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Modelling the impact of climate and land use changes on forest bird species for adaptive management of the Northern Sierra Madre Natural Park (Philippines)

This report written within the framework of the project on *Mainstreaming Climate Change in Biodiversity Planning and Conservation in the Philippines",* coordinated by the World Agroforestry Centre (ICRAF-Philippines).

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Summary

This study focused on the consequences of projected climate change by 2040 for nature in the Northern Sierra Madre Natural Park (NSMNP) and surroundings, especially forest types and bird species. It is expected that climate change not only influences bird species directly, but also indirectly by changing land use and shifts of habitats. This is investigated by modeling future changes in land use under three scenarios. i.e., A1, the worst case scenario, with agricultural land use being dominant over forest within the park plus the impact of a newly planned road dissecting and opening up the park has been taken into consideration; F1, with forest habitat types being dominant within the park over agriculture (but not outside the park) plus a moderate impact of the newly planned road and finally; F1-NR, the "standard" scenario, the same as F1 but without the newly planned road. A stepwise hierarchical modelling approach was used to predict the responses of forest birds in terms of species distribution under three land use scenarios and one climate change scenario in 2040. The modelling was done with a combination of techniques, GIS (ArcGIS 9.2), Maxent (MaxEnt, 2013) and Null model testing, with climate data extracted from the Bioclim data website (http://www.worldclim.org/bioclim) and future climate data from the IPCC4 model data from CIAT (http://www.ccafs-climate.org/data/). The model UKMO – HADCM3 was used, with scenario SRES A1B. Data on the presence of forest bird species were gathered at multiple sites (495 survey points in total) with different types of land use from 2000-2012. Land use data were extracted from five Landsat 5 MSS satellite images, years 2009-2010, and used for supervised classification. The results show that in all scenarios lowland Dipterocarp forest is strongly declining probably because of transitions of natural forested areas into climate-change induced agricultural land use in combination with a distance to road-effect (in areas outside the park in scenario F1-NR and also inside the park under scenarios A1 and F1) . High elevation forest types showed a shift upwards and, for montane forests, a slight decline in distribution. The model outcomes of the scenarios with and without the newly planned road shows the strong impacts of road construction and its radiating effects on land use. The effects of climate and land use changes on forest bird species distribution are partly following the changes in forest habitats: under the A1 scenario, the model predicts a considerable decrease in most forest bird species. The same is true for endemic and red list bird species. For the F1 scenario, with forest dominant over agriculture inside the park, the changes are less severe. In fact most of the forest species are predicted to survive inside the NSMNP where they are protected against land use changes. Yet, the construction of the planned new road will be clearly visible in terms of reduced distributions of forest bird species. In case of no road construction in the park, the climate change effects are still predicted to reduce forest bird species distributions, but to a much lesser extent. This study includes for the first time the effects of (climate-induced) changed land use on forest habitats and includes the impact of (climate-induced) habitat changes on birds. In most studies the consequences of potential infrastructural works are not included, as done in this study that uses an overall innovative approach to model a realistic future scenario. It could be assumed that forest habitats should (largely) be protected in protected areas but the daily practice is that this is often not the case. Hence, the F1 scenario (forest first) for the NSMNP is probably too positive on the future protection of forest habitats within the park boundaries. It cannot enough be stressed that forest protection and conservation are imperative for the preservation of birds, forest and other wildlife and natural resources in the NSMNP.

Keywords Biodiversity Conservation - Species Range - Fragmentation - Endemism - Species Distribution Model - Maxent

Foreword

This report has been written based on research conducted during the period 2011-2012 within the framework of the project on Mainstreaming Climate Change in Biodiversity Planning and Conservation in the Philippines". This project, coordinated by the World Agroforestry Centre (ICRAF-Philippines), is a USAID funded project that aims to integrate the adaptation to a changing climate into biodiversity planning and management; a local climate-change initiative that develops strategies and actions to address climate change threats to terrestrial biodiversity and tropical forests in the Philippines.

This report covers the following objectives in the above project:

- Assist in assessing the potential impacts of climate change on terrestrial ecosystems in the Philippines including identification of the most vulnerable ecosystems;
- Support assessing the likely human responses to climate change in the proximity of protected areas and the resulting threats to conservation, and help develop appropriate adaptation strategies that mitigate these threats;

The objectives were addressed in collaboration with the counter-part organization Mabuwaya Foundation that was tasked with developing and showcasing appropriate climate change adaptation strategies and capacity building within this field. The Leiden University and VU University Amsterdam consortium together with the Mabuwaya Foundation covered component 3 of the project titled "Demonstrate Climate Change Adaptation in Biodiversity Conservation Areas", with the Northern Sierra Madre Natural Park as target biodiversity conservation area.

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1. Introduction

Various sources in the literature report about the complexity of determining to what extent recent observed changes in species ranges and natural systems in general have been caused by climate change (e.g., Parmesan and Yohe 2003).

Particularly short-term local changes are difficult to identify since most often such changes are not (primarily) caused by climate change but by changes in land use and natural fluctuations in abundance and distributions of species, with land-use change effects clearly overruling any (potential) climate change effect. Moreover, most species show a remarkable resilience to changes in species range area, which could be explained by the presence of a time-lag between habitat loss and species extinction (Brooks et al. 1999).

This line of thinking ignores, however, the effects of small systematic trends in climate change that may become more apparent in the longer term. Underlying indications for climate change are therefore often sought by the analyses of systematic trends across diverse species and geographic regions, notwithstanding debates about definitions of what constitutes a "systematic trend" (IPPC 2001, Parmesan and Yohe 2003). There are various sources in the literature showing documented statistical correlations between changes in climate and biological changes (Easterling et al 2000, Parmesan et al. 2000, Pounds 2001, Tamis 2005a, 2005b) and reporting evidence from recently observed trends in climate change influencing species ranges and advancement of spring events (Hughes 2000, McCarty 2001, Walther et al 2002, Pearson and Dawson 2003). For example, Parmesan and Yohe (2003) documented a range shift averaging 6.1 km per decade towards the poles (or 6.1 meters per decade upward) and a mean advancement of spring events by 2.3 days per decade based on a meta-analyses of a wide range of studies mainly covering the northern hemisphere. It is therefore concluded with "very high confidence" that climate change is already affecting biological systems, and we may expect that predicted future climate change will have a significant impact on the distribution of species.

Species distribution models (SDMs) are widely used to predict the potential changes in species distributions under climate change scenarios. However, there has been increasing concern about the type of explanatory variables and data used in these models (Austin and Van Niel 2011a, 2011b). Early studies of species' distributions only use climatic variables, such as mean temperature of coldest month, and species presence/absence data (Huntley et al., 1995; Sykes et al., 1996).Moreover, climate change SDMs tend to use low resolution data resulting in refugia that are created by local topography not being recognized (Austin and Van Niel 2011b). Predicting future distributions under climate change scenarios proved more successful for models using both climate and landscape variables as predictors: the inclusion of landscape variables resulted in the prediction of much larger areas of existing optimal habitat whereas models using only climate variables overestimate range reduction under climate change and fail to predict potential refugia (Austin and Van Niel 2011a).

It should be noted that species distribution is also a function of inter-species interactions (e.g., Davis et al 1998) and the ability of an individual species to migrate at a rate keeping pace with the changing climate which in turn depends on the dispersal characteristics of that species. Highly dispersive, mobile species such as birds will be able to fill potential new habitats generated under future climates as opposed to poor dispersers that are solely dependent on existing habitats that remain suitable under future climatic conditions (Peterson et al 2001). Moreover, species dispersal rate is controlled by the structure of the landscape over which migration will take place, including the occurrence of natural barriers such as rivers and mountains ranges and fragmented habitats associated with human-induced land use change due to, for example, logging activities and agricultural expansion onto forested land.

