Gadgil M. 1999a. Biodiversity assessment at multiple scales: Linking remotely sensed data with field information. Proc Natl. Acad. Sci. USA **96:** 9154–9158.

Nagendra H. & Gadgil M. 1999b. Satellite imagery as a tool for monitoring species diversity: an assessment, J. Appl. Ecol. **36:** 388–397.

Noss R.D. 1987. From plant communities to landscapes in conservation inventories: A look at the nature conservancy (USA). Biol. Conserv. **41:** 11–37.

Noss R.D. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. Forest Ecol. Manag. **115:**135–146.

Odum E.P. 1969. The strategy of ecosystem development. Science **164:** 262–270.

Oppel S. 2005. Long-term changes of a coastal bird breeding community on a small island – does natural succession compromise conservation values? Biodivers. Conserv. **14:** 3407–3422.

Özhatay N., Byfield A. & Atay S. 2003. Important Plant Areas of Turkey. WWF Türkiye, MAS Press. Ýstanbul.

Pax-Lenney M. Woodcock C.E., Maacomber S.A., Gopaal S. & Song C. 2001. Forest mapping with a generalized classified and Landsat TM data. Remote Sens. Environ**. 77 (3):** 241–250.

Pickett S.T.A. 1976. Succession: an evolutionary interpretation. Am. Natur. **110:** 107–109.

Pojar J., Klinka K. & Meidinger D.V. 1987. Biogeoclimatic Ecosystem classification in British Columbia. Forest Ecol. Manag. **22:** 119–154.

Raines G.L. 2002. Description and comparison of geologic maps with FRAGSTATS-a spatial statistics program. Comput. & Geosci. **28:** 169–177.

Rao K.S., Nautiyal S., Maikhuri R.K. & Saxena K.G. 2003. Local Peoples' Knowledge, Aptitude and Perceptions of Planning and Management Issues in Nanda Devi Biosphere Reserve, India. Environ. Manag. **31(2):** 168–181.

Saďd S. 2001. Floristic and life form diversity in post-pasture successions on a Mediterranean island (Corsica). Plant Ecology **162:** 67–76.

Sarmiento L., Llambí L.D., Escalona A. & Marquez N. 2003. Vegetation patterns, regeneration rates and divergence in an old-field succession of the high tropical Andes. Plant Ecology **166:** 63–74.

Saunders D.A., Hobbs R.J. & Margules C.R. 1991. Biological consequences of ecosystem fragmentation – a review. Conserv. Biol. **5:**18–32.

Schriever J.R. & Congalton R.G. 1993. Mapping forest cover in New Hampshire using multitemporal Landsat Thematic Mapper data. ASPRS/ACSM, Ann. Convent. Exposit. **3:** 333–342.

Simberloff D. 1999. The role of science in the preservation of forest biodiversity. Forest Ecol. Manag. **115:** 101–111.

Song C. & Woodcock C.E. 2003. Monitoring forest succession with multitemporal Landsat images: Factors of uncertainty. IEE Transactions on Geoscience and Remote Sensing. **41 (11):** 2557–2567.

Song C. & Woodcock C.E. 2002. The spatial manifestation of forest succession in optical imagery the potential of multiresolution imagery. Remote Sens. Environ. **82:** 271–284.

Temple A.S. 1985. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. In: Verner M.L & Ralph C.J. (eds), Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates, Madison, Wisconson. Wisconsin Press, Madison, Wisconson, pp. 301–304.

Terzioğlu S. & Anşin R. 2001. A chorological study on the taxa naturalized in the Eastern Black Sea Region. Tr. J. of Agric. and Forest. **25:** 305–309.

Treitz P.M., Howerth P.J., Shuffling R.C. & Smith P. 1992. Application of detailed ground information to vegetation mapping with high spatial resolution digital imagery. Remote Sens. Environ. **42:** 65–82.

UNESCO 2005. Twenty-three New Biosphere Reserves Added to UNESCO's Man and the Biosphere (MAB) Network, www.unesco.org/mab, press release no: 2005–76.

UNESCO 1973. International classification and mapping of vegetation. Paris, 93 pp.

Urban D.L., O'Neill R.V. & Shugart H.H. 1987. Landscape ecology: A hierarchical perspective can help scientist understand spatial patterns. BioScience**37:** 119–127.

Venema H.D., Calamai P.H. & Fieguth P. 2005. Forest structure optimization using evolutionary programming and landscape ecology metrics. Eur. J. of Operational Research **164:** 423–439.

Wang R.W., Yang C.H., Zhao G.F. & Yang JX 2005. Fragmentation Effects on Diversity of Wasp Community and Its Impact on Fig/Fig Wasp Interaction in *Ficus racemosa* L. J. Integrat. Plant Biol. **47(1):** 20–26.

Watt A.S. 1947. Patterns and processes in the plant community. J. Ecology **35:** 1–22.

Whittaker R.J., Willis K.J. & Field R.J. 2001. Scale and species richness: towards a general, hierarchical theory of species diversity. J. Biogeogr. **28:** 453–70.

Wilkie D.S. & Finn J.T. 1996. Remote Sensing Imagery for Natural Resources Monitoring: A Guide for First-Time Users. Columbia University Press, New York.

Wolter P.T., Mladenoff D.J., Host G.E. & Crow T.R. 1995. Improved forest classification in the Northern Lake States using multi-temporal Landsat imagery. Photogramm Eng. Rem. Sens. **61:**1129–1143.

WRI 2000. World Resources 2000–2001 – People and ecosystems: The fraying web of life. World Resources Institute, Washington.

WWF & IUCN 1994. Centres of plant diversity. A guide and strategy for their conservation. Volume 1: Europe. Africa. South West Asia and the Middle East. Cambridge. United Kingdom. IUCN Publication Unit.

Zhuang X.Y. & Corlett R.T. 1997. Forest and forest succession in Hong Kong, China. J. Tropical Ecol. **14:** 857–866.

Zinko U., Seibert J., Dynesius M. & Nilsson C. 2005. Plant species numbers predicted by a topography-based groundwater flow index. Ecosystems **8:** 430–441.

Received September 20, 2008
Accepted January 10, 2009