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Linking processes and pattern of land use change

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Projecting land use change and its effects on endemic birds in the northern Sierra Madre, Philippines

Abstract

Fragmentation of habitat due to human induced land use changes poses an important threat to biodiversity. For conservation management it is important to understand the relation between the landscape and biodiversity and to develop indicators that provide quantitative measures of changes in biodiversity. To take appropriate conservation measures it is also important to make projections of future land use patterns and determine how these patterns can be influenced by policies. This chapter combines landscape-biodiversity relations with land use projections from state of the art land use modelling. The research is carried out in the Philippines, which is a global hotspot of biodiversity. This chapter evaluates the relation between endemic bird species richness and the landscape by taking into account both variables at the location itself as well as landscape characteristics. All variables are derived from a land use map. This facilitates the projection of species richness based on the projected land use maps using the same relations. Scenarios with high and low agricultural expansion were evaluated with two main variants for the level of forest protection. Results show that even with the same total area per land use type, the spatial pattern of the land use types can cause differences in the value of the landscape for bird conservation. Spatial policies like park protection can be used to influence the spatial pattern of land use and therefore the biodiversity. Combining the ecological studies with a land use model has additional value for nature conservation, because the land use models can incorporate the human factor, incorporate the dynamics between different land use types and can create projected maps of future landscapes. In this way one can better assess the implications of different (land use) policy variants for nature conservation.

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6.1 Introduction

Habitat loss due to land use changes such as deforestation, forest fragmentation and agricultural expansion has been identified as an important threat to (avian) biodiversity (e.g. Tilman *et al.* 1994; Turner 1996; Myers *et al.*, 2000; Brooks *et al.* 2002; Sodhi *et al.* 2004; Henle *et al.* 2004). To assess the impact of land use changes on biodiversity it is important to understand the relation between landscape and biodiversity and quantify association between species and habitats (e.g. Buckland and Elston, 1993; Bailey *et al.*, 2002; Dauber *et al.*, 2003). These relations are often described with statistical models (e.g. Buckland and Elston, 1993; Guisan and Zimmerman, 2000; Fazez *et al.*, 2005). Habitat – species relations derived with statistical models can be used to take informed decisions on conservation management (e.g. Bunnell and Huggard, 1999; MacNally *et al.*, 2003; Gibson *et al.*, 2004). However, the actual effect of (conservation) policies on the landscape, and therefore on biodiversity, is difficult to assess based on these statistical relations alone for two reasons. Firstly, changes in land use types are often interdependent (Verburg *et al.*, 2002). A spatial measure at one location will have its influence on land use at other locations. For example habitat protection at one location can divert pressure for agriculture to elsewhere, where it has also an influence on biodiversity. Secondly, landscape metrics are often related in a non-linear way (e.g. Hargis *et al.*, 1998), for example the relation between an increase in habitat and total edge. Therefore, the effect of, for example, an increase in habitat on biodiversity cannot be predicted accurately without expressing the land use changes in a spatially explicit way. Spatially explicit land use models can offer the means to create projections of land use changes in maps based on policies and land use development.

Currently, land use models enable land use scientists to make projections of future landscapes under different scenario conditions (e.g. Briassoulis, 2000; Veldkamp and Lambi 2001) by simulating competition and interactions between land use types in a spatially explicit and temporally dynamic way. If the relation between biodiversity and the environment is known and future landscape maps are available through land use modelling the effect of conservation policies and land use developments on future biodiversity can be assessed more quantitatively, which can be used as a tool for conservation planning and policy decision-making.

The combination of high numbers of endemic species and severe loss of natural habitat causes the Philippines to be one of the most important conservation hotspots for biodiversity in the world (Myers *et al.*, 2000). Past and current land use changes, especially deforestation in the last century (Kummer, 1992; ESSC, 1999), are the major threat to this unique biodiversity (Brooks *et al.*, 2002). The Philippines has 408 resident bird species of which 187 are endemic (Kennedy *et al.*, 2000; WBCP, 2004; IUCN, 2005). Of these 187 endemic bird species 175 (94 %) are forest-dependent; Fifty-three percent of these Philippine endemic forest bird species are threatened or near-threatened (IUCN, 2005), mainly as a result of deforestation (Brooks *et al.*, 1997; Brooks *et al.*, 2002).

When studying the impact of deforestation on birds, total species richness, where all species have equal value, might not be a good indicator of recovery or decline of forest avian biodiversity as forest species are usually replaced by edge or open area species (Johns, 1991; Ghazoul and Hellier 2000). In the case where forest is the natural habitat the number of forest dependent species, or in this chapter endemic forest bird species, provide a much more meaningful indicator that can highlight changes in the conservation value of the area. (In the remainder of the chapter endemic forest bird species are referred to as endemic bird species).

The objective of this study is to evaluate the impact of land use changes and the influence of land use policies under different scenarios on species richness of endemic forest birds in a transition zone from agriculture to forest. Firstly, the relation between landscape properties and the occurrence of endemic bird species is determined for the current situation. This information will then be used to create a map with an index for endemic species richness. Secondly, spatially explicit land use projections will be modelled for three scenarios. The scenarios vary in the implementation of conservation policies and the level of economic and population growth. Thirdly, the changed landscape characteristics are derived from these land use projections and species maps will be created for the scenarios using the relations derived from the present landscape. These projected endemic species maps will be compared with the current situation and amongst each other to determine the possible impact of the different scenario settings on endemic bird occurrence. We will discuss the value of the combination of methods presented for nature conservation management.

6.2 Material and methods

6.2.1 Study area

The study area is located in the municipality of San Mariano, Isabela Province, the Philippines, in the north-eastern part of the island Luzon (Figure 6.1). Part of the study area is situated in the Sierra Madre Mountains, which are covered with one of the largest contiguous areas of forest left in the Philippines and stretches from Quezon province to the northeastern tip of Luzon. The study area covers approximately 48,000 ha. The topography is hilly in the western part and becomes steeper towards the east where the mountain range is situated. At present, the study area has a land use gradient from intensive agriculture, with mainly rice and yellow corn, near San Mariano to a scattered pattern of rice, yellow corn, banana, grasses and trees to residual and primary forest in the eastern part of the study area. Throughout the area remnant forest patches and patches with secondary forest are present. (In this chapter the term secondary forest is used for all low-density forest types such as secondary growth and logged over forest remnants). Altogether this leads to a mosaic landscape with a large variety of land use types.