Tropical rainforest fragmentation has led to a local loss of species, with isolated fragments suffering from reduction in species richness with time after excision from continuous forest (Turner 1996). The number of species lost in fragmented habitats is related to fragment size and the number of species persisting in remaining fragments (e.g. Connor and McCoy 1979). Brooks et al. (1997) used the species area relationship to calculate the number of endemic species predicted to become globally extinct following forest fragmentation and deforestation on the islands of the Philippines and Indonesia. They found a strong correlation between forest area loss and the number of endemic species listed as threatened by the IUCN. Similar correlations were found in North America (Pimm and Askins 1995). Yet, some species are more susceptible to rapid extinction through deforestation than others. Quite some other research has been conducted on aspects of habitat loss and fragmentation, especially the creation of habitat edges (e.g. Laurance 1991), minimum viable population size (e.g. Smith 1997), and the interaction between the biota of fragments and that of the surrounding matrix of human-altered vegetation (e.g. Fahrig and Merriam 1994). The former is also analysed in the framework of the metapopulation theory (e.g. Opdam 1988, Hanski 1991, Vögeli ert al 2010).

The project area in the Philippines embraces a tropical wet mountainous environment under increasing pressure from global climate change: the Northern Sierra Madre Natural Park (NSMNP) and its neighbouring buffer zone located in the north-eastern part of the island Luzon. It is an area identified by BirdLife International as one of the seven Endemic Bird Areas in the Philippines (Stattersfield et al. 1998). Yet, in addition to climate change, this particular area faces other forms of serious threats leading to forest habitat fragmentation and deforestation including (illegal) logging and the expansion of agriculture and road networks onto forested lands. It is expected that the impact of local land-use change on forest bird species of the NSMNP will be severe and in fact overrule the impact of global climate change during next decades. On-going integrated changes in the environment may ultimately lead to extinction of forest bird species, including the precious endemic bird species which made the Philippines known as hotspot and mega diversity country. The prime objective of this study is therefore to model the local impact of climate change and changes in land use on forest bird species distribution. The modelling exercise will provide information on the expected impacts by 2040, generating inputs for long-term biodiversity planning, protected area management and local conservation initiatives to be undertaken in the study area, while setting examples for elsewhere in the country.

1.1. Climate change and species distribution in the Philippines

The Philippines is experiencing climate change over past decades, which is evident from rising temperatures and more extreme weather events as explained below. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) conducted a climate trend analysis using available observed data from 1951 to 2009 leading to the following historical results (DOST-PAGASA 2011):

- an increase in annual mean temperature in that period by 0.57 °C (for Tmax and Tmin, the increases have been 0.35 °C and 0.94 °C)

- a significant increase in number of hot days (e.g., for Tuguegarao an expected increase in Days w/ Tmax >35 °C from 2769 at present to 3930 by 2035) but decrease of cool nights, and those of rainfall (extreme rainfall intensity and frequency) are not clear, both in magnitude (by what amounts) and direction (whether increasing or decreasing), with very little spatial coherence.

In the same report (DOST-PAGASA 2011), based on outputs of simulations under the IPCC mid-range emission scenario (IPCC SRES), future climates are projected to show a rise in annual mean temperatures of 0.9 °C to 1.1 °C in 2020 and of 1.8 °C to 2.2 °C in 2050 in all areas in the country. Projections for extreme events show that hot temperatures (days with maximum temperature exceeding 35 °C earlier) will continue to become more frequent, number of dry days (days with less than 2.5mm of rain) will increase in all parts of the country and heavy daily rainfall (exceeding 300mm) events will also continue to increase in number in the Luzon and Visayas regions. In terms of seasonal rainfall change, there will be a reduction in rainfall in most provinces during the summer season making the usually dry season drier, while rainfall increases are likely in most areas of Luzon and Visayas during the southwest monsoon and the transitional (transition from southwest to northeast monsoon) seasons, making these seasons still wetter. This implies a likelihood of both droughts and floods in areas where these changes are projected, suggesting an increase in climate variability and extreme events.

The Philippines is regularly in the news because of recurrent natural disasters related to severe weather events with flooding, typhoons and related storms. The country was recently placed fourth among more than 190 countries around the world that have suffered the most extreme weather events over the past 20 years, according to the 2013 Global Climate Risk Index (Harmeling and Eckstein 2012). Likewise, the Philippines were ranked 14th in last year's report of countries most vulnerable to climate change and extreme weather events. The extreme climatic events have adversely affected the Philippine economy and associated sectors in water resources, agriculture, environment and protected areas. For example in September 2006, tropical storm Xangsane resulted in a total damage of US$ 134 million on housing and associated properties and US$ 83 million in agriculture (NDCC, 2006 in Lasco et al 2008). Moreover, the Philippines is periodically affected by the ENSO (El Niño-Southern Oscillation) phenomenon that induces prolonged wet and dry seasons (Lasco et al 2008).

Climate change is projected to exacerbate the multiple threats facing biodiversity in the Philippines today, yet, its local impacts have not been fully investigated. The few studies published in peer-reviewed journal so far cover climate change effects on amphibians (e.g., Alcala et al 2012), most work on other studies likely to be on-going. Exact knowledge of the impact on biodiversity is considered of the utmost importance to control further species loss in a country known as one of the hottest of the hotspots for biodiversity conservation (Myers et al 2000). As a result of the specific bio-geographical history, the more than 7,000 islands of the Philippine archipelago harbour a very high number of endemic species with 1.9 % of the World's plants and vertebrates occurring only here (Myers et al 2000). Originally covered with tropical forest, most Philippine endemic species are forest species. Yet the very reasons which promoted speciation on islands like the Philippines in bio-geographical history also leave island endemics highly vulnerable to recent and rapid impacts by humans (Fordham and Brook 2010). The Philippines has lost more than 70 % of its forest cover since 1900 (ESSC 1999) with a current forest cover of about 25 % of land area (World Bank 2010). As a result of primary habitat loss, many Philippine forest species are threatened with extinction including a large number of birds (Brooks et al 2002). Climate change is expected to further drive land use change, potentially increasing threats to the survival of species already threatened by deforestation (Sodhi et al. 2010).

Currently 627 bird species are known from the Philippines (Kennedy et al. 2000; WBCP 2009; IUCN 2013) of which 410 are resident (breed in the Philippines). Of these, 181 species are endemic to the country (44 % of resident species). Seventy bird species are listed as threatened (15 Critically Endangered, 12 Endangered, 47 Vulnerable) and another 59 as near-threatened. Five species are data deficient (IUCN 2013).

1.2. Description of study region: Northern Sierra Madre Park (NSMP) and buffer zone area

The Northern Sierra Madre Natural Park covers a total of 359,486 ha of terrestrial and coastal areas in Isabela Province, Northeast Luzon. With an altitudinal range of 0 – 1.844 m.a.s.l., it is one of the largest and most diverse protected areas in the country and one of ten priority sites of the National Integrated Protected Area System (NIPAS). The NSMNP is home to numerous species of flora and fauna, many of which are rare and endangered.

These include a large number of commercially important, but severely threatened tree species of the Dipterocarp family such as *Shorea* spp. and *Hopea* spp. The NSMNP also protects rare forest types such as mangrove forest, forest on ultrabasic soils and mossy forest on mountain tops and ridges.

The park is part of an Endemic Bird Area (EBA) (Stattersfield et al. 1998), hosting nearly 50% of all bird species recorded in the Philippines including the critically endangered Philippine eagle *Pithecophaga jefferyi* and the Isabela Oriole *Oriolus isabellae*, one of the rarest birds in the world.

The currently known biodiversity of the NSMNP includes 1,079 tree species, 55 mammals, 294 birds, 23 amphibians, 61 reptiles including the World's rarest crocodile, the Philippine crocodile Crocodylus mindorensis, 36 freshwater fish and 128 butterfly species (Nordeco & DENR 1997, Van Weerd 2002 & unpublished data, Co et al. 2004, van Weerd and Udo de Haes 2010, Brown et al 2013).

