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 chapte 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.

Based on: Overmars, K.P., Van Weerd, M., Prins, M., Thijs, W. Projecting land use change and its effects on enden birds in the northern Sierra Madre, Philippines. Journal of Applied Ecology (Submitted).

6.1 Introduction

Habitat loss due to land use changes such as deforestation, forest fragmentation and agricultural expansion has been identifi ed 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 importar 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 oft en described with statistical models (e.g. Buckland an Elston, 1993; Guisan and Zimmerman, 2000; Fazey *et al*.; 2005). Habitat – species relations derived with statistical models can be used to take informed decisions on conservation management (e.g. Bunnel and Huggard, 1999; MacNally *et al*., 2003; Gibson *et al*., 2004). However, the actual eff ect of (conservation) policies on the landscape, and therefore on biodiversity, is diffi cult to assess based on these statistical relations alone for two reaso Firstly, changes in land use types are oft en interdependent (Verbu *et al*., 2002). A spatia measure at one location will have its infl uence on land use at other locations. For examp habitat protection at one location can divert pressure for agriculture to elsewhere, where it has also an infl uence on biodiversity. Secondly, landscape metrics are oft en related ir non-linear way (e.g. Hargis *et al*., 1998), for example the relation between an increase in habitat and total edge. Therefore, the eff ect of, for example, an increase in habitat on bic versity cannot be predicted accurately without expressing the land use changes in a spa explicit way. Spatially explicit land use models can off er the means to create projections 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 land scapes under diff erent 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 envir ment is known and future landscape maps are available through land use modelling the eff ect 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 biodive sity in the world (Myers *et al*., 2000). Past and current land use changes, especially defor estation in the last century (Kummer, 1992; ESSC, 1999), are the major threat to this uniq biodiversity (Brooks *et al*., 2002). The Philippines has 408 resident bird species of which 1 are endemic (Kennedy *et al*., 2000; WBCP, 2004; IUCN, 2005). Of these 187 endemic bird species 175 (94 %) are forest-dependent; Fift y-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 spe cies have equal value, might not be a good indicator of recovery or decline of forest avia biodiversity as forest species are usually replaced by edge or open area species (Johns, 1 Ghazoul and Hellier 2000). In the case where forest is the natural habitat the number of est dependent species, or in this chapter endemic forest bird species, provide a much mc meaningful indicator that can highlight changes in the conservation value of the area. (I remainder of the chapter endemic forest bird species are referred to as endemic bird spe

The objective of this study is to evaluate the impact of land use changes and the infl uen of land use policies under diff erent scenarios on species richness of endemic forest birds a transition zone from agriculture to forest. Firstly, the relation between landscape prop ties and the occurrence of endemic bird species is determined for the current situation. T information will then be used to create a map with an index for endemic species richnes Secondly, spatially explicit land use projections will be modelled for three scenarios. Th 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 wil be compared with the current situation and amongst each other to determine the possib impact of the diff erent scenario sett ings on endemic bird occurrence. We will discuss th value of the combination of methods presented for nature conservation managemen

6.2 Material and methods

6.2.1 Study area

The study area is located in the municipality of San Mariano, Isabela Province, the Philip pines, 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 con- tiguous 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 topograp is hilly in the western part and becomes steeper towards the east where the mountain ra 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 scatt ered patt ern 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 for 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 a mosaic landscape with a large variety of land use type

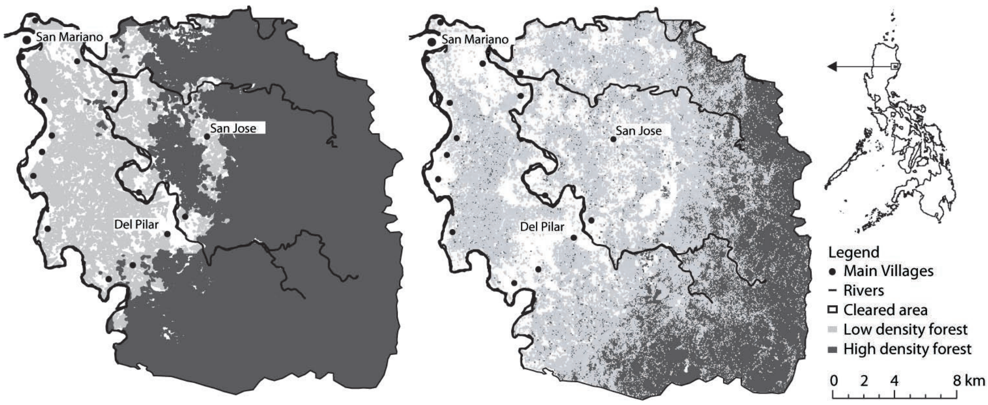

Figure 6.1: Location of the study area in the Philippines and land use maps, with a focus on forested areas, for 1972 and 2001