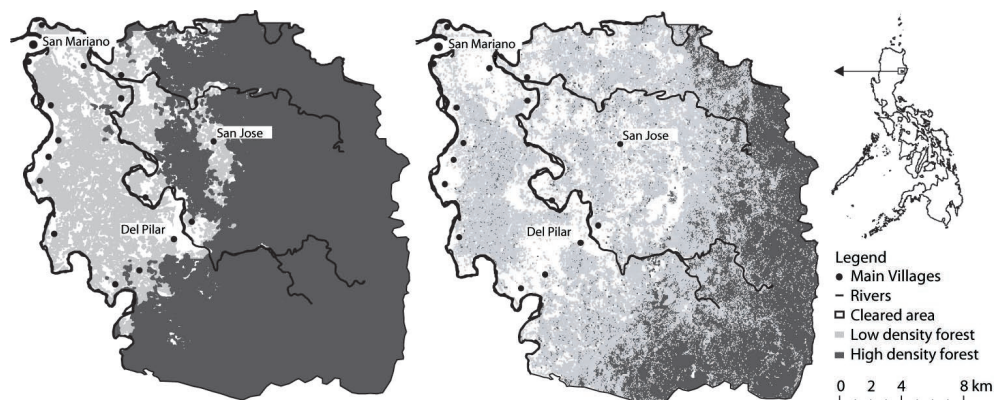


Figure 6.1: Location of the study area in the Philippines and land use maps, with a focus on forested areas, for 1972 and 2001

Before migration started about a century ago the study area was covered with tropical rain forest and few people lived in the area. Currently, most of the area has been cleared and approximately 20,000 people inhabit the area. The main cause of this deforestation in the area is commercial logging, which occurred between 1960 and 1990. Furthermore, small-scale logging and agricultural expansion have caused forest degradation. Figure 6.1 shows the state of the forest in 1972 and 2001. In this period approximately 18,000 ha of natural forest was converted in the study area. About one third of the converted area was completely cleared and two thirds of the original forest is currently residual forest, forest regrowth or extensive banana plantation. Complete clearing of land was mainly caused by farmers who clear land that commercial loggers have logged selectively. Some of the cleared areas are currently grassland. Often, these grasslands are claimed by farmers who keep those lands for their inheritors, but do not have the time to cultivate them at the moment. The grasslands are burned regularly on purpose or accidentally as a result of spreading fire. This burning obstructs regeneration of forest (Snelder, 2001).

Since a logging moratorium was enacted in 1992 commercial logging was abandoned in the area (Persoon and van der Ploeg, 2003). The moratorium made people switch from logging based activities to agriculture. The municipality has projected population growth to be 2.86 per year based on the average growth over the period 1975-1995. This includes immigration from outside the municipality. Though illegal, selective logging still occurs which mainly provides wood for local use and the furniture industry in the region. This small-scale logging, though less extensive than the previous commercial logging operations, poses a threat to the quality of remaining forest as a habitat for forest dependent species. Hunting and the continued removal of remnant forest for agriculture pose additional threats. In 1997, 280,000 ha of remaining forest of the Sierra Madre in Isabela Province were declared a protected area: the Northern Sierra Madre Natural Park (NSMNP). This largest protected area of the Philippines was established to protect remaining forest and associated biodiversity, among which 119 resident lowland forest bird species of which 40 are endemic to the Philippines and 21 are classified as threatened or near-threatened (Van Weerd, 2002). The portion of the NSMNP in San Mariano is, on paper, totally protected but environmental law enforcement is weak or corrupted (Van der Ploeg and Van Weerd, 2004) and illegal logging continues on a large scale (Van Weerd *et al.*, 2004).

6.2.2 Methods

Species richness mapping

To assess the landscape value for avian biodiversity in the study area it is important to determine the relation between habitat and landscape characteristics and endemic species richness. This relation is determined with regression analysis and used to create a predictive endemic species richness map for the entire study area on a 50 by 50 m grid (Gibbs *et al.*, 2004, Luoto *et al.*, 2004). To make projections of future endemic species richness the relations from the regression analysis are applied to the modelled land use maps representing the possible future landscape.

The dependent variable in the regression analysis is the number of endemic bird species which is determined with point counts taken over a period of 15 minutes. This variable is not the absolute number of endemics occurring on a location. Therefore, the predicted values for endemic species richness should be interpreted as an index rather than absolute species richness. The assumption is that the number of endemic species observed in a point

count is proportional to the actual number of endemic species present and their relative abundance. The index is used to quantify the relative differences of endemic bird occurrence between sites and to predict the conservation value of future landscapes for endemic bird species.

The occurrence of species should be studied at multiple levels, because habitat selection of bird species depends on factors at different scales (Atauri and Di Lucio, 2001; Daul *et al.*, 2003; Luoto *et al.*, 2004). Given the extent and the aims of this study we have chosen to identify two scales to explain endemic species richness: local variables, which describe the habitat of the observation point, and landscape characteristics, which describe the structure of the surrounding landscape (Atauri and De Lucio, 2001). The structure of the surrounding landscape, e.g. the diversity and disturbance of the landscape and the proportion of different land use types, are important co-determinants of the occurrence of species (Daube *et al.*, 2003). This study does not go into the details of describing the internal structure of the vegetation. All independent variables are derived from the land use map.

The landscape is considered to be a heterogeneous and dynamic continuum of habitats. Therefore, locations (points or cells) are the unit of analysis and all land use types in the landscape mosaic are considered to be potentially suitable for endemic birds to use as their habitat or to travel through. This is in contrast to approaches that evaluate islands of suitable habitat (e.g. forest) in a sea of absolute hostile matrix (Luoto *et al.*, 2004), without any specification of this matrix. Therefore, fragment size as such was not incorporated as a variable. Instead we considered the proportion of each land use type within distances 250 and 1000m from each location to include the availability of a preferred habitat (land use) in the neighbourhood. This approach enables the assessment of the value of the mixed agriculture-nature landscape for certain species and its use for nature conservation.

In many studies, species richness is related to a multitude of variables including both biotic variables that describe habitat and landscape structure and abiotic variables based on topography, climate, soils type, etc. (e.g. Osborne *et al.*, 2001). In this approach only the biotic variables are used assuming that endemic bird species richness is determined by the different available habitats (land use types) and the spatial pattern of these. The other variables (slope, climate, accessibility, etc) are considered to be determinants of the land use pattern and are used in the land use model to project the future land use map. So, these variables influence bird species richness indirectly through their influence on landscape (land use map).

Because the dependent variable consists of counts Poisson regression is used. Count data has only positive values and Poisson regression can deal with this type of data (Crawley 1993). Analysing count data using standard linear regression is not appropriate because the variance will not be constant and it might predict negative values. Poisson regression accounts for this by assuming a Poisson error structure and using the log link function (Crawley, 1993). Poisson regression is regularly used in ecological applications (e.g. Lob and Martín-Piera, 2002; Mac Nally *et al.*, 2003; Gibson *et al.*, 2004). To select variables to incorporate in the model the variables were tested one by one on their influence on the deviance, which is a relative measure for the goodness-of-fit. In the first step the variable causing the highest change in deviation was included in the model after which the procedure was repeated to select a subsequent variable. The results based on the regression analysis with the point count data are used to construct a predictive map of the index. All independent variables are available in maps and using the loglink function predictions for all cells can be calculated.

Land use modelling

To make projections of land use changes the CLUE-S (Conversion of Land Use and its Effects at Small regional extent) modelling framework was used (Verburg *et al.*, 2002; Verburg and Veldkamp, 2004; Verburg *et al.*, 2004c). This model can dynamically simulate the competition and interactions between land use types. Because of its explicit focus on spatial processes this model is very well suited to produce maps of future land use patterns. The projected land use patterns will form the basis to project future occurrence of endemic birds.