The NSMNP is home to two indigenous peoples: the Agta and the Kalinga who are highly dependent on the products offered by the NSMNP for their livelihood. About 25,000 migrant farmers and fishermen also live within the multiple use zone of the park and the 2.6 million people living in Cagayan Valley (NSI 2010) depend on the ecosystem services provided by the park, notably the regulation of water flows during the dry and wet season. The NSMNP is managed by a multi-stakeholder Protected Area Management Board (PAMB) that consists of representatives of indigenous people, migrants, local environmental NGOs, local governments (the nine municipalities that are, partly, covered by the park) and the Provincial Government.

A new road, linking Ilagan with Divilacan, is currently in the planning phase. This road would dissect the protected area and open up now remote forest areas.

2. Methodology

2.1. Bird survey sites

Data on the presence of bird species were gathered at multiple sites with different types of land use (various forest types, grassland, corn, rice, other agricultural; areas; Figure 1, Table 1) from 2000 – 2012 in all seasons. In total, 495 survey points were used in 391 unique locations in undisturbed and disturbed contiguous forest, forest patches and the surrounding agricultural matrix landscape in the NSMNP and in the park buffer zone.

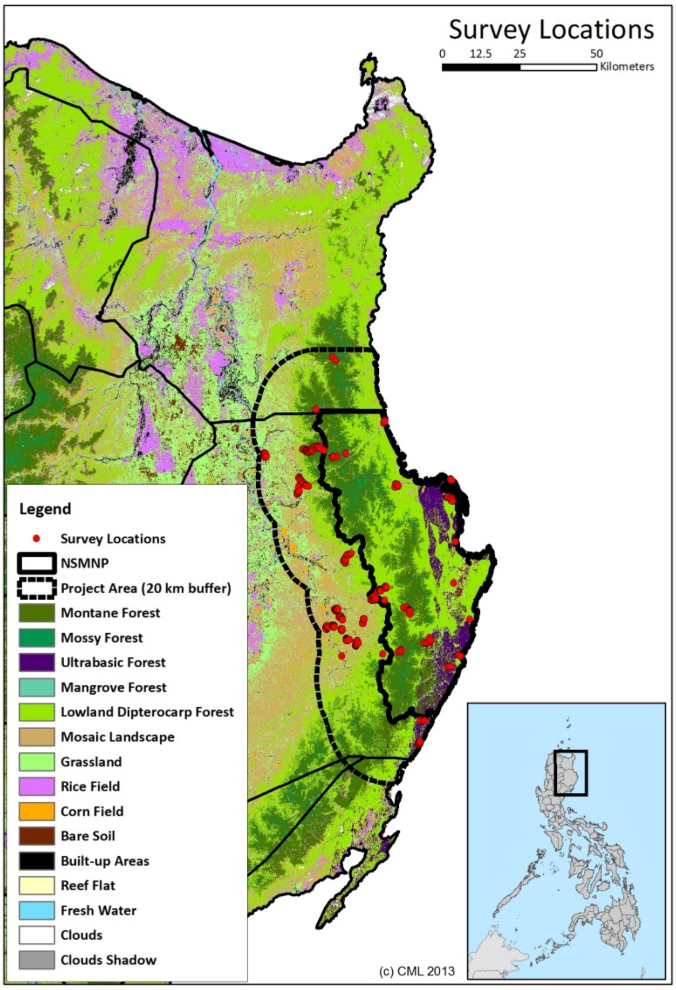


Figure 1: The project area with the bird survey locations (391 in total, shown in clusters) distributed over the Northern Sierra Madre Natural Park (NSMNP) and neighbouring buffer zone.

Table 1: The number of bird survey points in various land use types in the NSMNP

Land use type	**Survey Points**
Lowland dipterocarp forest undisturbed	47
Lowland dipterocarp forest disturbed	140
Lowland dipterocarp forest patch	110
Montane forest	25
Mossy forest	26
Ultrabasic forest	28
Mangrove forest	12
Grassland	46
Cornfields	31
Ricefields	20
Other agricultural areas	10
Total	**495**

2.2. Data collection

Data on bird species were gathered using the point count methodology. Survey points were selected randomly in a larger survey area in a homogenous land use type. Depending on the size of the land use type, 1-20 different points were used. Sampling points were regularly spaced throughout the larger survey area with a minimum distance of 100 m between points. Counts were performed over a 15 minute period at each point after an initial 5 minute waiting period to avoid disturbance bias. Usually two observers conducted the count, with one observer noting down observations. One of the observers was either Edmund Jose, Dominic Rodriguez, Joni Acay, Wouter Thijs, Marijn Prins or Merlijn van Weerd; all seasoned observers with a good knowledge of Philippine birds. Both aural and visual identification techniques were used, based on Kennedy et al. (2000), Scharringa (2005) and field experience of the observers. Surveys were conducted in the morning (5.30 – 10 am) and later afternoon (16.00-18.30). All observed and heard bird species were recorded, including observation time at the point count, the distance and observation manner (visual and aural recognition). In addition for each point count, the GPS coordinates, altitude, date, start time and weather conditions were recorded.

An ACCESS (Microsoft Office Access 2010, Microsoft Corporation) database was made with all count information for further analyses. Additional observations of rare species in the northern Sierra Madre were included based on observations in 1991 and 1992 by NORDECO and DENR (1998) and by Lagerveld (2002) in 2002.

2.3. Explanatory and response variable preparation and selection

In literature different variables are used for the modelling of bird species' distribution, including bioclimatic (BioClim) variables such as annual mean temperature and annual precipitation (Elith, Graham et al. 2006; Buermann, Saatchi et al. 2008; Loiselle, Graham et al. 2010; Anderson and Gonzalez 2011), ecological variables and topographical variables such as elevation, range, ground slope, distance to roads or ecotones (Elith, Graham et al. 2006; Young, Franke et al. 2009; Anderson and Gonzalez 2011; Moreno, Zamora et al. 2011).

Table 2 lists all 41 environmental variables that were available and considered in the variable selection procedure in this study for compiling maps and building models. The climate data were extracted from the Bioclim data website (http://www.worldclim.org/bioclim). All 19 bioclim data were considered for the selection of variables to be used in the model building exercise (see Figure 2 with examples of annual mean temperature and annual precipitation for 2010 and those predicted for 2040). There were eight topographical variables (e.g. height, slope, distance to contiguous forest), one soil variable (with five soil classes) and 13 land use types (see Figure 3 with examples of maps based on topographic and soil data used in this study).

Table 2: Variables used in the research version (: variables used in analyses); part I explanatory variables and part II response variables ("species").*

Group parameter	**Description (explanation) (unit)**
I EXPLANATORY VARIABLES	
Climate	source Bioclim (BIO1 … BIO19)
bio_1_sma.asc*	annual mean temperature (^{o}C*10)
bio_2_sma.asc	mean diurnal range (mean of monthly (max temp-min temp)) (^{o}C*10)
bio_3_sma.asc	isothermalithy (BIO2/BIO7)*100 (no unit)
bio_4_sma.asc*	temperature seasonality (standard deviation*100) (^{o}C*10)
bio_5_sma.asc	max temperature of warmest month (^{o}C*10)
bio_6_sma.asc	min temperature of coldest month (^{o}C*10)
bio_7_sma.asc*	temperature annual range (BIO5-BIO6) (^{o}C*10)
bio_8_sma.asc	mean temperature of wettest quarter (^{o}C*10)
bio_9_sma.asc	mean temperature of driest quarter (^{o}C*10)
bio_10_sma.asc	mean temperature of warmest quarter (^{o}C*10)
bio_11_sma.asc	mean temperature of coldest quarter (^{o}C*10)
bio_12_sma.asc*	annual precipitation (mm)
bio_13_sma.asc	precipitation of the wettest month (mm)
bio_14_sma.asc	precipitation of the driest month (mm)
bio_15_sma.asc*	precipitation seasonality (coefficient of variation) (no unit)
bio_16_sma.asc	precipitation of wettest quarter (mm)
bio_17_sma.asc	precipitation of driest quarter (mm)
bio_18_sma.asc	precipitation of warmest quarter (mm)
bio_19_sma.asc	precipitation of coldest quarter (mm)
Elevation	GIS-calculations
srtm_max_sma.asc	maximum height (m)
srtm_mean_sma.asc	mean height (m)
srtm_min_sma.asc	minimum height (m)
srtm_rang_sma.asc	height range (max-min) (m)
srtm_slme_sma.asc	mean slope (degrees)
srtm_slmx_sma.asc	maximum slope (degrees)
Distance	
m_road_d_sma.asc*	distance to main roads (decimal degrees, 1 degree=110 km)

