Chapter 13
Landscape Approaches and GIS for Biodiversity Management

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13.1 Landscape Approaches for Biodiversity Management

Landscape approaches and geographical information systems (GIS) have been playing an increasing role in biogeography and conservation biology over the last decade (Gaston, 2000; Foody, 2008; Gillespie, Foody, Rocchini, Giorgi, & Saatchi, 2008). Within this period, the number of papers using GIS published in the journal Landscape Ecology has roughly doubled (Anderson, 2008). Especially remote-sensing applications have grown in importance within recent years. Remote sensing now routinely provides environmental information ranging from global to local scales, and geographical information systems provide, among other applications, necessary interfaces to store, analyse and visualise spatial data; increased computational capacities triggered even more such applications. In this chapter, we demonstrate how the combination of landscape approaches, remote sensing and GIS aids conservation and management of biodiversity. We therefore summarise six case studies from Dadia National Park (Dadia NP), in north-eastern Greece. The studies aimed at (1) modelling of nesting habitat for a flagship species, (2) evaluation of land-use change, (3) detecting statistical dimensions and spatial patterns of landscape structure, (4) testing the performance of landscape metrics as indicators of biodiversity, (5) developing a GIS approach for a systematic raptor monitoring, and (6) developing a decision-support system to optimise conservation of biodiversity in managed forests.

13.2 Study Area and GIS Data

The study area, the Dadia NP, is situated in the Evros prefecture in north-eastern Greece (Fig. 13.1). Its extent of about 430 km^2 includes two strictly protected core areas covering 73.5 km^2. The mountainous area (altitudes ranging from 20 to 645 m above sea level) is covered by extensive pine (*Pinus brutia, P. nigra*)

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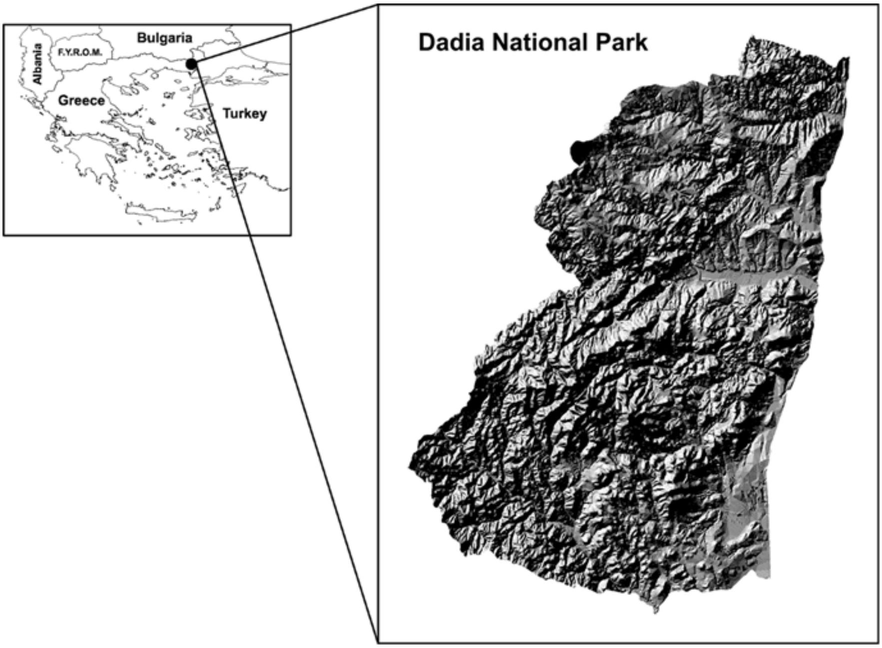

Fig. 13.1 Map of the case study area, Dadia National Park, located in NE Greece

and oak (*Quercus frainetto, Quercus cerris, Quercus pubescens*) forest, but it also includes a variety of other habitats such as pastures, agricultural fields, torrents and stony hills (Catsadorakis & Källander, 2010). Dadia NP is an essential refuge for breeding populations of a unique assemblage of raptors (Poirazidis et al., 1996, 2010a). It contains the only remaining Black Vulture (*Aegypius monachus*) breeding colony in the Balkan Peninsula (Poirazidis, Goutner, Skartsi, & Stamou, 2004; Skartsi, Elorriga, Vasilakis, & Poirazidis, 2008), and a high diversity of passerines (Kati & Sekercioglu, 2006), amphibians and reptiles (Kati, Fofopoulos, Ioannidis, Poirazidis, & Lebrun, 2007), butterflies (Grill & Cleary, 2003), grasshoppers (Kati, Dufrêne, Legakis, Grill, & Lebrun, 2004b), and vascular plants (Kati, Lebrun, Devillers, & Papaioannou, 2000; Korakis et al., 2006).