The CLUE-S model consists of an allocation module and a series of inputs (Figure 6.2). The allocation module is a computer program that iteratively computes land use allocation for time step (e.g. a year) for all land use types simultaneously. To allocate land use change in a landscape the model combines a set of mechanisms that are considered to determine the land use system, which are parameterised by the inputs of the model. The total quantity of each land use type in the study area per modelling step, the so-called 'land claim', is not modelled in the allocation module, but is imposed to the model as an input. In this study the land claim was constructed as a scenario study from fictitious story lines. (For more information see Verburg *et al.*, (2002) and Chapter 5)

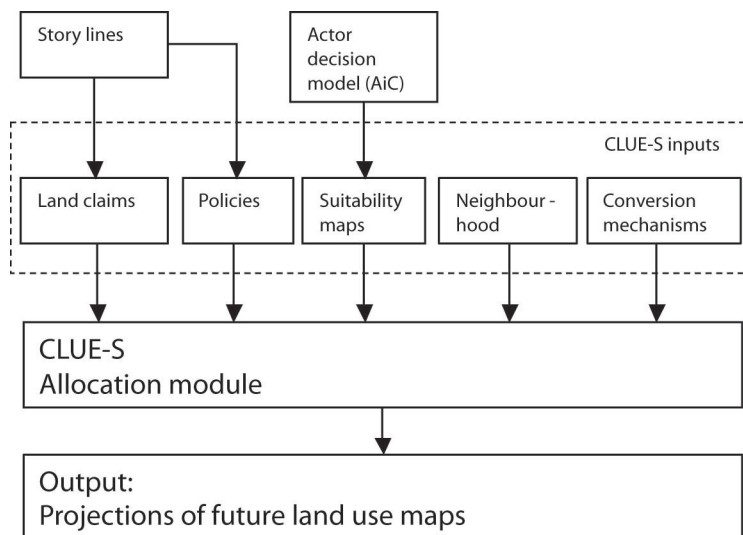


Figure 6.2: Graphical representation of the CLUE-S modelling framework

The mechanisms of land use allocation included in the model can be divided in location mechanisms and conversion mechanisms. The first location mechanism is a 'suitability' based on the relation between land use and a broad set of biophysical and socio-economic factors. The basic assumption behind this mechanism is that a location changes into a certain land use in those locations where the 'suitability' is relatively high for that land use type. The suitability maps are constructed using the Action-in-Context (AiC) framework (De Groot, 1992) as described in Overmars and Verburg (2006) (Chapter 5). The 'deeper analysis' scheme of the AiC framework was used to structure the decision-making process of actors on the basis of their options and motivations and the structural and cultural

context that determines these options and motivation:

The second location characteristic is the neighbourhood effect (Verburg *et al.*, 2004c). The neighbourhood function can mimic spatial processes in land use change that occur between a location and the land use type in its neighbouring cells, for example imitation and dispersion processes. However, this was not studied in detail in this research. Because the cell size of the application is smaller than the average parcel size, a small neighbourhood effect was implemented in the model for all land use types. This simulates the clustering of land use types into fields and patches.

The conversion mechanisms that can be incorporated in the model are the so-called conversion elasticities and land use type specific transition sequences. The conversion mechanisms can be used to assign influence to the land use history and determine the temporal dynamics of the model (Verburg *et al.*, 2002). The conversion elasticities are implemented in the model as an increased suitability on those locations that are currently under that specific land use. Conversion elasticities can be explained as the resistance of a land use type to change location. For example, tree plantations will not easily be moved to another location because of the costs to do so, whereas arable crops can shift quite easily. The conversion elasticities that are incorporated are estimated based on field knowledge of the authors and are partly calibrated.

The transition sequence is a set of rules that determine the possible land use conversions. Not all land use changes are possible and many land use conversions follow a certain sequence. Sometimes these conversions include a temporal constraint and they can also be applied to a specific part of the study area only. The transition rules were used to incorporate the conservation measures of the scenarios in the models. Therefore, the detailed specification of the transition rules was incorporated in the scenarios section.

6.2.3 Data

Fieldwork was carried out between February and May 2004 by two observers working closely together. One was assigned to observe avian biodiversity in forest patches and the other concentrated on the other land use types. According to a stratification of the landscape from intensive agriculture to natural forest a number of study locations was determined and at those locations a total of 193 point counts of fifteen minutes were carried out (Bibby *et al.*, 1992). To check the accuracy of detecting birds with point counts, the point count data was compared with the data from a mist-netting experiment. Per site between 0 and 4.5 percent of the species was only detected with mist-netting (Thijssen, 2005). This showed that the observers missed only few birds with point count observations and the point count data could be used for further analysis. The locations were spaced such that double counting was avoided. For each point count all visually and acoustically detected birds were recorded. The point count location was determined using a GPS receiver. Time and weather conditions were recorded since these might have an influence on the occurrence of birds (Thijssen, 2005). Furthermore, the observers recorded a variety of land use and habitat characteristics. This land use information was actually used to construct the location variables for the regression analysis, because the direct observations have a higher accuracy than the land use map.

The landscape characteristics for analysis were derived from the land use map. For every land use type the percentage of cover was determined within a radius of 250m and 1000m. These measures account for matrix influences and patch size. Patch size itself was not taken

into account. Furthermore, the total edge of forest and secondary forest combined was determined within a radius of 50, 250 and 1000 m. Shannon's diversity index of the surrounding landscape was determined for 50, 250 and 1000 radii (e.g. Daub *et al.*, 2003). All variables are described in Table 6.1

Land use data were interpreted from three remote sensing images: a Landsat ETM+ image (<http://www.landsat.org>) from June 2001, an ASTER image from March 2002 and a SPOT image of July 2001. The first two images were first divided into a large number of classes by unsupervised classification. Subsequently, these classes were reclassified into land use classes using a set of 96 field observations. After this the SPOT image was used to improve the classification of wet rice fields. The classification of banana fields and secondary forest was improved using the NDVI of the SPOT image. Finally, the image was resampled to 50 by 50 m grid that coincides with the other data (Figure 6.4 upper left). The accuracy of this map at the pixel level is 68 percent. A detailed description of the explanatory variables used for the suitability maps of the land use model is in Overmars and Verburg (2006) (Chapter 5).

6.2.4 Scenarios

The land use model is used to make projections of the landscape in maps under different scenario conditions for the period 2001-2015. The scenarios were constructed by combining information from policy documents concerning planning at the village, municipal and regional level, unstructured interviews with local stakeholders and field knowledge of the authors. In this chapter scenario refers to a story line and its quantification to an aggregated land claim that serves as an input for the CLUE-S model. The scenarios are projections of the future rather than predictions or forecasts (Rotman *et al.*, 2000). Quantification of the scenarios is based on interpretations of the storylines by the authors and basic data available to make general calculations. Four scenarios were developed: Scenario 1 assumes high agricultural expansion and scenario 2 a low expansion. For both scenarios two variants (A and B) were developed: one that has low forest protection and one with a high level of forest protection (Figure 6.3). For scenario 2 the two variants led to the same results. Therefore only scenario 2B is described in this chapter.