Group parameter	Description (explanation) (unit)
dist_cont_forest_sma.asc	distance to contiguous forest (m)
Soil	GIS analyses
hwsd_ubf_sma.asc*	dominant soil type, including ultrabasic soil
Land use	GIS analyses
lu_bare_sma.asc*	bare (agricultural or natural) area (# satellite pixels = 30 x 30 m)
lu_built_sma.asc*	urbanized area (incl. roads) (unit see above)
lu_corn_sma.asc*	agricultural area, corn (unit see above)
lu_fresh_sma.asc*	fresh water area (unit see above)
lu_grass_sma.asc*	agricultural area, grassland (unit see above)
lu_ldf_sma.asc*	natural area, lowland dipterocarp forest (unit see above)
lu_mgf_sma.asc*	natural area, mangrove forest (unit see above)
lu_monf_sma.asc*	natural area, mountainous forest (unit see above)
lu_mosf_sma.asc*	natural area, mossy forest (unit see above)
lu_mscl_sma.asc*	mosaic of natural and agricultural area (unit see above)
lu_reef_sma.asc	ocean, coastal reef (unit see above)
lu_rice_sma.asc*	agricultural area, rice (unit see above)
lu_ubf_sma.asc*	natural area, ultra basic forest (unit see above)
II SPECIES	
All_species_121026.csv*	Presence at one location at one time
landuse_types_Luzon_GT.csv	ground truthing points land use (presence)
landuse_types_Luzon_VGT.csv*	same, virtual ground truthing points land use (presence)

The future climate data used for modeling in this study were derived from the IPCC4 model data from CIAT (available at http://www.ccafs-climate.org/data/). The model used is UKMO – HADCM3 (Gordon et al 2002), with scenario SRES A1B and down-scaled with the Delta method (see: http://www.ccafs-climate.org/downloads/docs/Downscaling-WP-01.pdf) to a resolution of 30 arc seconds.

The topographic ("elevation") explanatory variables were all calculated with GIS based on the SRTM 90m Digital Elevation Data provided by the CGIAR Consortium for Spatial Information (version 2008; http://srtm.csi.cgiar.org/). The "distance" variables were calculated with GIS from Esri maps and road data (delivered with ArcGIS 9.2; see
http://www.arcgis.com/home/group.html?owner=esri&title=ESRI%20Maps%20and%20Data)
whereas the land use variables are derived by the satellite-images classification procedure explained in Figure 5. Soil types were derived from the soil map available on the Harmonized World Soil Database website (FAO/IIASA/ISRIC/ISSCAS/JRC 2012). Soils classified as podzols or histosols with ultrabasic forest were, however, re-classified as ultrabasic soils. Finally the species variables were derived from the data gathered in the field.

Figure 2 shows examples of current (2010) and predicted (2040) maps for two Bioclim data sets considered in this study: annual mean temperature (Figure 2A, 2b) and annual precipitation (Figure 2C, 2D). Annual mean temperatures, which increase 1.5 – 2.0 ^{o}C on average, are predicted above 27 ^{o}C for most lowland areas in 2040 whereas temperatures of less than 21 ^{o}C, which covered high elevation areas of the NSMNP in 2010, will have almost disappeared by 2040. The changes in annual precipitation for the 2010 – 2040 period are small, the most apparent change occurring in the Southeastern part of the region. Whereas it is predicted that it becomes drier throughout the region, the mountain range is not becoming wetter as one may expect (drier seasons become drier, wetter seasons become wetter).

For the selection of most important explanatory variables Pearson's correlation analysis and a PCA in the statistical package R were carried out. Explanatory variables with a correlation > 0.80 were grouped. From these groups the variable with the highest loadings on the principal axes were selected. If there were little differences the more simple variables were selected. The first two principal axes heavily correlated with temperature/height (1st axis) and precipitation (2nd axis) and the following axis all were explained by one or more land use parameters.

All height and slope variables were highly correlated with temperature, and therefor excluded from further analysis. Distance to contiguous forest (derived from the land use map) was not included, because this parameter could not be (easily) determined in the future scenarios. After selection 19 explanatory variables (5 climate, 1 distance, 1 soil and 12 land use variables), marked with an * in Table 1, remain for further analysis. In later modelling it was decided to omit the soil variable in bird modelling.

There are two types of response variables: birds and land use. All bird observations were used for analysis. All groundtruthing points (including the virtual ones) for land use were used in a first run of Maxent to check for possible bias. Predicted maps for the 2010 situation were compared with the GIS-map derived from satellite images for 2009-2010. It was concluded that the present land use map derived from the groundtruthing points showed some clear regional biases. Therefor 100 random grid cells per land use were selected from the present land use map derived from satellite images, using the statistical package R, weighed to their area (with a minimum of the first quantile to avoid inclusion of "noise" areas).