Satellite images (IKONOS, July 2001, pixel size 1 m) of the study area were digitised to produce a vector map including 14 different habitat types related to the dominant forest tree species and six classes of the percentage of mixed forest. Out of this initial habitat base map, further maps differing in the number of land-cover categories were produced for the case studies.

13.3 Case Study 1 – Modelling Nesting Habitat as a Conservation Tool for the Eurasian Black Vulture

This study[1] formulated habitat models in order to predict the potential nesting habitat of Black Vulture in Dadia NP, a priority breeding species for the area as well as over the rest of the Balkan Peninsula (Skartsi et al., 2008). The aims of this study were (1) to identify crucial determinants of suitable nesting habitat characteristics and (2) to build empirical models for the prediction of nesting habitat. Using logistic regression and 16 environmental variables, separate models regarding geomorphology, vegetation types, and disturbance factors were obtained and combined using Bayesian statistics. At the final stage a Boolean map of the mature forest refined the present suitable nesting habitat (Fig. 13.2). The geomorphology contributed more than all other predictors to the final overall model of a suitable Black Vulture nesting habitat. The nesting preference in areas with steep slopes seems to be adaptive, as such areas provide better foraging opportunities and protection from predators

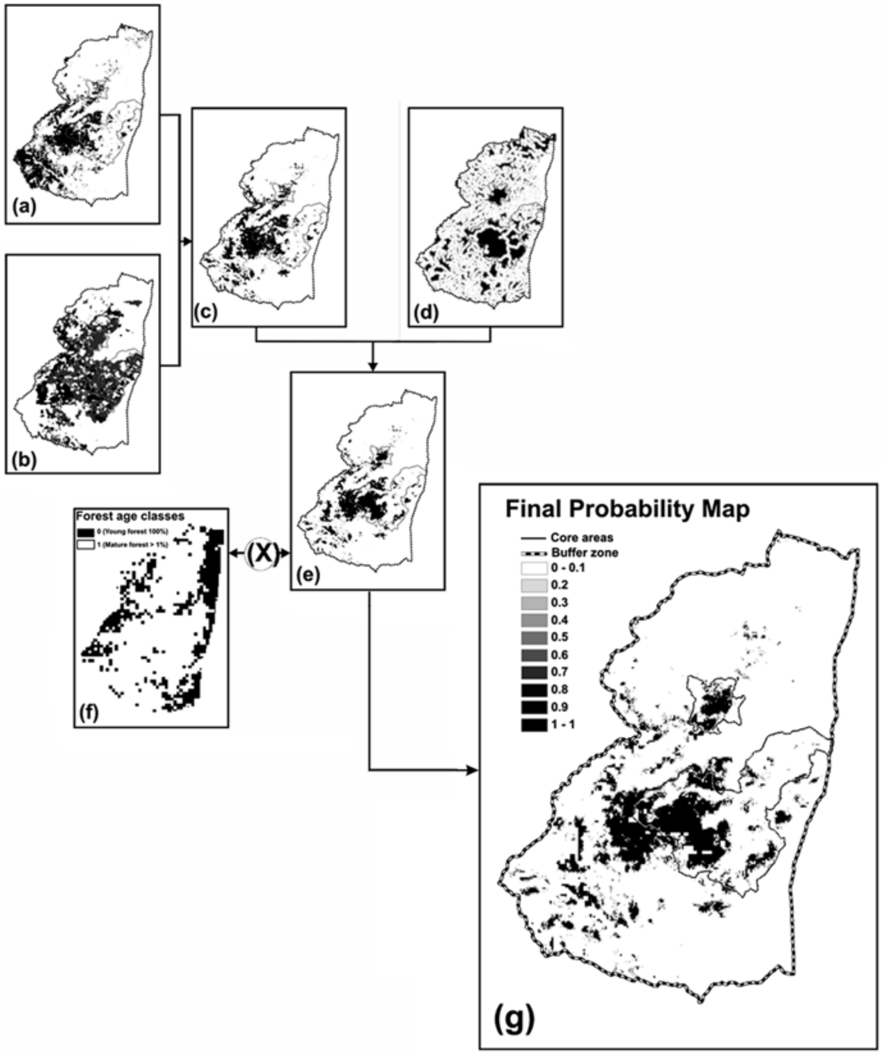

Fig. 13.2 Maps of probability of occurrence for the nest sites of the black vulture[3]