Before migration started about a century ago the study area was covered with tropical ra forest and few people lived in the area. Currently, most of the area has been cleared and proximately 20,000 people inhabit the area. The main cause of this deforestation in the a is commercial logging, which occurred between 1960 and 1990. Furthermore, small-scale logging and agricultural expansion have caused forest degradation. Figure 6.1 shows th state of the forest in 1972 and 2001. In this period approximately 18,000 ha of natural for 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 farmer who clear land that commercial loggers have logged selectively. Some of the cleared are are currently grassland. Oft en, 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 fi res 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 to switch from logging based activities to agriculture. The municipality has projected population growt 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 s cies. Hunting and the continued removal of remnant forest for agriculture pose additior 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 are endemic to the Philippines and 21 are classifi ed as threatened or near-threatened (V Weerd, 2002). The portion of the NSMNP in San Mariano is, on paper, totally protected environmental law enforcement is weak or corrupted (Van der Ploeg and Van Weerd, 2(and illegal logging continues on a large scale (Van Weer *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 speci richness. This relation is determined with regression analysis and used to create a predic tive endemic species richness map for the entire study area on a 50 by 50 m grid (Gibs *et al.*, 2004, Luotc *et al.*, 2004). To make projections of future endemic species richness the re tions from the regression analysis are applied to the modelled land use maps representi 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 absolu species richness. The assumption is that the number of endemic species observed in a po

count is proportional to the actual number of endemic species present and their relative abundance. The index is used to quantify the relative diff erences of endemic bird occur- rence between sites and to predict the conservation value of future landscapes for ender bird species

The occurrence of species should be studied at multiple levels, because habitat selection of bird species depends on factors at diff erent scales (Atauri and Di Lucio, 2001; Daub *et al*., 2003; Luoto *et al*., 2004). Given the extent and the aims of this study we have chosen t identify two scales to explain endemic species richness: local variables, which describe t habitat of the observation point, and landscape characteristics, which describe the struct of the surrounding landscape (Atauri and De Lucio, 2001). The structure of the surround landscape, e.g. the diversity and disturbance of the landscape and the proportion of diff ent 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 th vegetation. All independent variables are derived from the land use ma

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 suitable habitat (e.g. forest) in a sea of absolute hostile matrix (Luot *et al*., 2004), without any specifi cation of this matrix. Therefore, fragment size as such was not incorporated a 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 mi agriculture-nature landscape for certain species and its use for nature conservatio

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 base 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 diff erent available habitats (land use types) and the spatial patt ern of these. The other variables (slope, climate, accessibility, etc) are considered to be determinants of th land use patt ern and are used in the land use model to project the future land use map. So, these variables infl uence bird species richness indirectly through their infl uence on landscape (land use map)

Because the dependent variable consists of counts Poisson regression is used. Count dat 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 regressio 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 infl uence on the deviance, which is a relative measure for the goodness-of-fi t. In the fi rst step the variab causing the highest change in deviation was included in the model aft er which the pro- cedure 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. A independent variables are available in maps and using the loglink function predictions 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; Verbur *et al*., 2004c). This model can dynamically simulat 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). T allocation module is a computer program that iteratively computes land use allocation p time step (e.g. a year) for all land use types simultaneously. To allocate land use change a landscape the model combines a set of mechanisms that are considered to determine th 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 n modelled in the allocation module, but is imposed to the model as an input. In this stud the land claim was constructed as a scenario study from fictitious story lines. (For more information see Verburg *et al*., (2002) and Chapter 5)