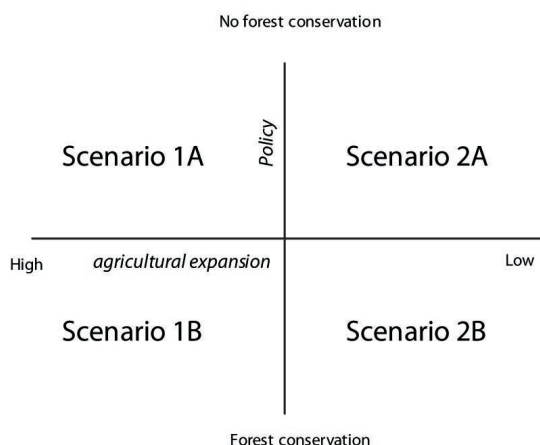


Figure 6.3: Four scenarios based on two levels of agricultural expansion and two levels of forest conservation

Projecting land use change and its effects on endemic bird

Table 6.1: Descriptives of the variables included in the endemic species richness analysis (n = 193)

Variable	Description	Min.	Max.	Mean	St.dev.
<u>Dependent variable</u>					
Endemics	Number of endemic species observed in 15min point count	0	11	1.91	2.46
<u>Independent variables (local)</u>					
Arable	Location has land use type arable	0	1	0.16	
Rice	Location has land use type rice	0	1	0.11	
Banana	Location has land use type banana	0	1	0.04	
Grass	Location has land use type grass	0	1	0.23	
Sec. forest	Location has land use type secondary forest	0	1	0.43	
Forest	Location has land use type forest	0	1	0.03	
<u>Independent variables (landscape characteristics)</u>					
Arable250	Fraction arable within 250m	0.00	0.86	0.36	0.23
Banana250	Fraction banana within 250m	0.00	0.59	0.12	0.12
Grass250	Fraction grass within 250m	0.00	0.77	0.20	0.12
Secondary250	Fraction secondary forest within 250m	0.00	0.70	0.14	0.18
Forest250	Fraction forest within 250m	0.00	0.91	0.09	0.22
Forsec250	Fraction forest and secondary forest within 250m	0.00	1.00	0.23	0.31
Water250	Fraction water within 250m	0.00	0.46	0.03	0.07
Arable1000	Fraction arable within 1000m	0.00	0.71	0.36	0.21
Banana1000	Fraction banana within 1000m	0.00	0.49	0.16	0.13
Grass1000	Fraction grass within 1000m	0.09	0.37	0.20	0.06
Secondary1000	Fraction secondary forest within 1000m	0.00	0.31	0.10	0.09
Forest1000	Fraction forest within 1000m	0.00	0.68	0.10	0.23
Forsec1000	Fraction forest and secondary forest within 1000m	0.00	0.91	0.20	0.29
Water1000	Fraction water within 1000m	0.00	0.20	0.03	0.04
SHDI50	Shannon's diversity index of the landscape within 50m	-0.61	1.54	0.62	0.42
SHDI250	Shannon's diversity index of the landscape within 250m	0.29	1.56	1.12	0.24
SHDI1000	Shannon's diversity index of the landscape within 1000m	0.88	1.72	1.28	0.24
TE50	Total edge within 50 m (km)	0.00	0.50	0.09	0.13
TE250	Total edge within 250 m (km)	0.00	3.20	0.98	0.95
TE1000	Total edge within 1000 m (km)	0.00	35.75	12.80	9.09

Scenario 1A: High agricultural expansion without forest conservation measures

Scenario 1 is a 'business as usual' scenario and projects the continuation of the current situation. Population growth will remain high and is projected to be three percent per year (3%) due to natural growth and in-migration. People in the area will remain highly dependent on agriculture. Out-migration as well as off-farm employment will not increase. The area used for the production of rice and arable combined is assumed to increase with 2.7 percent per year. The production of rice is determined to be self-sufficient for the inhabitants of the study area by 2010. The remaining projected increase in agricultural area will be realized as growth in arable land. Banana area is assumed to decrease yearly by 100 ha, because of problems with marketability and diseases. Forest is projected to decrease by 200 ha per year due to use of small-scale logging. The quantity of secondary forest is stable but dynamic because of clearing and regrowth. The remainder of the area is grassland. The land use claim is depicted in Figure 6.4

No new land use policies are considered in this scenario and those that are present are considered to be ineffective. Thus, in this scenario land use can change without any policy constraints. All land use transitions that are biophysically possible are allowed (Figure 6.5A). Using the land use claim as model input does not control for the modelling of an increase and a decrease simultaneously (e.g. logging and regrowth of forest at different locations), because these cancel each other out. To include the typical land use dynamics the area some land use conversions were forced to occur in the model (Figure 6.5A)

Scenario 1B: High agricultural expansion with forest conservation measures

This scenario has largely the same storyline as scenario 1A and will use the same land claim. The difference between the two scenarios is that in scenario 1B the park boundary will be fully respected, which prevents agriculture and clearing of forest in the park (see Figure 6.5B). This will result in additional pressure outside the park, because all changes to agriculture will be realized outside the park. Furthermore, the forced transition from secondary forest to arable (slash and burn agriculture *kaingin*) was left out of the model to project improved forest management throughout the area.