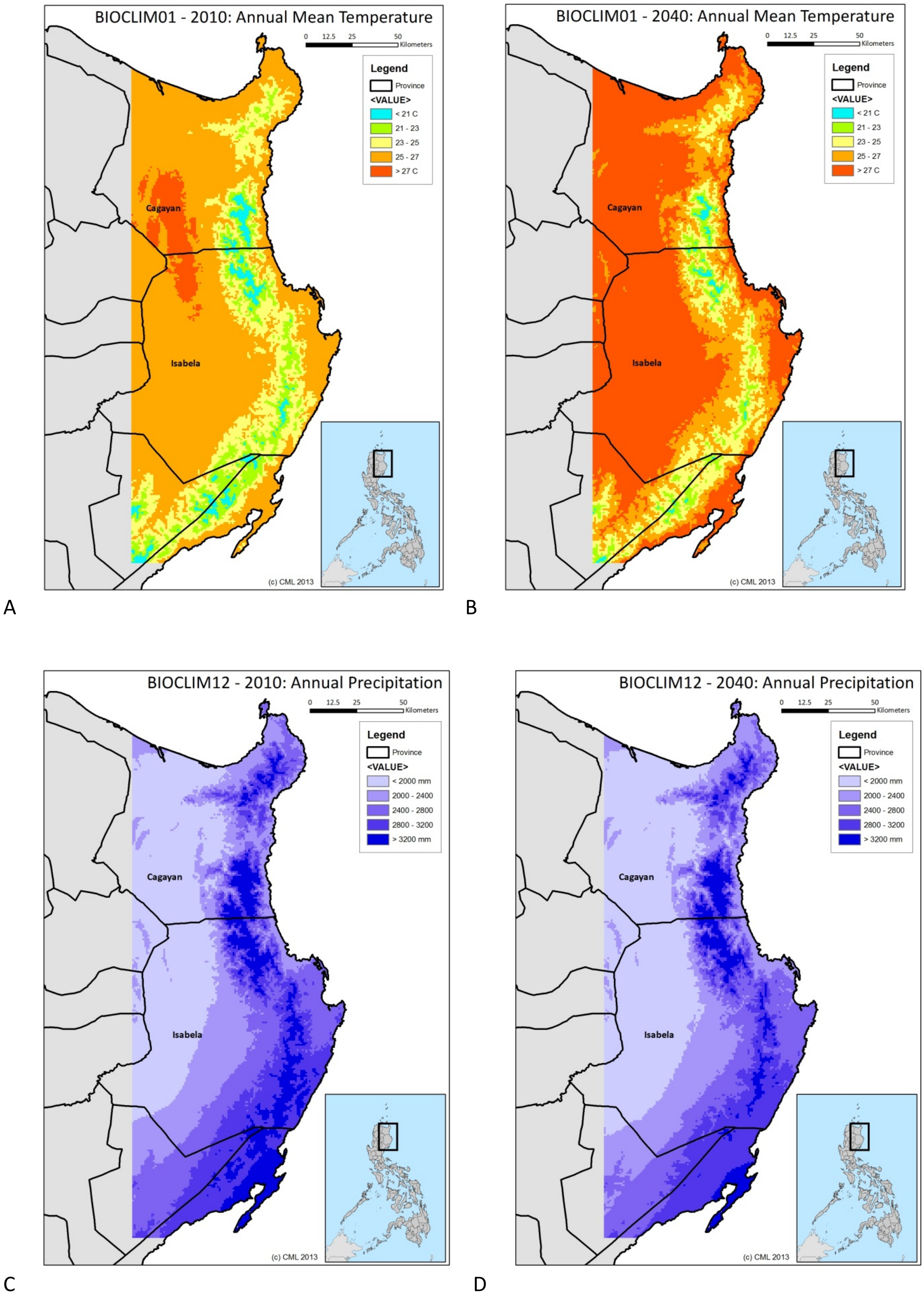
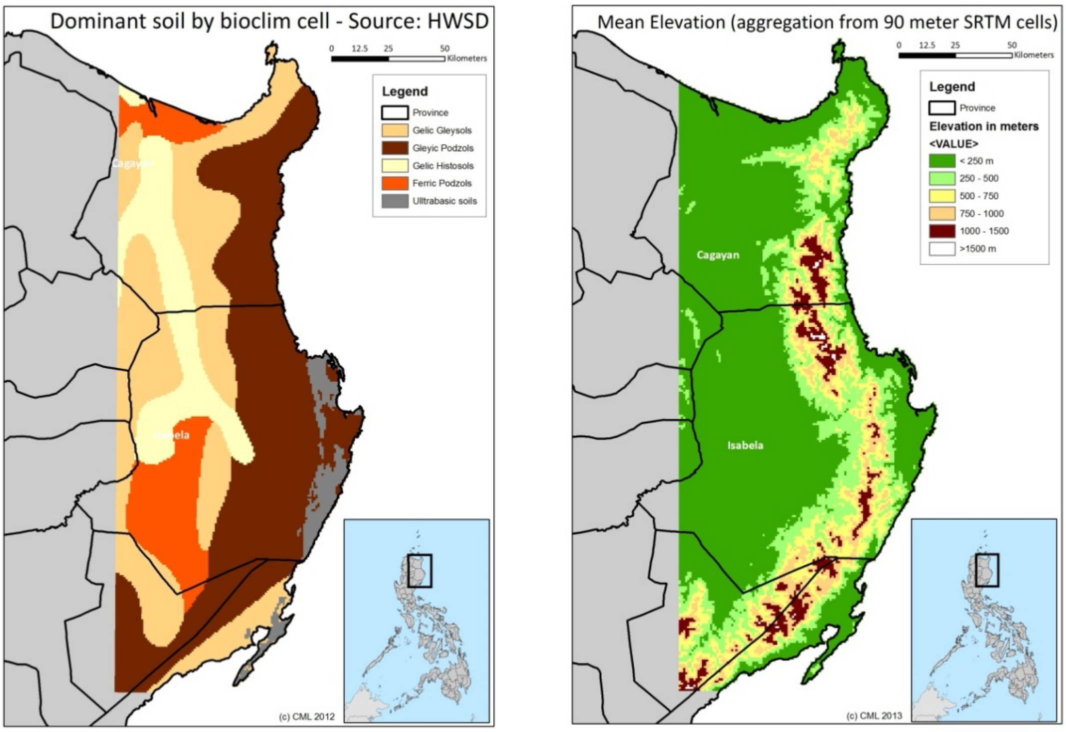
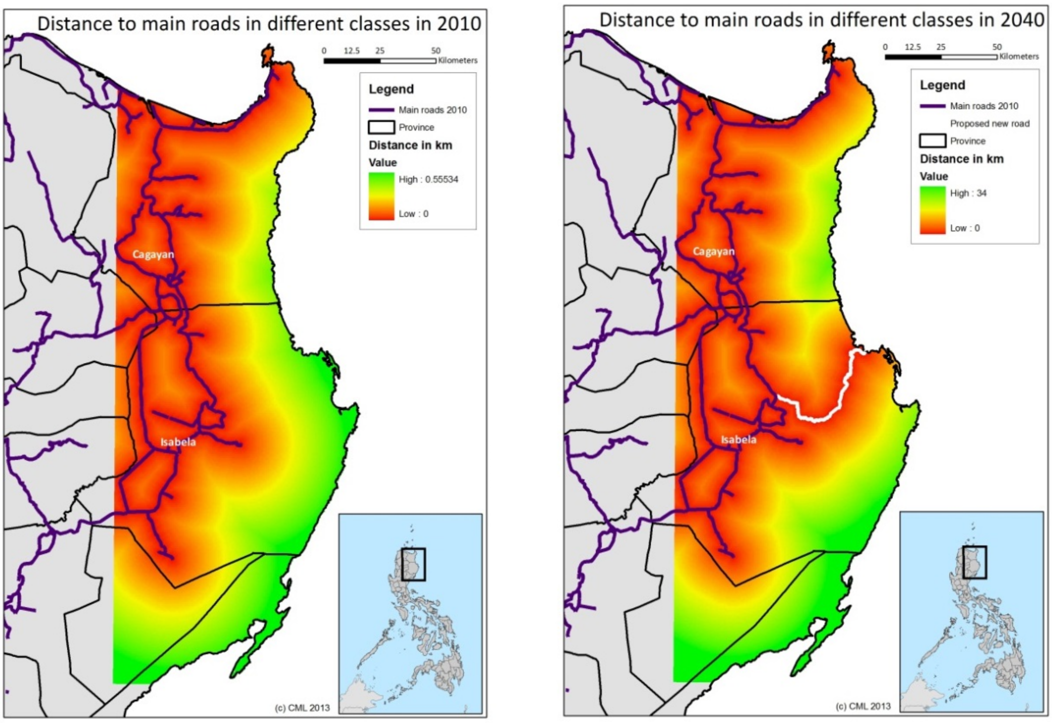


Figure 2: Annual mean temperature and annual precipitation under present (A, C) and climate change (B, D) conditions for the project area and its surroundings in Northeast Luzon (Philippines)



A B

Figure 3: Dominant soil types (A) and mean elevation (B) in the project area and its surroundings in Northeast Luzon (Philippines)



A B

Figure 4: The (projected) distance to road for present (A) and future climate change conditions (B), the latter including a planned road crossing the project area in NE-SW direction, Northeast Luzon (Philippines).

2.4. Classification of land use types

The various steps followed to classify the land use types for compilation of a land use map is shown in Figure 5.

2.4.1. Satellite Image classification in Multispec

To create a recent, fine scale (grid size 30 x 30 m) land use map of northeast Luzon, the first step was to perform a supervised classification of five Landsat 5 MSS satellite images: 2 from 2009 and 3 from 2010 (path 115, rows 48 and 49 taken within seconds from each other in March 2009 and path 116, rows 47-49 taken at the same time in February 2010; source: (http://earthexplorer.usgs.gov). The 2009 (eastern images) and 2010 (western images) were merged (using ArcGIS 9.2) and the two combined images (western and eastern) were classified separately.