(Hiraldo & Donázar, 1990; Fargallo, Blanco, & Soto-Largo, 1998; Donázar, Blanco, Hiraldo, Soto-Largo, & Oria, 2002). The results of this study were used to improve Black Vulture Monitoring, forest management and the zonation of the National Park.

13.4 Case Study 2 – Forest Re-growth Since 1945 in the Dadia Forest Nature Reserve

In this study,[2] the focus was drawn on the interpretation of aerial photographs and satellite images in order to identify land-use patterns in Dadia NP for 1945, 1973 and 2001, and thus to quantify the land-use changes among these years. The landscape was classified to the three categories forest, openings, and agricultural land, and the most obvious change was a dramatic decline in forest openings (Table 13.1), caused mainly by land abandonment and reforestation programs. During a period of 50 years, the landscape lost part of its characteristic heterogeneity and mosaic-structured character, landscape qualities that are very important for the maintenance of biodiversity of several groups of organisms (Atauri & De Lucio, 2001; Torras, Gil-Tena, & Saura, 2008).

Table 13.1 Land-use change in Dadia National Park from 1945 to 2001

Land use	Zone	1945	1945–1973	1973	1973–2001	2001
		[km^2]	[%]	[km^2]	[%]	[km^2]
Forest	Core area	37.7	+33	50.1	+20	60.2
	Buffer zone	160.5	+15	183.9	+37	251.2
	Total area	198.2	+18	234.0	+33	312.6
Openings	Core area	33.3	–40	20.1	–50	10.1
	Buffer zone	119.4	–27	87.0	–67	28.6
	Total area	152.7	–30	107.1	–64	38.7
Agricultural land	Core area	1.9	+43	2.7	–40	1.6
	Buffer zone	76.4	+12	85.4	–21	67.2
	Total area	78.3	+13	88.1	–22	69.0

13.5 Case Study 3 – Towards a Core Set of Landscape Metrics for Biodiversity Assessments: A Case Study from Dadia National Park

Landscape metrics in the GIS environment can be used to facilitate the investigation of the relation between landscape structure and biodiversity (Hill & Curran, 2003; Honnay, Piessense, & Landuy, 2003). Data reduction analyses have been applied to tackle the problem of highly correlated indices (Riitters, Neill, & Hunsaker, 1995; Cushman, McGarigal, & Vell, 2008), but valid landscape predictors for fine-scale Mediterranean forest-mosaics have been missing. In this study,[4] we used a wide array of related variables of landscape structure, (1) to investigate correlations and statistical dimensions of landscape structure at landscape and class level, (2) to provide a core set of representative variables, (3) to evaluate the stability of the detected dimensions across scales, and (4) to describe the characteristic landscape pattern of Dadia NP. Therefore, we produced a map of nine land-cover categories that we converted to raster format with a grain of 5 m. We used FRAGSTATS (McGarigal & Marks, 1995) for the computation of the 119 landscape metrics investigated in the study and applied correlation analysis and factor analysis, regarding both landscape and class level metrics in a parallel way. Landscape diversity, edge contrast (a measure related to fragmentation) and area-weighted mean patch shape were stable at landscape level across the three tested scales. The representative set of metrics consisted of Simpson's Diversity Index, Mean Edge Contrast Index, and the Area-Weighted Mean Shape Index. The pattern analysis revealed a dispersed pattern for landscape diversity, with high values in the vicinity of the borders between core areas and the buffer zone, and a clustered pattern for edge contrast, presenting a gradient from the unfragmented core areas to the agricultural land in the east of the reserve (Fig. 13.3).