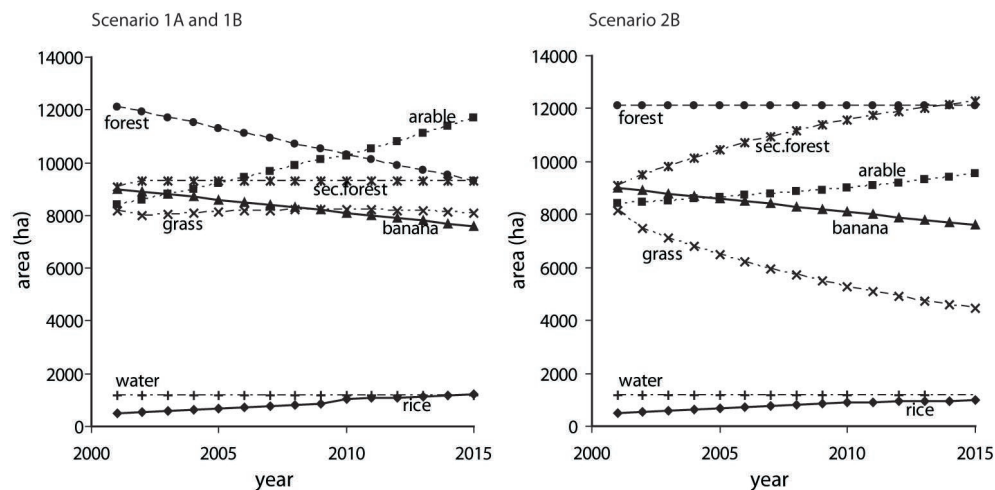


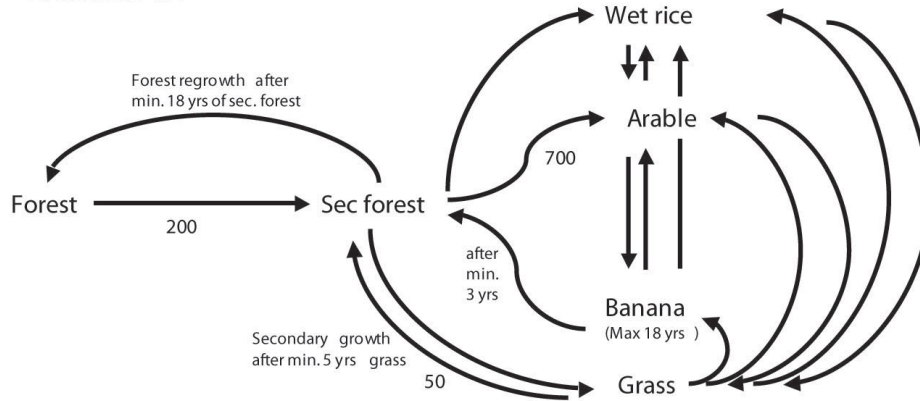
Figure 6.4: Land use claims for the scenarios 1A and 1B (left) and scenario 2B (right).

Scenario 2B: Low agricultural expansion with forest conservation measures

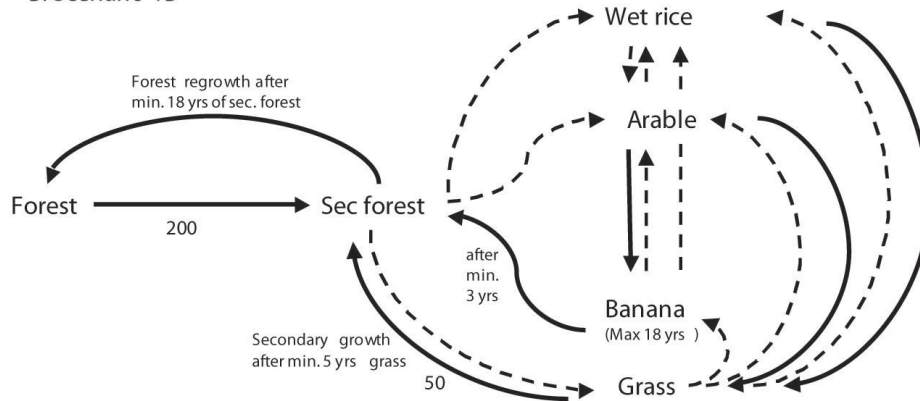
Scenario 2B has a different focus on the economic changes and population development. This scenario describes a situation with less agricultural expansion and improved forest conservation measures. Population growth is projected to be less than the current rate due to population control measures and a stricter immigration policy. People in densely populated areas that have a small piece of land will shift to agricultural systems that are more productive. In general, people become less dependent on agriculture. In scenario 2B total population growth is considered to be 1.5 percent resulting in an increase of the agricultural area with 1.2 percent per year. Like in the other two scenarios, self-sufficiency in rice is accomplished from 2010 onwards and the remaining agricultural growth is in arable crops and banana will decrease with 100 ha per year. In this scenario secondary forest will increase due to significant regrowth of secondary forest on grasslands. This

Projecting land use change and its effects on endemic bird:

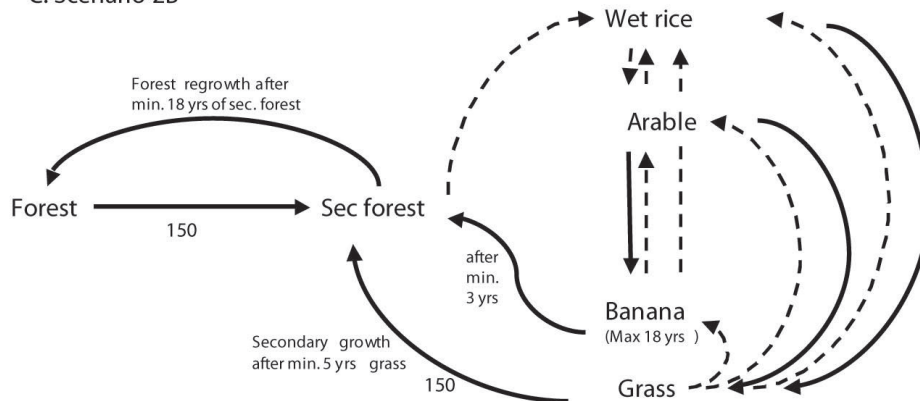
A. Scenario 1A



B. Scenario 1B



C. Scenario 2B



- - Conversion possible in scenarios 1a, 1b and 2
- - - - - Conversion possible outside the park
- 200 - Forced conversions to model land use dynamics (ha)

Figure 6.5A,B,C: Conversion rules included in the CLUE-S model

is possible because this scenario assumes that uncontrolled burning of grassland areas is prevented and that people reforest the grasslands, which is speeding up the regrowth of forest. Secondary forest is assumed to increase proportionally to the amount of grass with an average of 230 ha per year. Grassland makes up the remaining area. The land claim is in Figure 6.2.

As in scenario 1B the park boundary will be fully respected: agriculture is not allowed in the park. Although this scenario is positive for the environment still some illegal logging is included (Figure 6.5C). The area of forest is projected to be stable due to regrowth from secondary into 'mature' forest. Opening up secondary forest for arable agriculture, is strictly prohibited and enforced not only within the park (Scenario 1B), but also in areas under secondary forest outside the park (Figure 6.5C). So, in principle development of new agricultural area is only allowed in the idle grasslands. Conversions from secondary forest to grassland are also prohibited in the model.

6.3 Results

6.3.1 Endemic bird species richness

Statistical relations between landscape characteristics and endemic bird species richness are presented in Table 6.2. The best single predictor was the amount of forest and secondary forest within 250m of the location. The next best predictors were all local variables representing the land use type. The land use variables forest, secondary forest, banana and grass were included. The interpretation of the regression coefficients of the land use variables is therefore relative to the agricultural land use types arable and rice. Including more predictors with the stepwise procedure would result in models with collinearity between variables. The residuals were tested for correlations with observed cloud cover, precipitation and time of observation. These factors might have influenced the observations. However, no correlations between these factors and the residuals were found. To test for overdispersion the ratio of the deviance and the degrees of freedom was calculated. This ratio should be close to 1 (Crawley, 1993; Gibson *et al.*, 2004). If not, the model is overdispersed and the assumption of Poisson errors is not valid. In the model presented this ratio is 1.09, which is relatively low and we consider the assumption of Poisson distributed errors to be justified.