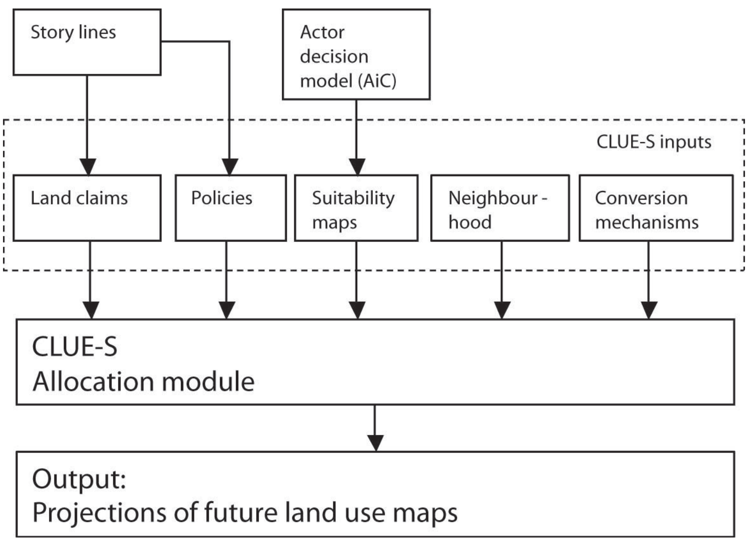

Figure 6.2: Graphical representation of the CLUE-S modelling framework

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-econom 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 u 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 cultura

context that determines these options and motivations.
The second location characteristic is the neighbourhood eff ect (Verbur *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 eff ect was implemented in the model for all land use types. This simulates the clustering land use types into fi elds and patches.
The conversion mechanisms that can be incorporated in the model are the so-called conversion elasticities and land use type specifi c transition sequences. The conversion mechanisms can be used to assign infl uence 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 specifi c land use. Conversion elasticities can be explained as the resistance of land use type to change location. For example, tree plantations will not easily be moved 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 fi eld knowledge 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 specifi c 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 specifi cation 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 stratifi cation 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 fi ft een minutes were ca out (Bibby *et al*., 1992). To check the accuracy of detecting birds with point counts, the po count data was compared with the data from a mistnett ing experiment. Per site between 0 and 4.5 percent of the species was only detected with mist nett ing (Thij s, 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. Tim and weather conditions were recorded since these might have an infl uence on the occurrence of birds (Thij s, 2005). Furthermore, the observers recorded a variety of land use an 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 1000 This measures account for matrix infl uences and patch size. Patch size itself was not tak

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). Al variables are described in Table 6.

Land use data were interpreted from three remote sensing images: a Landsat ETM+ ima (htt p://www.landsat.org) from June 2001, an ASTER image from March 2002 and a SPO image of July 2001. The fi rst two images were fi rst divided into a large number of class by unsupervised classifi cation. Subsequently, these classes were reclassifi ed into land u classes using a set of 96 fi eld observations. Aft er this the SPOT image was used to impr the classifi cation of wet rice fi elds. The classifi cation of banana fi elds and secondary fo 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 o this map at the pixel level is 68 percent. A detailed description of the explanatory variab 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 diff eren scenario conditions for the period 2001-2015. The scenarios were constructed by combining information from policy documents concerning planning at the village, municipal ar regional level, unstructured interviews with local stakeholders and fi eld knowledge of t authors. In this chapter scenario refers to a story line and its quantifi cation to an aggreg land claim that serves as an input for the CLUE-S model. The scenarios are projections o the future rather than predictions or forecasts (Rotmans *et al.*, 2000). Quantifi cation of th scenarios is based on interpretations of the storylines by the authors and basic data avail able to make general calculations. Four scenarios were developed: Scenario 1 assumes h 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 chapte

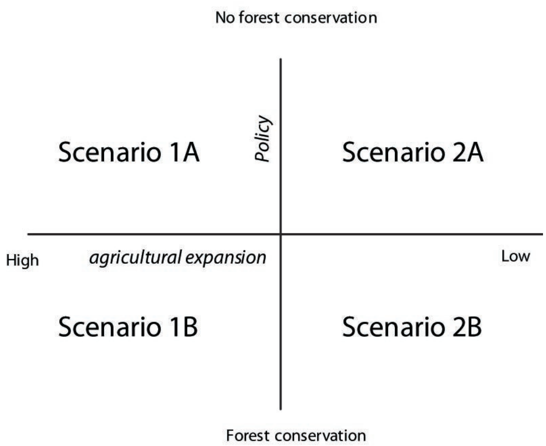

Figure 6.3: Four scenarios based on two levels of agricultural expansion and two levels of forest conservation