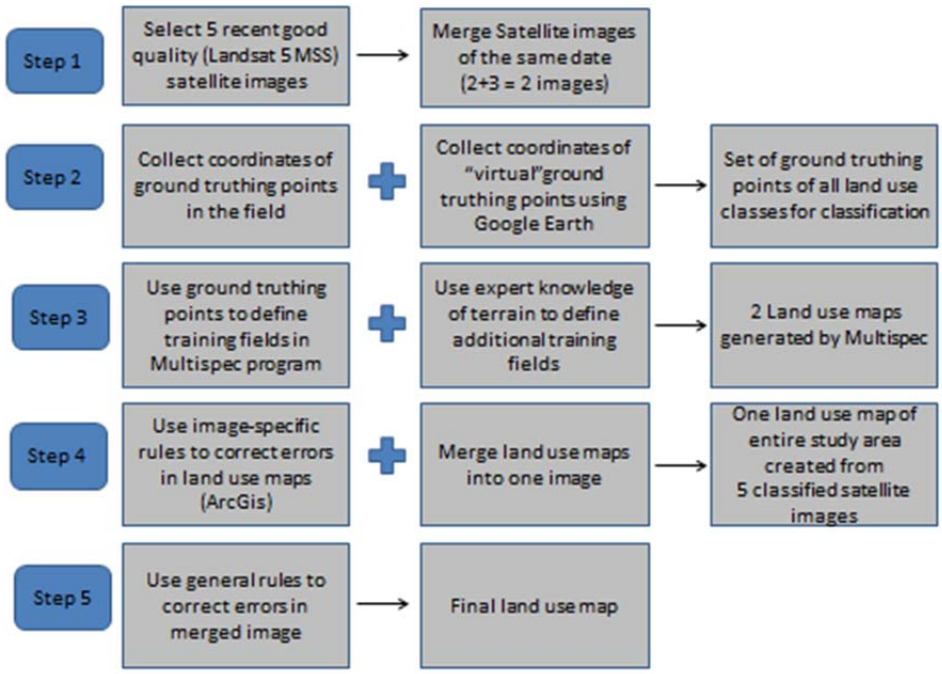


Figure 5: Flow chart showing the different steps in the compilation of the land use 2010 map.

The program Multispec (https://engineering.purdue.edu/~biehl/MultiSpec) was used for the classification. We identified land use classes a priori (Table 3) based on our knowledge of the research area and the importance of various habitat types for birds (Van Weerd and Snelder 2004, van Weerd and Udo deHaes 2010). Multispec uses training fields based on ground truthing data of a known land use class to classify all pixels with similar radiation spectra and extrapolates these classes for the entire satellite image. We used "real" ground truthing data, collected in the field with a GPS receiver but augmented the number of training fields to increase classification accuracy using "virtual" ground truthing data, based on an expert classification of land use class points created in Google Earth (Version 6.2.2.6613, Google 2012). Additional land use classes such as bare soil, rice fields, freshwater, ocean and built-up areas were classified directly in Multispec based on expert knowledge of the research area without ground truthing (Table 3). Different display compositions were used to select training fields for different land use classes. To select training fields for rice fields and corn fields the false colour layer composition 4/3/2 was used. The SWIR (Geo Cover) layer composition 7/4/2 was used to detect bare agricultural land, urban areas, fresh water, coral reefs and reef flats.

The two classified satellite images, consisting of the two and three merged images taken at the same date, were then combined. In order to refine the classification by Multispec, a set of rules was used to correct obvious errors with the program ArcMap (Esri ArcGIS 9). Mangrove forest > 20 m above sea level was reclassified into the nearest forest type. Montane and mossy forest < 500 m above sea level was reclassified into lowland forest. Lowland forest > 800 m above sea level was reclassified into montane forest. Ultrabasic forest in areas without ultrabasic soil types were reclassified into the nearest forest type. The resulting land use map was used as a basis for the modelling of bird species distributions.

Table 3: The number of ground truthing points used for classification of various land use classes of satellite images of northeast Luzon, Philippines.

Land use class	**Number of ground truthing points**
Lowland Dipterocarp Forest	116
Montane Forest	61
Mossy Forest	66
Mangrove Forest	61
Ultrabasic Forest	100
Mosaic Landscape (Forest fragments, grassland, shrub, cultivation)	61
Grassland	36
Rice field	31
Corn field	33
Bare soil	Directly trained and classified in Multispec
Built-up areas	Directly trained and classified in Multispec
Reef flat	Directly trained and classified in Multispec
Ocean	Directly trained and classified in Multispec
Fresh water	Directly trained and classified in Multispec
Clouds	Directly trained and classified in Multispec
Clouds Shadow	Directly trained and classified in Multispec

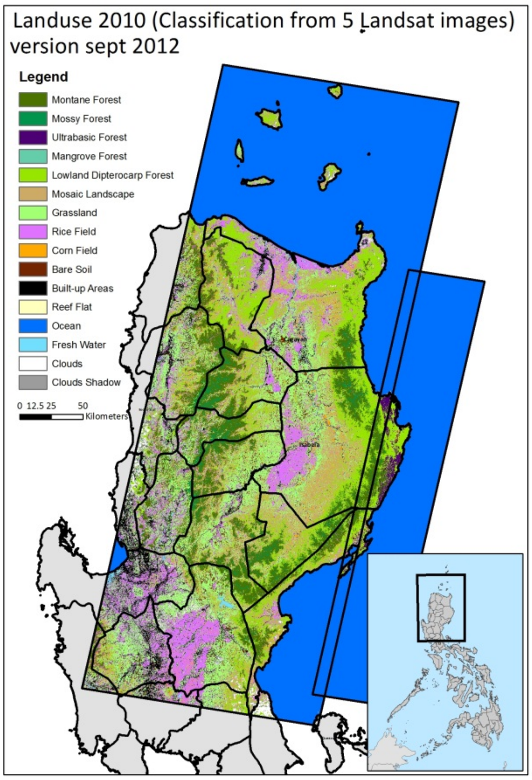
2.4.2. Creation of Boolean maps and conversion to MaxEnt gridcell format

Boolean maps were created for each class using the reclassify tool which classified a selected class with value 1 and all other classes with 0. The next step was to aggregate the Boolean maps to a gridcell-size that could be used by MaxEnt. The right gridcell-size used by MaxEnt is 30 arc-seconds x

30 arc-seconds. A BioClim layer was imported as reference. The gridcell-size of the input Boolean land use maps were derived from the gridcell-size of the LandSat image, which is 30 meters x 30 meters. By dividing the MaxEnt gridcell-size by the Boolean gridcell-size, expressed in decimal-degrees, the factor was calculated needed to convert the Boolean land use gridcell to a 'MaxEnt gridcell' (i.e., conversion factor of 31 was used). By using the raster calculator each Boolean land use map was aggregated to the right MaxEnt gridcell-size.. In other words, per MaxEnt-gridcell the number of land use gridcells was calculated per land use class. The maximum number of gridcells for a land use for a MaxEnt gridcell was 961.

After this, the extent of the land use maps had to be the same as the extent of the other environmental variables used in our study The clipped BioClim layer (for our study area) was used as a reference for the extent. The MaxEnt land use maps were converted (by clipping) to the same extent as this BioClim map.

The last step was to create land use maps in the right format that can be used by MaxEnt. The MaxEnt land use maps were converted to ASCII-format in ArcGIS 9.2



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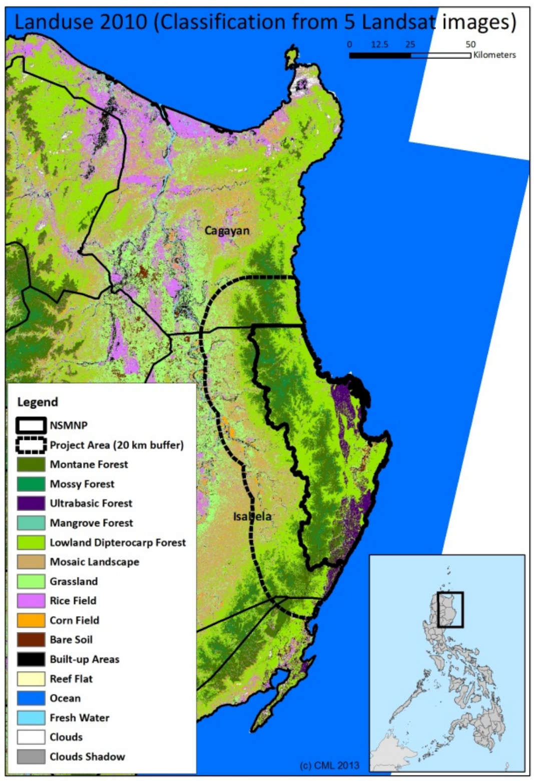


B

Figure 6: Land use map 2010 of North Luzon (A) with a close up (B) for the project area (including NSMNP and 20 km buffer zone used in this study to calculate model outcomes).