Table 6.2: Poisson regression results

Variables	b	sig.
Intercept	-2.89	0.000
Forsec250	1.43	0.000
Sec. forest	3.52	0.000
Forest	3.62	0.000
Banana	3.64	0.000
Grass	1.82	0.003
dev	177.96	

6.3.2 Land use projections

In Figure 6.6 the land use map of 2001 and the projected land use maps for the three scenarios are depicted. Comparing scenarios 1A and 1B (Figure 6.6 lower left and lower right respectively) it is clear that the inclusion of the restrictions in the nature park influences the spatial distribution of the forested area. The total area per land use type is exactly

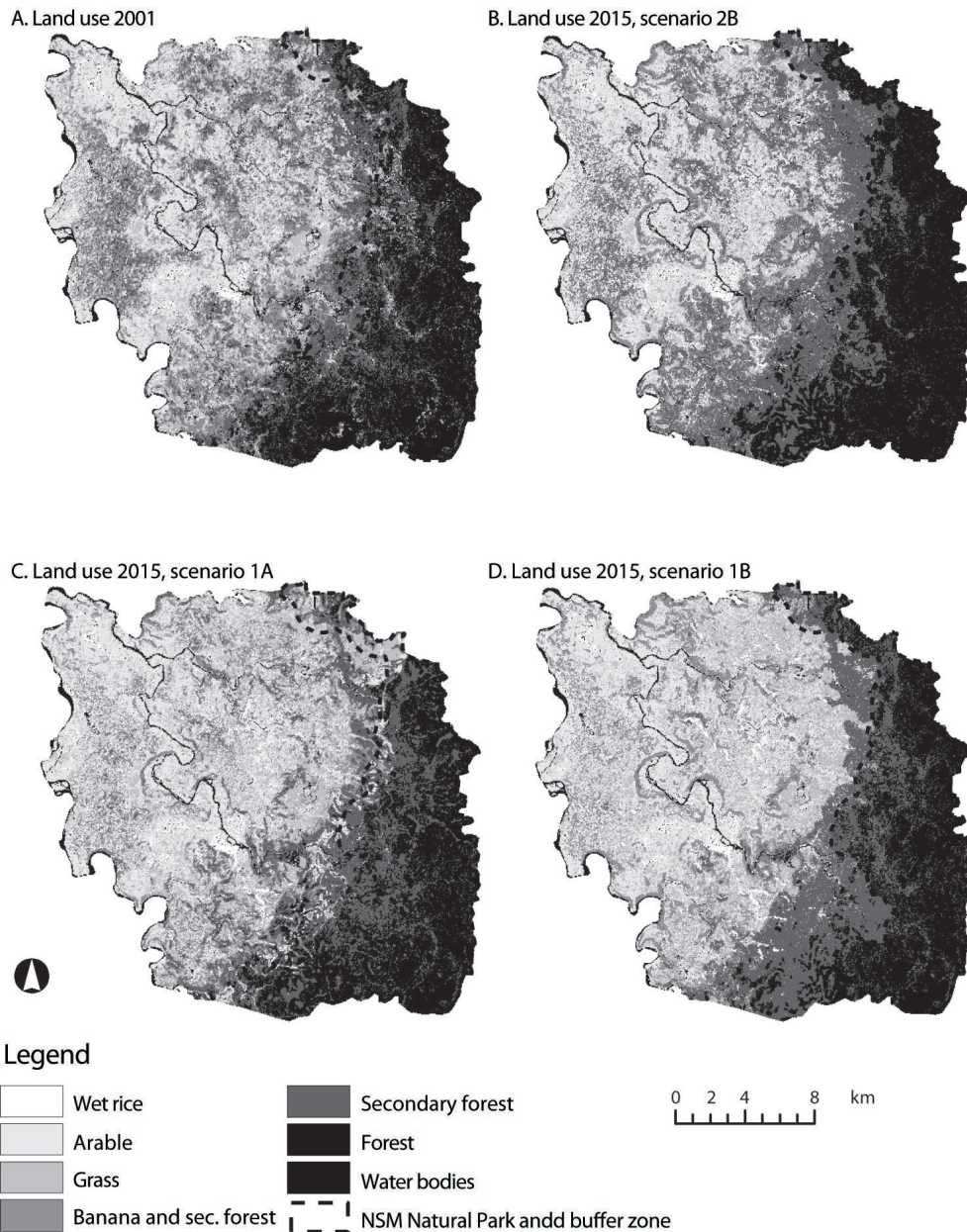


Figure 6.6: Land use map of 2001 and land use projections for the three scenarios

the same in these two scenarios; only the allocation of these land use types is different. Without park policy the northeastern part of the forested area is under threat and the forest edge shows a lot of disturbance. Regarding agriculture both scenarios 1A and 1B clearly show that extending activities in agriculture will occur mainly in the western and central part of the study area. This is caused by the accessibility of the market, but also by the unfavourable physical conditions in the eastern part. In this respect logging is more of a threat to the forest than is expansion of agriculture, although these can go hand in hand. Scenario 1B shows that the park policy diverts the pressure for agricultural use even more to the central and western part. In scenario 1B all secondary forest disappears from this area, whereas in scenario 1A secondary forest patches remain in this area. Scenario 2 shows some intensification of the agricultural areas at the expense of grasslands. Many areas show regeneration of grass to secondary forest. The park is protected and forest in the park is increasing. In the central area in the south some forest is converted to secondary forest, because the scenario includes some illegal logging. On other parts secondary forest turns into 'mature' forest. Both removal of forest by logging and regrowth of forest from secondary forest occur in the model, but the total forest area was projected to be stable. In the net effect is that forest is only changing location.

6.3.3 Avian endemic species projections

Spatial projections of endemic bird richness were created by combining the land use projections with the relations between endemic species richness and the landscape derived through the regression analysis. A map with the endemic species richness index for 2001 is presented in Figure 6.7A. This figure shows that endemic species richness is highest in the eastern part, which is covered with closed forest. In the cultivated landscape in the west and central part of the study area endemic species do occur in secondary forest and banana/secondary forest patches, but at these locations the endemic species richness is lower than in dense forest. To better visualize the differences in endemic species richness between 2001 and the year 2015 for the three scenarios, difference maps are presented instead of the index maps (Figure 6.7B, C and D). Scenario 1A shows a decrease in endemic species richness throughout the area with a larger decrease near the forest fringe. Especially in the northeastern part of the area this scenario projects major land use changes from forest to agriculture and grassland, which has a large impact on the biodiversity on this location. Scenario 1B, including the forest conservation policies, shows a larger decrease of species richness in the cultivated area (west and north in the study area) compared to scenario 1A and less near the forest fringe due to protection of the natural park. Scenario 2B generally shows an increase in species richness, due to the projected regrowth of forest and secondary forest. However, in the south central area a slight decrease of species richness occurs due to some small-scale logging that was projected in this scenario.