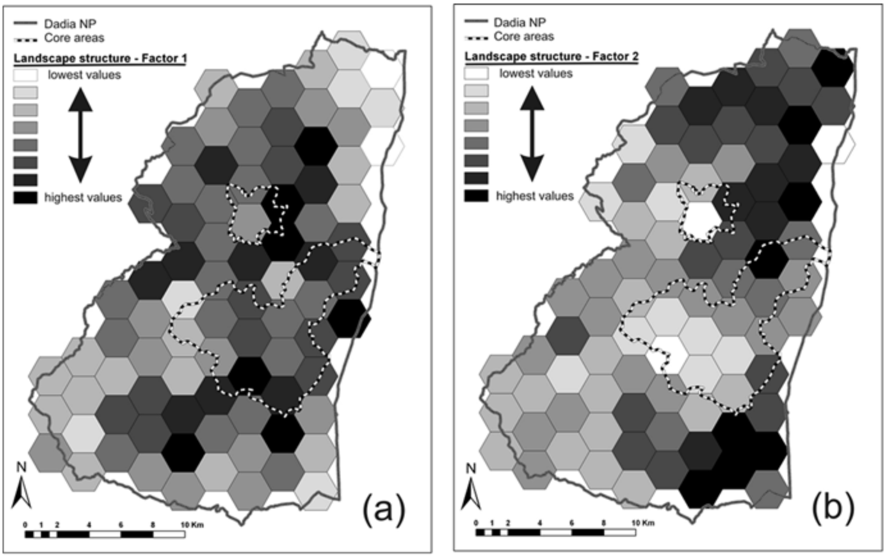

Fig. 13.3 Pattern of the main dimensions of landscape structure in Dadia National Park. (**a**) Landscape diversity (Factor 1) and (**b**) edge contrast (Factor 2)

13.6 Case Study 4 – Testing the Performance of Landscape Metrics as Indicators for Biodiversity

Since only some empirical studies tested the relations between landscape structure and the species diversity of multiple taxa (Hernández-Stefanoni, 2006; Yamaura, Amano, & Katoh, 2008), we tried to fill this gap in this case study.[5] We analysed the relations of 52 landscape structure variables with overall biodiversity and with species richness of the six taxa woody plants, orchids, orthopterans, amphibians, reptiles and birds. Species data were collected by Kati et al. (2004a), based on standard methods; landscape structure variables were computed for circular areas of five different extents around the sampling plots. For each taxon the species richness was modelled with each individual landscape variable at each scale as the predictor, based on a linear mixed model using the software R (R Development Core Team, 2008). Additionally, we tested the performance of sets of three landscape-structure variables as predictors of species richness, using AIC to compare sets composed by different methods such as expert knowledge, several methods of ordination (see previous case study or Schindler, Poirazidis, & Wrbka, 2008), decision trees, random choice, and optimal sets after testing all possible combinations.

In this study, landscape metrics proved to be good indicators of species richness regarding the taxa woody plants, orthopterans, reptiles and for overall biodiversity. Metrics regarding patch shape, proximity, texture and diversity resulted frequently in significant univariate models, while metrics regarding similarity or edge contrast hardly contributed to significant models. Our results revealed that the scale affected the performance of landscape metrics. Woody plants, orthopterans and birds were better predicted at smaller scales, while reptiles were predicted best at larger scales. Regarding the different methods of composing sets, optimal sets performed always significantly better than all other methods. The statistical methods performed slightly better than random choice, while the expert knowledge performed slightly worse than random. The revealed pattern of relations and performances will be useful to understand landscape structure as driver and indicator of biodiversity, and to improve management decisions in Mediterranean forests and similar mosaic landscapes.

13.7 Case Study 5 – Development of a Geographic Information System for Territory Analysis of Raptor Species

Dadia National Park is well known for its high diversity of breeding birds of prey, a community in total exceeding 300 territories (Poirazidis et al., 2010a). An integrated monitoring plan was implemented by WWF – Greece in 1999, aiming at the effective conservation of biodiversity and ecological values of the area. In this case study[6] we describe the development of a GIS approach to estimate the territories of breeding raptors. All raptors within 34 permanent plots were counted and each plot was censused five times during the breeding seasons 2001–2005. Raptor observations were labelled in GIS, showing flight trajectories, possible nest sites, the number of synchronously observed individuals, age, sex, and different territorial activities under different symbols to enable analyses that consider all the information obtained in the field. The progressive analysis per species was based on eight criteria related to territorial behaviour, general observations and biology of the species as well as to landscape features (Poirazidis et al., 2006, 2010c). Breeding territories were differently classified as confirmed or possible. The GIS approach for estimating raptor territories was particularly effective for strictly territorial species like most of the eagles, buzzards, hawks, and falcons (Table 13.2). Less territorial species, such as the Egyptian Vulture (*Neophron percnopterus*) and the Short-toed Eagle (*Circaetus gallicus*) demanded a large amount of data to enable precise territory estimations.