2.5. Modelling

A stepwise hierarchical modelling approach was used to model the responses of bird species in terms of range distribution for the year 2040 under three land use scenarios (Table 4) and one climate change scenario.

The steps followed in this approach are presented in the flow chart of Figure 7.

In general changes in forest bird species distributions are the consequence of climate change ánd habitat (forest) change. So, in step 1, 2 and 3 first land use is modelled, and the results were used as input for the bird modelling (step 4).

Table 4: Land use scenarios used for the modelling exercise in this study (all with same climate change scenario UKMO – HADCM (Gordon et al 2002))

Scenario	**Year**	**Description**
2010	2010	Baseline scenario, present situation
2040 A1	2040	Agriculture dominates over forest, also inside the NSMNP. The proposed road dissects the NSMNP and opens up current forest areas for conversion (Climate + Road + Agriculture effects).
2040 F1	2040	Agriculture dominates over forest but not inside the NSMNP where forest is protected. The proposed road dissects the NSMNP but forest prevails over agriculture. Only very near the road agriculture becomes dominant over forest ("Standard": Climate + Road effects).
2040 F1-NR	2040	Agriculture dominates over forest but not inside the NSMNP where forest is protected. No road is constructed and most forest areas in the NSMNP remain far from roads (Climate-only effects).

Modelling was done with a combination of techniques, GIS (ArcGIS 9.2), Maxent (MaxEnt, 2013) and Null model testing (Raes and ter Steege 2007). MaxEnt (maximum entropy method) is a niche-based modelling program developed for modelling species' geographical distributions with presence-only data. There is a difference between the fundamental niche and the realized niche of species. In nature the realized niche is often smaller than the fundamental niche. MaxEnt is a model that estimates the realized niche of a species based on presence-only data gathered in the study area. Hence, the potential distribution will be smaller than the overall distribution of species (Phillips, Anderson et al. 2006). Furthermore, areas that are known not to be inhabited by certain species can be excluded in the MaxEnt modelling exercise and, consequently, potential suitable areas for such species can be removed. The advantage of MaxEnt modelling is that it is able to produce better geographic species distribution models than for example GARP analysis or Cokriging (Moreno, Zamora et al. 2011). In fact, it outperforms the majority of other modelling approaches, especially when sample sizes are small (Hsu et al 2012). MaxEnt calculates a probability distribution over a grid, which may be interpreted as an index of habitat suitability for a species (Elith et al 2011, Hsu et al 2012). In addition, the programme gives an estimate of the relative contribution of each environmental variable to the model by means of iterative calculations.

MaxEnt modelling was further performed using the following settings:

1) 75% of the species records were used to train the model. 25% of records were used for 'random test percentage' in order to test the created MaxEnt distribution model (Moreno, Zamora et al. 2011; Scharg, Konrad et al. 2011; Phillips, Dudik et al. 2012).

2) Response curves were created to interpret the outcome of different variables that contribute to the model (Elith, Graham et al. 2006; Scharg, Konrad et al. 2011).

3) The Receiver Operating Characteristic curve (Area Under the Curve (AUC)) of the test set was used to assess the predictive value of the distribution models. AUC ranges from 0 to 1. An AUC of 0.5 indicates a distribution model that is no better than a random model; the higher the AUC (AUC > 0.5), the better the distribution model (Elith, Graham et al. 2006; Moreno, Zamora et al. 2011).

2.5.1. Land use modelling

Step 1 represents the modelling of land use, taking into account the construction of a (planned) road crossing the Sierra Madre Mountain Range in East – West direction. Land use distribution was modelled under current climate conditions and subsequently projected on future scenarios for the years 2020 and 2040 whereby 2020 was used as an intermediate step. The Steps 2 and 3 account for the time-lag between climate change and the responses of forest trees to climate change due to dispersal limitation and persistence (e.g., trees will not immediately disappear when climate conditions have become unfavourable; see Table 5 for dispersal distances used for six different forest types). Step 4 considers three land use scenarios a) extension of agriculture as a result of both climate change and road-network expansion in spite of the presence of protected forest in the NSMP (i.e., agriculture predominates forest in the analysis) and b) the same as under a) but taking into account the presence of protected forest in the NSMP (i.e., forest predominates agriculture in the analysis) and c) same as b but no new road crossing the Sierra Madre Mountain Range. The null model test (Raes and ter Steege 2007) was used to test the validity of the land use models, which were all significant at $P<0.01$. Steps 2 -4 were all performed using spatial analysis tools in ArcGIS 9.2.

2.5.2. Modelling bird species distribution

Bird species distributions were modelled with Maxent (Maximum Entropy Method; Maxent, 2013). Of the in total 229 bird species identified in the research area, 118 species occurred in five or more or more grid cells. A null method was applied to validate the significance of bird species distribution models (Raes and ter Steege 2007). The models of eleven bird species proved not to be more discriminating than their null models ($P < 0.05$). So in the end information of 107 bird species was used in further modelling for 2040. The remaining 107 species were used to generate three sets of species richness distribution maps, i.e., maps for all forest bird species (based on 60 species in total), maps for all endemic forest bird species (based on 46 species in total), and maps for all red list bird species (based on 7 species in total).

The three land use scenarios are used for modelling bird species (richness) distribution in 2040. The modelled land use projections together with 6 other environmental variables were used as predictors in models of bird species distributions.

To create a bird species richness maps, MaxEnt probability distributions were converted to predicted presence map for each species using the maximum training sensitivity plus specificity threshold. Next every single-bird-species map of a group (e.g. forest birds species) was overlaid to produce a (group) species richness maps. These steps have been done in ArcGIS 9.2 and batched in an automated procedure using Python 2.4.