The difference maps are useful to make a general assessment of the relative changes in endemic bird species richness in the area. For conservation purposes it can be important to look more specifically to certain group of species or to one species only. The index presented can be used for this purpose. In the case of endemic bird species in this study are the species found in locations with a low index (the western part) are species that are also observed in the areas with a high index. The extra species one will observe in an area with high number of endemic species are not present in areas with a low index. These species are more dependent on a specific habitat (*i.e.* the forest), and may even be threatened, and

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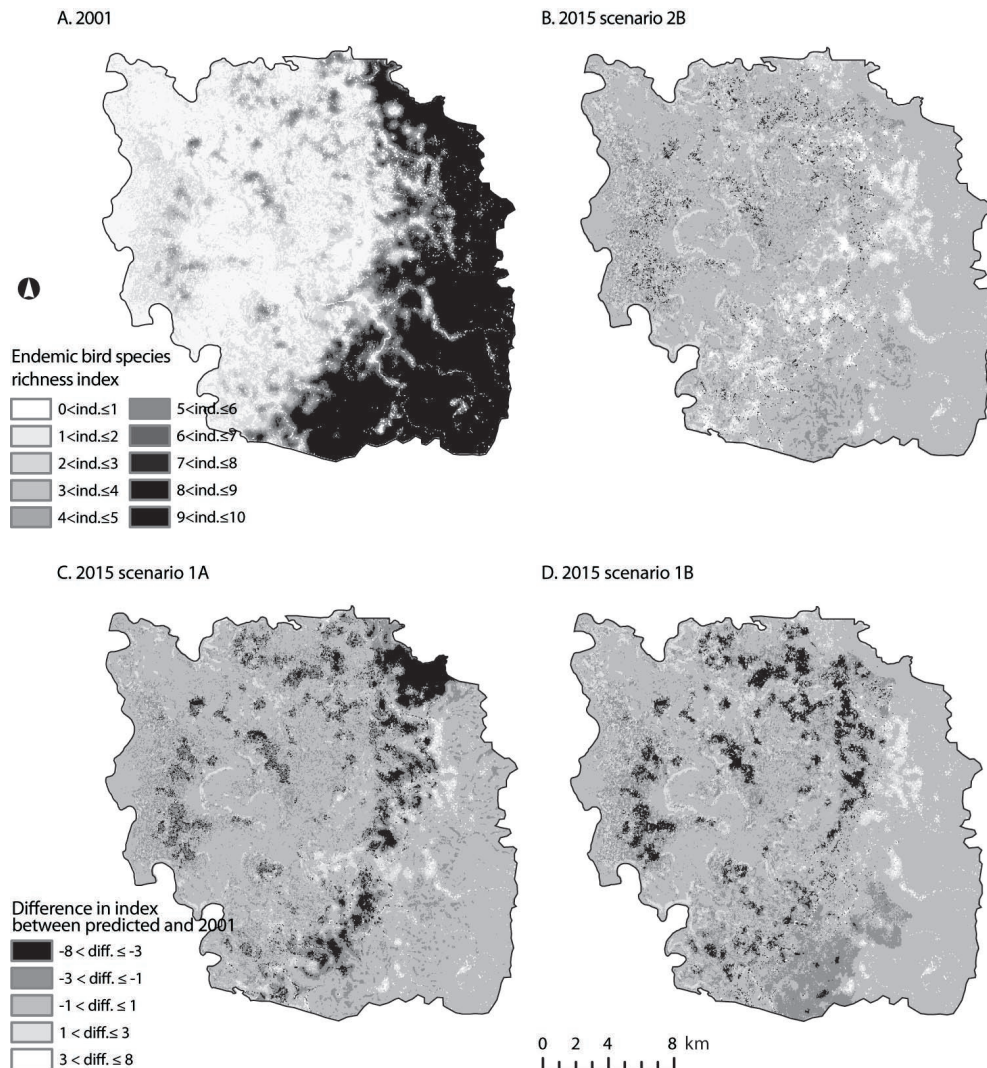


Figure 6.7: Endemic bird richness projection for 2001 and changes for the three scenarios

therefore it is important to conserve landscapes that can support these birds. To assess the effects for the areas with a high number of species the maps were reclassified into areas with index greater than or equal to 6 and with an index less than six. The changes from one category to the other were calculated for the scenarios 1A and 1B (Figure 6.8) as an illustration to analyse the spatial output for a species group of a high conservation importance. This analysis shows that the two scenarios are very different for the change the class with index six and higher. Scenario 1A has a much larger area that changed from class six and higher to less than six than scenario 1B. Even though the total effect looks similar (Figure 6.7C and D), from a conservation perspective it is very important where species loss occurs since this determines which species are lost

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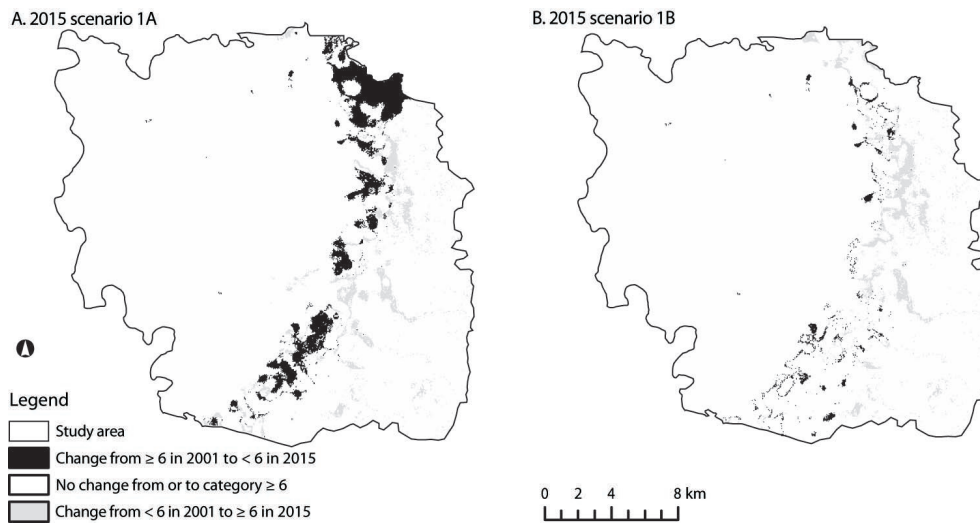


Figure 6.8: Changes from ≥ 6 in 2001 to < 6 in 2015 (black) and vice versa (gray) for scenario 1A and scenario 1B

Table 6.3 shows a summary of the changes for the different scenarios. In this table the increase for species richness is classified into 9 classes to facilitate comparison. The drawback of this table compared to the maps of Figure 6.7 is that it does not reveal shifts in the location of biodiversity. The table provides a net effect per class (Table 6.3A). Considering that the higher classes are more important than the lower classes one can estimate the effect for nature conservation. The effect is even clearer if the areas per class are summed (Table 6.3B) starting at class 8-9. The accumulated areas show what the effect is for the habitats of birds that fall into a specific class under the assumption that birds in a lower class always occur at locations with a higher class *i.e.* a bird that occurs in location with class 3-4 will also occur in classes 2-3, 1-2 and 0-1). For example, the suitable habitat for birds that occur in class 7-8 increases from 13054 to 15672 hectares under scenario 2).