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

Variable	Description	Min.	Max.	Mean	St.dev.
Dependent variable					
Endemics	Number of endemic species observed in 15min point count	0	11	1.91	2.46
Independent variables (local)					
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	
Independent variables (landscape characteristics)					
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 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-suffi cient 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 ineff ective. Thus, in this scenario land use can change without any pol 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 diff erent 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 measur
This scenario has largely the same storyline as scenario 1A and will use the same land claim. The diff erence between the two scenarios is that in scenario 1B the park boundar 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 agricultur *kaingin*) was left out of the model t project improved forest management throughout the are

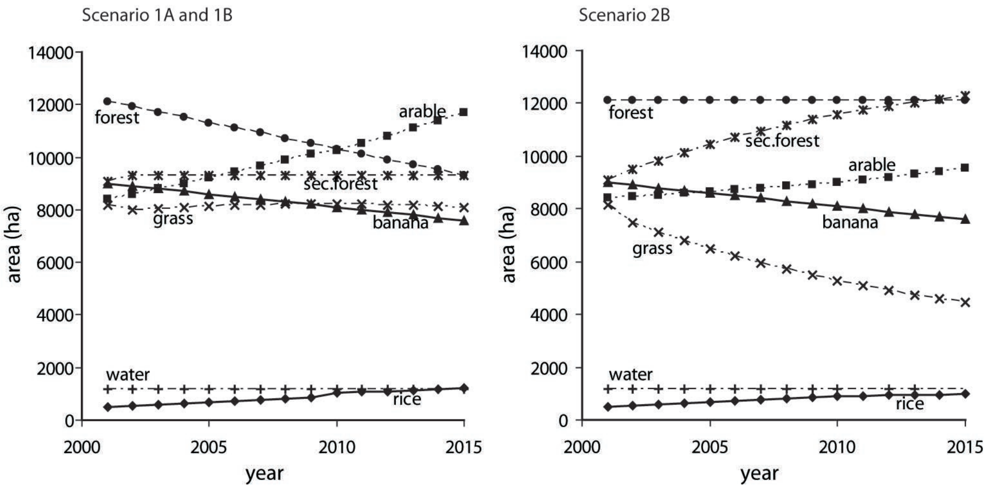

Figure 6.4: Land use claims for the scenarios 1A and 1B (left) and scenario 2B (right

Scenario 2B: Low agricultural expansion with forest conservation measur
Scenario 2B has a diff erent focus on the economic changes and population developmen 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 ar 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-suffi cie 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 signifi cant regrowth of secondary forest on grasslands. This