Table 13.2 Summary of the species-specific problems and advantages of the GIS-based methodology for the estimation of raptor population sizes at local scale (values are scaled from 1 = not any to 6 = very high)

Species	Problems with low territoriality	Problems with secretiveness or late arrival	Frequent key observations, high accuracy	Total usefulness GIS method
White-tailed Eagle	4	2	4	4
Golden Eagle	1	2	4	6
Imperial Eagle	2	5	4	4
Lesser spotted Eagle	3	2	5	6
Short-toed Eagle	5	1	4	4
Booted Eagle	2	3	4	5
Egyptian Vulture	6	3	6	5
Common Buzzard	2	1	5	6
Long-legged Buzzard	2	3	5	6
Honey Buzzard	2	5	4	4
Black Kite	6	3	2	3
Marsh Harrier	5	2	2	3
Goshawk	1	4	3	4
Levant Sparrowhawk	2	6	3	3
Sparrowhawk	2	4	3	4
Peregrine Falcon	3	2	5	6
Lanner Falcon	2	2	5	6
Hobby	1	5	3	4
Eurasian Kestrel	1	2	4	6
Black Stork	6	1	4	4

13.8 Case Study 6 – Conservation of Biodiversity in Managed Forests: An Integrated Approach Using Multi-Function Forest Services

In this case study[7] we developed a decision-support system to optimise the conservation of biodiversity in managed forests. We investigated timber production and biodiversity, the main ecosystem services of the Mediterranean forest landscape of Dadia NP. We produced (1) a series of spatially explicit habitat suitability models for higher plants, amphibians, small forest birds and raptors and an overall model for total local biodiversity, (2) maps related to timber production and (3) three management scenarios and a decision-support system based on a conflict assessment. Thus, we were able to establish integrated management concepts, and to assess the effects of different management strategies on the two main ecosystem services.