Table 6.3: Area per class of endemic species richness for 2001 and the three scenarios (ha) and accumulated area (starting with class 9) representing the total area per class where the bird species of this class can be found

A. Area (ha per class)					B. Accumulated area (ha)			
Index class	2001	Sc.1A 2015	Sc.1B 2015	Sc.2B 2015	2001	Sc.1A 2015	Sc.1B 2015	Sc.2B 2015
0 < ind. ≤ 1	17970	22148	22157	16111	48416	48416	48416	48416
1 < ind. ≤ 2	335	80	25	97	30446	26268	26259	32305
2 < ind. ≤ 3	7814	7004	6836	5802	30110	26189	26234	32208
3 < ind. ≤ 4	3550	1999	1033	4044	22296	19185	19397	26406
4 < ind. ≤ 5	1707	1496	926	2615	18747	17186	18365	22363
5 < ind. ≤ 6	1706	1434	1224	1958	17040	15690	17439	19748
6 < ind. ≤ 7	2280	1388	2560	2118	15334	14257	16215	17790
7 < ind. ≤ 8	4234	4695	5488	4636	13054	12868	13655	15672
8 < ind. ≤ 9	8820	8173	8167	11036	8820	8173	8167	11036

6.4 Discussion and conclusions

The relation between the occurrence of endemic species and the landscape was explained with a model that incorporates variables of land use (habitat) at the location itself and the fraction of forest and secondary forest within 250 m of the location. Besides the last mentioned relation the analysis did not show any other clear relations between endemic species occurrence and the spatial landscape characteristics. An explanation for this is that a number of spatial landscape characteristics are correlated. Therefore, these variables cannot be included together in the same model because this would introduce collinearity. On the other hand, land use (habitat) itself is an important determinant of species occurrence and already explains a large part of the variability in the occurrence of endemic birds. A number of the landscape characteristics were simply not significant in a model that already included the land use variables. A similar conclusion was drawn by Fairbanks (2004); in this study, though at a much larger scale, also concluded that most relations were explained by land use and spatial metrics played a secondary role.

This study had its focus on a transition zone from intensive agriculture to the forest fringe and the results are valid for that area. In the entire contiguous forest, which is largely outside the study area, a larger number of endemic species occurs (Van Weerd, 2002). A predictive model including more observations in the forest could be quite different, since the forest exhibits also differences in the occurrence of endemic birds. These differences are not shown in this study because the model only includes the forest fringe. However, even from this study it is clear that forest protection is of critical importance to conserve this group of species. The mosaic landscape of agriculture and natural habitat has relatively low contribution to the conservation of endemic forest species in the study area.

In this study one specific indicator was used to create a map of avian biodiversity, but one could think of many others. Examples of alternative approaches are to model total species richness of birds or to model one target species. Another approach is to create specific habitat maps for a number of target species and combine this into one map (Store and Jokimäki, 2003). This approach could also include species from different taxa (Dauber *et al.*, 2003). Others (e.g. Luoto *et al.*, 2004) argue to combine species richness with species distribution models.

It is important to use appropriate indicators in assessing biodiversity in landscapes for policy-making. Conclusions regarding biodiversity can be very different or even opposite for different indicators. Therefore, it is important to choose the right indicator(s) for optimal conservation and land use management. For example, increased habitat diversity will often enlarge the total number of species (Atauri and de Lucio, 2001; Steiner and Koehler, 2000; Luoto *et al.*, 2004), but threatened species might need a completely different landscape, like large patches of forest habitat (Luoto *et al.*, 2004). Furthermore, species from different taxa may even be more different in their preference for habitat and landscape condition. Dauber *et al.* (2003) did not find any correlation between species richness for the three taxa they included in their study.

This study had its focus on endemic species richness of birds because on the one hand it specifies a group of species that is of interest for nature conservation and on the other hand it is more general than having one target species. However, the case study results should be interpreted with care regarding their use to conserve biodiversity in general. The results indicate the effects for endemic bird species richness. To assess the actual impact of management strategies based on this study these policies should also be evaluated for other species.

The land use model used in this study is an appropriate tool to make projections of future landscapes under different scenarios. The strength of the CLUE-S land use model is to allocate a predefined land claim. This land claim is specified outside the model. Thus, the effect of the policy measures on the quantities of land use change is not calculated in the model. In the case of scenario 1A and 1B, with and without forest protection respectively, the total amount of land use changes is the same. The analysis shows solely the effect of a different allocation. Including the effect on the land use claim would require an extra analysis preceding the CLUE-S analysis, in which the change in land claim due to park protection would be determined.

The scenarios are a projection of events that may happen. Many more scenarios could be created according to insights of stakeholders and policy-makers. However, in this respect it is important to realize that this scenario study is not a visualization of plans. In that case maps of the development plans could have been assessed on their value for biodiversity. The scenario study is a visualization of a possible future and assumes that a large part of the land use system functions autonomously and cannot be planned.

The result from this case study shows that forest conservation leads to a different land use pattern and that these differences are relevant for biodiversity conservation. This effect was most prominent in the scenarios 1A and 1B that project a high rate of agricultural expansion. The scenarios 2A and 2B were almost the same because these scenarios did not project high pressure on the (secondary) forest. This scenario study shows that in those areas that are currently under pressure (scenarios 1) conservation policy can result in a more favourable landscape even if the total areas per land use types are the same.

The use of this combined methodology is that it can quantify effects of land use change on biodiversity. Understanding of the land use change process including its human component is important to be able to exert influence to this system and to change its course for benefit of biodiversity conservation (Henle *et al.*, 2004). Land use modelling can visualize the future landscape pattern based on a set of demographic, economic, technological, cultural and policy drivers (Geist and Lambin, 2002) and can incorporate the influence of conservation management policies. The land use modelling approach can identify specific hotspots of land use change; the combination with a biodiversity assessment can identify specific hotspots of biodiversity change. To pinpoint these priority areas it is not only necessary to know where certain species occur, but also if this area is under threat, which can be provided by the land use model. The identification of hotspots can be used to prioritize nature conservation efforts by introducing policies that influence land use changes in the hotspots. The analysis depicted in Figure 6.8 shows that the hotspots of change in biodiversity, which are relevant for nature conservation, can be different from the pattern of land use change, because this is co-determined by the occurrence of certain species.

For nature conservation in practice it is important to translate research results into rules and guidelines for applied research and practical tools (Henle *et al.*, 2004). Coupling of land use models and biodiversity research can be used as a tool to support management decisions in nature conservation in practice. Several applications that couple land use models to biodiversity assessments have been carried out (Menc *et al.*, 2001; Eppink *et al.*, 2004; Jepsen *et al.*, 2005). Eppink *et al.* (2004) and Jepsen *et al.* (2005) provide biodiversity values for the landscape as a whole, but do not present their biodiversity indicators in a spatial explicit way. Menor *et al.* (2001) use a land use model to identify priority areas for nature conservation based on threats to natural habitat and the current protection status.

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The strength of the methodology presented in this chapter is that the land use changes are projected in a dynamic, spatially explicit way including competition of land use and the effects of land use policies and that subsequently these land use changes are translated into changes in biodiversity (for a specific indicator) in a quantitative, spatially explicit way. With this method different conservation policies can be quantitatively evaluated and spatial policies for optimal conservation management can be tailored to the area of interest.