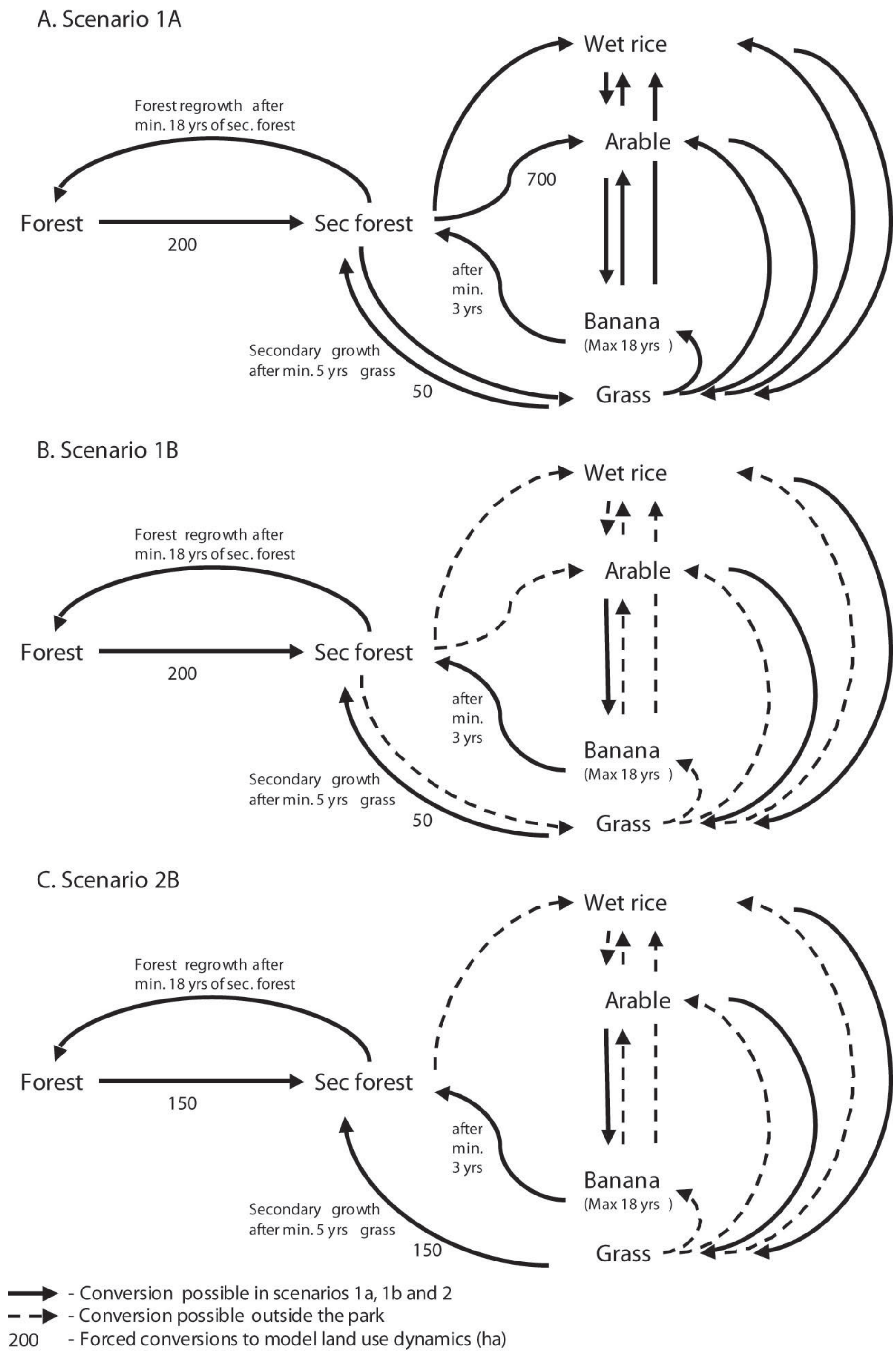

Figure 6.5A,B,C: Conversion rules included in the CLUE-S model

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 wi 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 regrowt 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 are under secondary forest outside the park (Figure 6.5C). So, in principle development of n agricultural area is only allowed in the idle grasslands. Conversions from secondary for to grassland are also prohibited in the mode

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 second ary 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 coeffi cients of the land us 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 infl uenced the observa tions. However, no correlations between these factors and the residuals were foun
To test for overdispersion the ratio of the deviance and the degrees of freedom was calcu lated. 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 present this ratio is 1.09, which is relatively low and we consider the assumption of Poisson dist uted errors to be justifi ec

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 infl uences the spatial distribution of the forested area. The total area per land use type is exactly