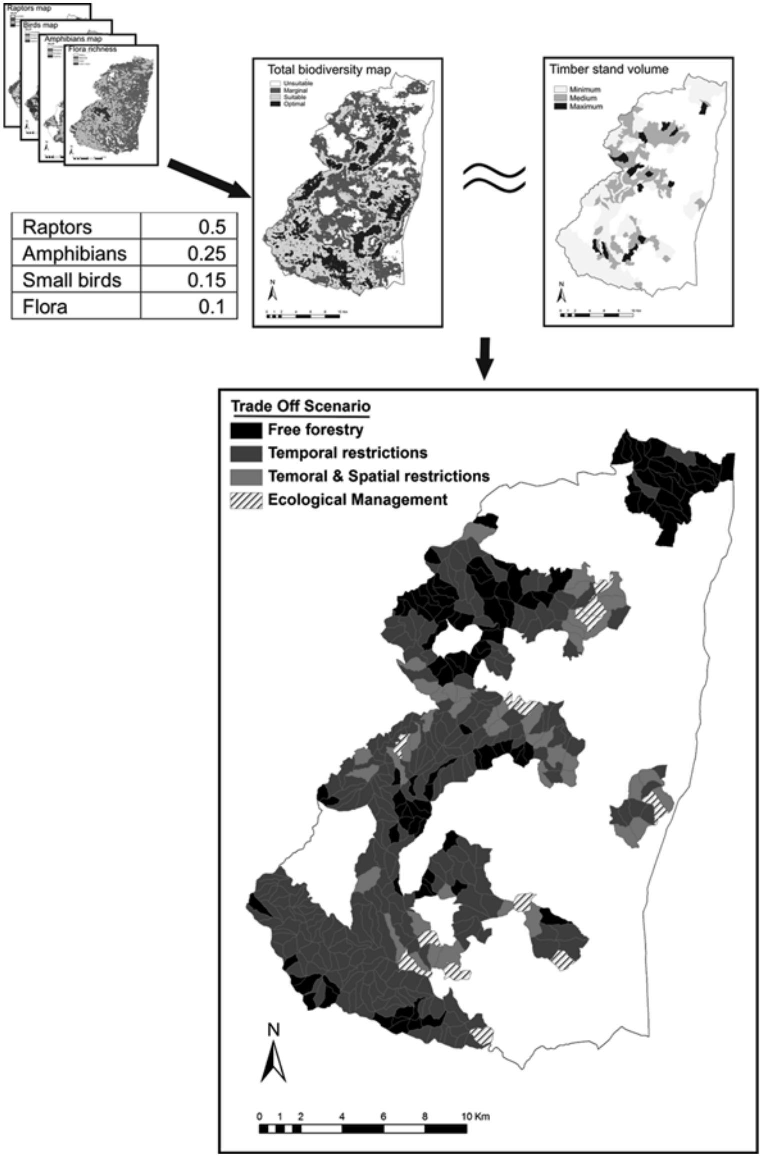

Fig. 13.4 Map of Dadia NP after the trade-off scenario considering conservation of biodiversity and timber production

Spatial modelling was based on data of several systematic field surveys. We used 23 eco-geographical variables to derive predictors for species habitat suitability, and modelled five taxa as surrogates for the total biodiversity in Dadia NP, namely grasses and shrubs (combined later to “higher plants”), amphibians, small forest birds (mainly Passerines) and raptors. For the three groups of fauna we created species distribution maps, while regarding plant species we used the accumulated number of plant species as a proxy of biodiversity. For the raptor data set (Poirazidis et al., 2006) we pooled data from 5 years and plotted the centre of their yearly territories. All the data were converted to a raster grain of 50 × 50 m, and Environmental Niche Factor Analysis (ENFA) was performed within the BIOMAPPER software (version 3.2; Hirzel, Hausser, Chessel, & Perrin, 2002). The total timber standing volume per sub-section was estimated using the official forest service inventory for the current forest management plan 2006–2016. The relative thematic maps were classified into four bins, (1) unsuitable, (2) marginal, (3) suitable and (4) optimal regarding habitat suitability, and (1) minimum, (2) medium, (3) large and (4) maximum regarding timber stand volume. We considered four different forest-management actions at the stand level: management (1) without limitations, (2) with temporal restrictions, (3) with temporal and spatial restrictions and (4) focused on the ecological values. Three general management scenarios were formulated: Conservation, timber production and trade off. A major output was the map of the proposed forest-management categories of the trade-off scenario (Fig. 13.4).

13.9 Conclusions and Implications for Biodiversity Management

Landscape approaches involving GIS and integrated statistical approaches proved to be useful to understand the relations of pattern and changes of landscape structure with the present biodiversity and the habitat suitability for different groups of organisms. This knowledge was essential to establish conservation strategies for biodiversity, for instance regarding the maintenance of habitat heterogeneity in both the core and buffer zone of the reserve (Grill & Cleary, 2003; Kati et al., 2004b; Kati and Sekercioglu, 2006), and for the optimisation of other ecosystem services such as timber production. Habitat suitability modelling for selected groups of organisms to develop management scenarios for managed forests is highly recommendable.

Landscape surveillance should be integrated into the ecological monitoring of key and indicator species to aid the evaluation of the management effects on both forest and wildlife. Further research regarding species, taxa and landscape indicators on a larger scale would be desirable to further extrapolate and validate the models, and enable an even more complete strategy for biodiversity conservation and management.

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Notes

1. This and the following case studies draw upon the already published papers. Thus, for each study we indicate the concrete reference. Study 1 emerges from Poirazidis et al. (2004).
2. Triantakonstantis et al. (2006).
3. (a) A geomorphological model, (b) a vegetation-type model, (c) a model combining a and b, (d) a disturbance model, (e) a model combining c and d, (f) a Boolean map of mature forest, and (g) the final map combining e and f.
4. Schindler et al. (2008).
5. Schindler et al. (2009).
6. Poirazidis et al. (2006, 2009).
7. Poirazidis et al. (2008, 2010b).
8. The managed forests are categorised into the four management options free forestry, temporal restrictions, temporal and spatial restrictions, and ecological management.

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