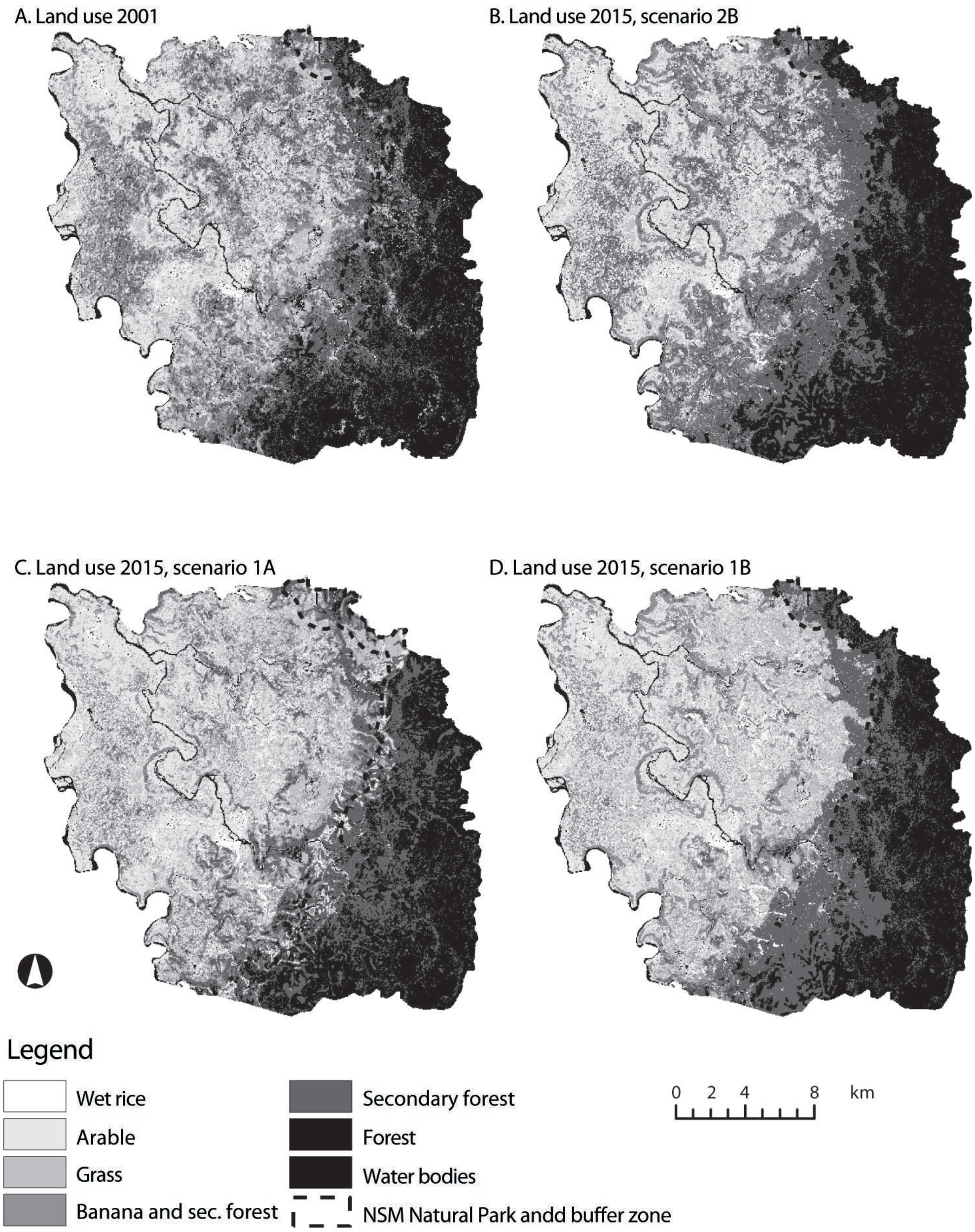

Figure 6.6: Land use map of 2001 and land use projections for the three scenarios

the same in these two scenarios; only the allocation of these land use types is diff erent. 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 anc central part of the study area. This is caused by the accessibility of the market, but also b 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 ev more to the central and western part. In scenario 1B all secondary forest disappears fron this area, whereas in scenario 1B secondary forest patches remain in this area. Scenario 2 shows some intensifi cation 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 second forest, because the scenario includes some illegal logging. On other parts secondary fore turns into 'mature' forest. Both removal of forest by logging and regrowth of forest fron secondary forest occur in the model, but the total forest area was projected to be stable. S the net eff ect is that forest is only changing locatio

6.3.3 Avian endemic species projections

Spatial projections of endemic bird richness were created by combining the land use prc jections 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 fi gure shows that endemic species richness is highest i 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 anc banana/secondary forest patches, but at these locations the endemic species richness is l than in dense forest. To bett er visualize the diff erences in endemic species richness betw 2001 and the year 2015 for the three scenarios, diff erence 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 t northeastern part of the area this scenario projects major land use changes from forest ir 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 specie richness in the cultivated area (west and north in the study area) compared to scenario 1 and less near the forest fringe due to protection of the natural park. Scenario 2B generall shows an increase in species richness, due to the projected regrowth of forest and second ary 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 scenari

The diff erence 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 specifi cally to certain group of species or to one species only. The index pr sented 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 als observed in the areas with a high index. The extra species one will observe in an area wi high number of endemic species are not present areas area with a low index. These spec are more dependent on a specifi c habitat*i.e.* the forest), and may even be threatened, anc

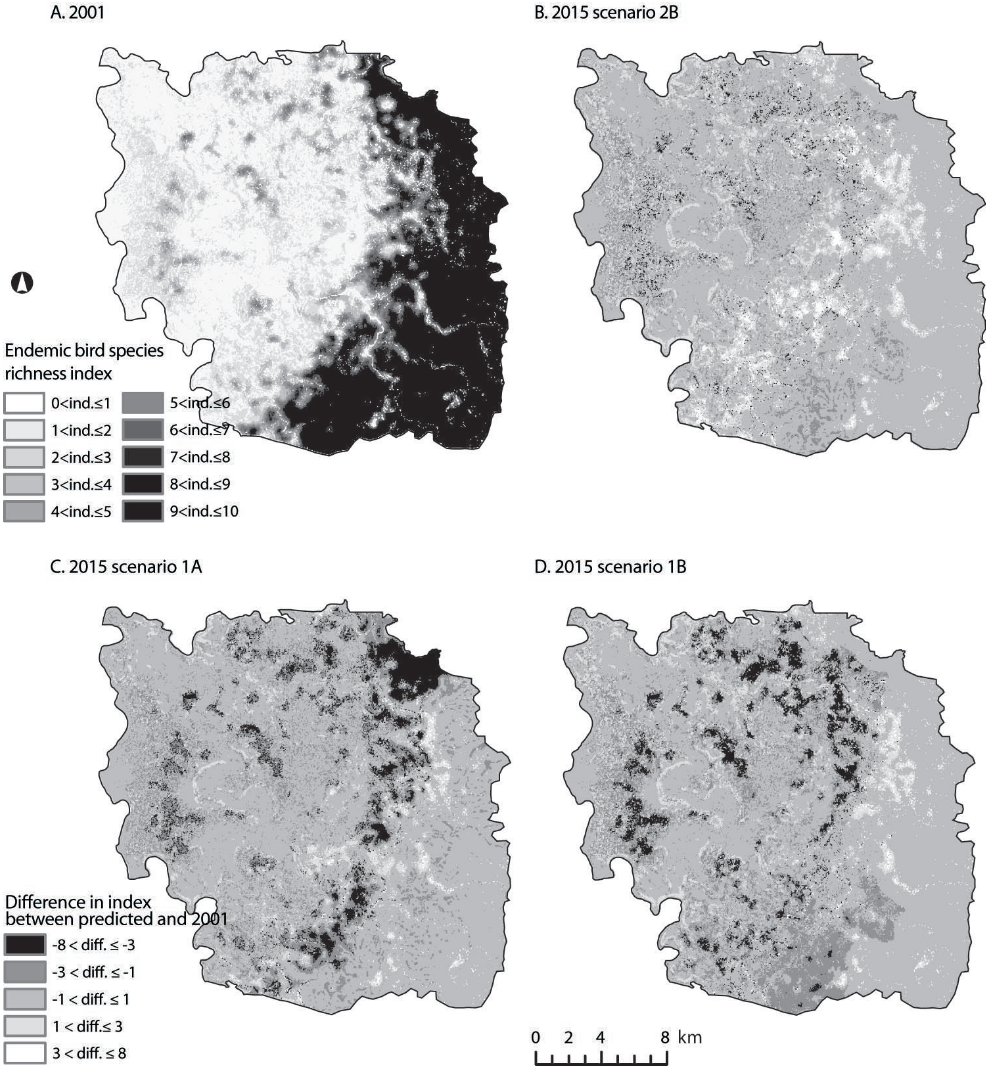

Figure 6.7: Endemic bird richness projection for 2001 and changes for the three scenarios

therefore it is important to conserve landscapes that can support these birds. To assess the eff ects for the areas with a high number of species the maps were reclassifi ed 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 diff erent for the change the class with index six and higher. Scenario 1A has a much larger area that changed fro class six and higher to less than six than scenario 1B. Even though the total eff ect 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 los

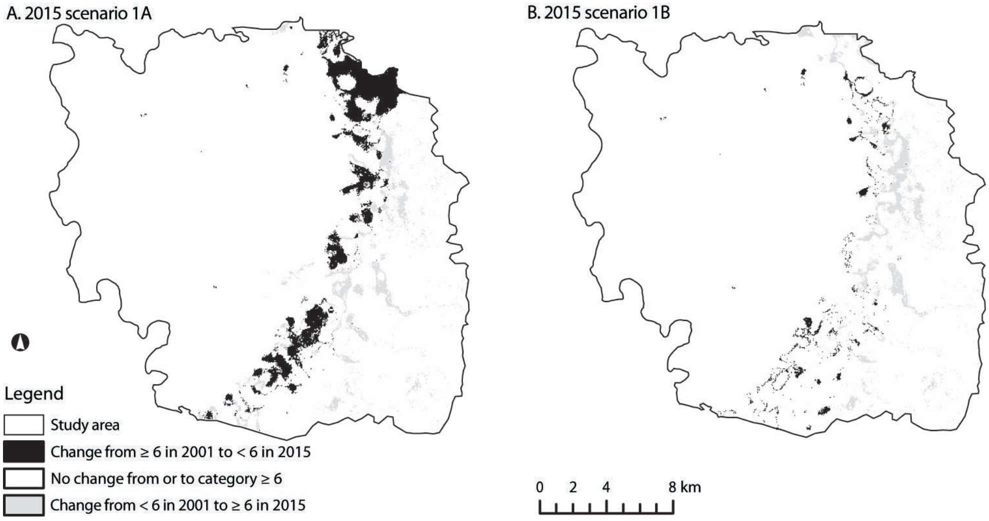

Figure 6.8: Changes from = 6 in 2001 to < 6 in 2015 (black) and vice versa (gray) for scenario 1A and scenario 1B

Table 6.3 shows a summary of the changes for the diff erent scenarios. In this table the ir for species richness is classifi ed into 9 classes to facilitate comparison. The drawback of this table compared to the maps of Figure 6.7 is that does not reveal shift s in the locatio of biodiversity. The table provides a net eff ect per class (Table 6.3A). Considering that t higher classes are more important than the lower classes one can estimate the eff ect for nature conservation. The eff ect is even clearer if the areas per class are summed (Table 6 starting at class 8-9. The accumulated areas show what the eff ect is for the habitats of bi that fall into a specifi c class under the assumption that birds in a lower class always occ at to locations with a higher class *i.e.* a bird that occurs in location with class 3-4 will als 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 to15672 hectares under scenario 2I

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 th 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 explaine 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 th a number of spatial landscape characteristics are correlated. Therefore, these variables ca not be included together in the same model because this would introduce collinearity. C the other hand, land use (habitat) itself is an important determinant of species occurrenc and already explains a large part of the variability in the occurrence of endemic birds. A number of the landscape characteristics were simply not signifi cant in a model that alre included the land use variables. A similar conclusion was drawn by Fairbanks (2004); th study, though at a much larger scale, also concluded that most relations were explained land use and spatial metrics played a secondary rol

This study had its focus on a transition zone from intensive agriculture to the forest frin 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 diff erent, sin the forest exhibits also diff erences in the occurrence of endemic birds. These diff erence not show 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 are

In this study one specifi c indicator was used to create a map of avian biodiversity, but c 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 speci 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 diff erent 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 diff erent or even oppos for diff erent indicators. Therefore, it is important to choose the right indicator(s) for opt conservation and land use management. For example, increased habitat diversity will of enlarge the total number of species (Atauri and de Lucio, 2001; Steiner and Koehler, 200 Luoto *et al.*, 2004), but threatened species might need a completely diff erent landscape, like large patches of forest habitat (Luoto *et al.*, 2004). Furthermore, species from diff eren taxa may even be more diff erent in their preference for habitat and landscape condition Dauber *et al.* (2003) did not fi nd any correlation between species richness for the three ta they included in their study

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

The land use model used in this study is an appropriate tool to make projections of futu 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, t effect of the policy measures on the quantities of land use change is not calculated in th model. In the case of scenario 1A and 1B, with and without forest protection respectivel 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 respe 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 o the land use system functions autonomously and cannot be planne
The result from this case study show that forest conservation leads to a different land u pattern and that these differences are relevant for biodiversity conservation. This effec 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 n 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 sam

The use of this combined methodology is that it can quantify effects of land use change biodiversity. Understanding of the land use change process including its human compo- nent is important to be able to exert influence to this system and to change its course for benefit of biodiversity conservation (Henl *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 c conservation management policies. The land use modelling approach can identify speci hotspots of land use change; the combination with a biodiversity assessment can identif specific hotspots of biodiversity change. To pinpoint these priority areas it is not only n essary to know where certain species occur, but also if this area is under threat, which ca be provided by the land use model. The identification of hotspots can be used to priorit nature conservation efforts by introducing policies that influence land use changes in t hotspots. The analysis depicted in Figure 6.8 shows that the hotspots of change in biodiv sity, which are relevant for nature conservation, can be different from the pattern of lar use change, because this is co-determined by the occurrence of certain specie
For nature conservation in practice it is important is to translate research results into rul 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 fo nature conservation based on threats to natural habitat and the current protection status

The strength of the methodology presented in this chapter is that the land use changes a projected in a dynamic, spatially explicit way including competition of land use and the eff ects of land use policies and that subsequently these land use changes are translated changes in biodiversity (for a specifi c indicator) in a quantitative, spatially explicit way. With this method diff erent conservation policies can be quantitatively evaluated and sp tial policies for optimal conservation management can be tailored to the area of intere