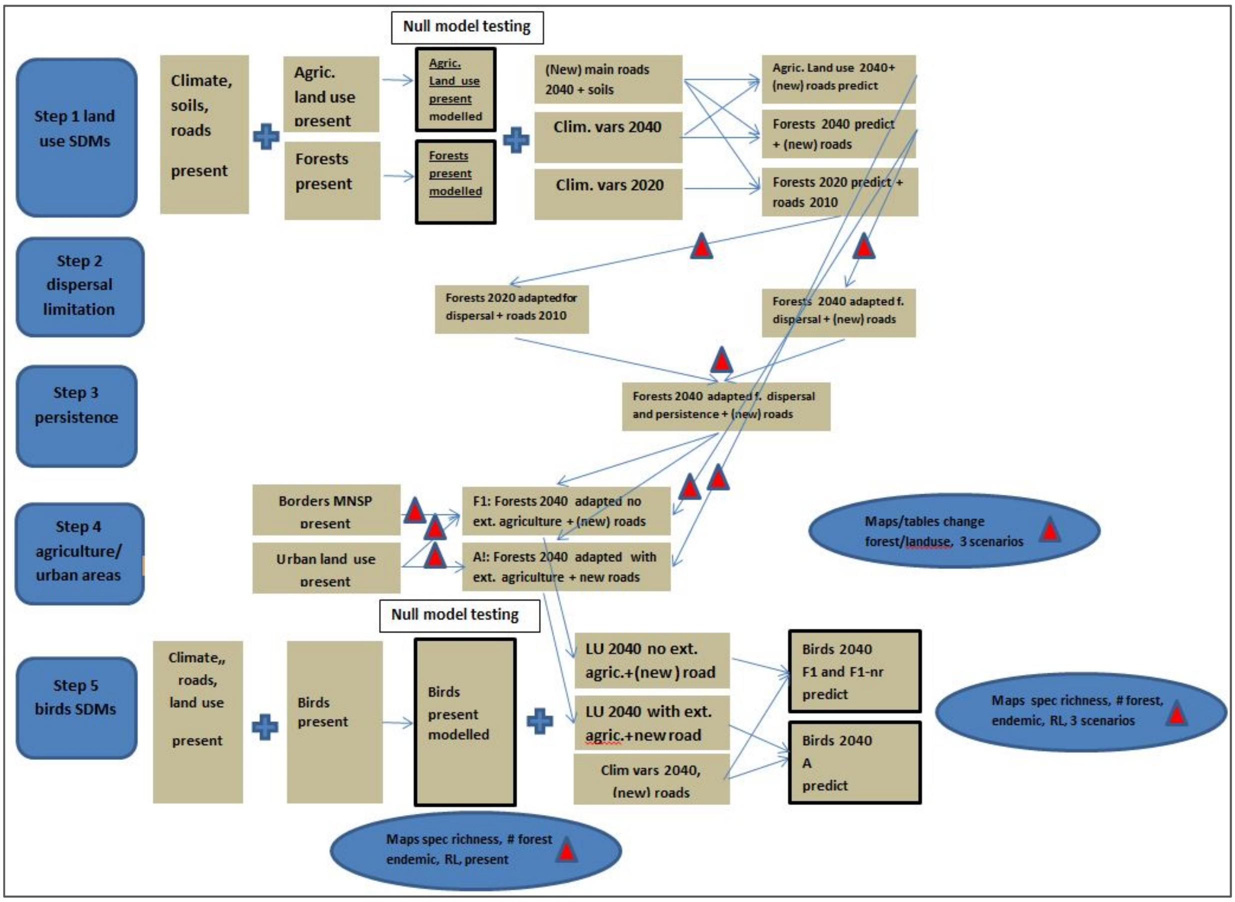


Figure 7: The stepwise hierarchical modeling approach followed in this study. The year 2040 is the target year for the produced models.

*Table 5: The six forest types, associated characters and the maximum dispersal distance at target years. Means are calculated as area-weighed means. Quartiles are unweighed, * = determined by human actions; ** = determined by abiotic factors (presence sea or ultrabasic soils).*

Forest type (abbr.)	Altitude mean (quartiles) (m)	Slope mean (degr.)	Age of maturity (years)	Persistence (years)	Maximum dispersal distance (m)	
					2020	2040
Mangrove Forest (MGF)	15 (8-40)	2.9	10	20	(0)**	(0)**
Mosaic Forest and agricultural areas (MOS)	135 (60-385)	6.0	10	(0)*	(0)*	(0)*
Ultra basic Forest (UBF)	255 (80-360)	12.8	15	20	(0)**	(0)**
Lowland Dipterocarp forest (LDF)	345 (65-405)	13.7	15	20	650	1950
Mountainous Forest (MTF)	860 (515-880)	20.5	20	20	468	1405
Mossy Forest (MSF)	945 (535-890)	20.7	20	20	468	1405

In addition to bird species richness maps, examples of individual bird species of the same family with different distribution patterns and ranges were selected for species distribution modelling as well. The following bird species selection criteria were used: endemism, trait (generalists / specialists), altitudinal presence, and its presence in disturbed or undisturbed forest.

3. Results

3.1. Impact of climate change on land use

The results of the predicted impact of climate change on land use by 2040 will be discussed below for the 3 major forest types occurring in and around the NSMNP: the lowland Dipterocarp forest, the montane forest and the mossy forest.

3.1.1. Lowland Dipterocarp Forest (2010 – 2040)

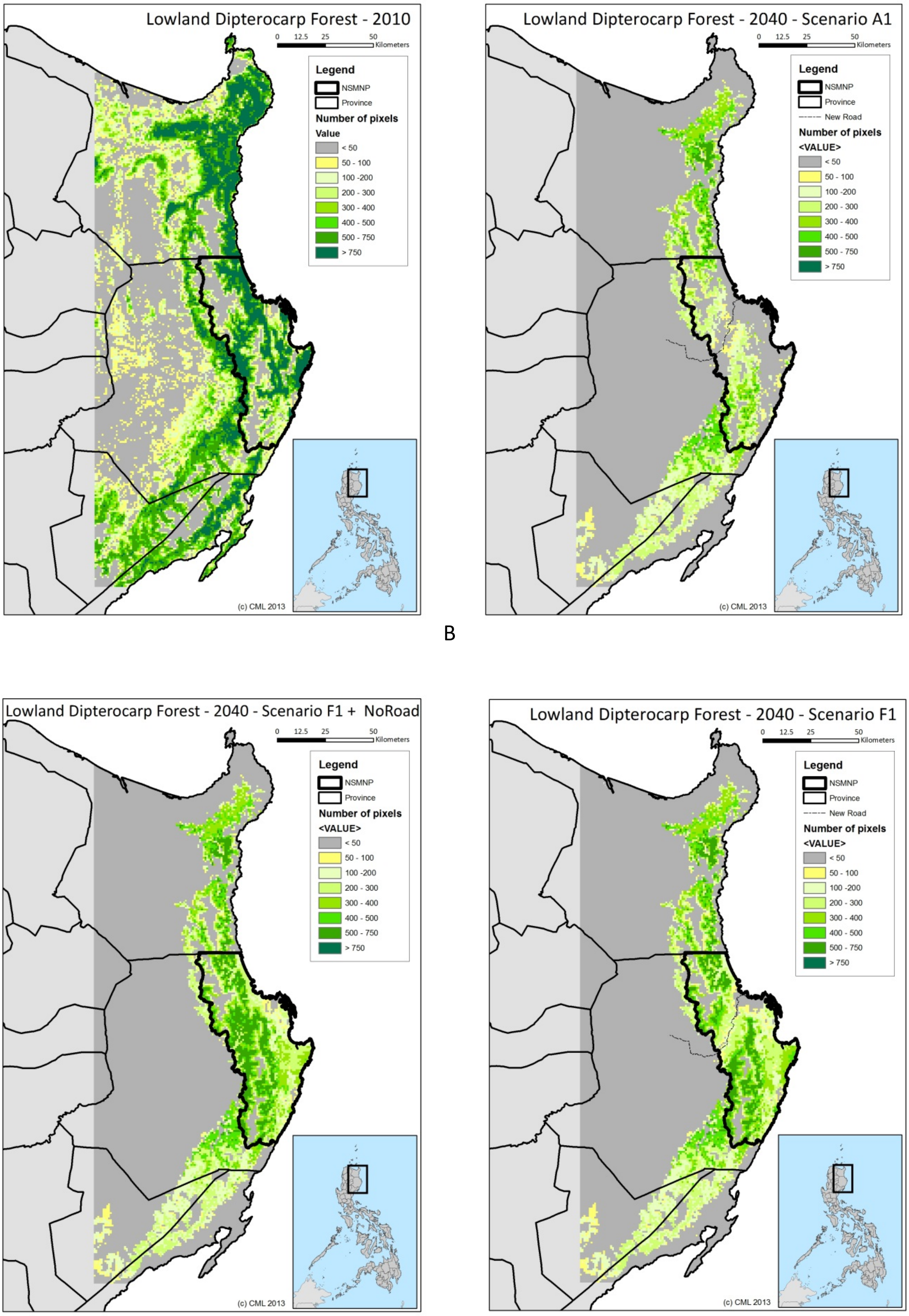
Comparing the 2010 map with the 2040-scenario maps (Figure 8), the most significant changes in land use are in the areas outside the park where most lowland Dipterocarp forest is converted into agriculture. Also inside the park, a reduction in Dipterocarp forest can be clearly seen and this is most evident in the A1- with road scenario map (Figure 8B) and least in the F1- No Road scenario map (Figure 8C). Moreover, the lowland Dipterocarp forest zone moves slope-upward along the mountain range inside the park, which is most evident in the F1 and F1 –No Road scenario maps (Figure 8C and BD), with grey-colored units turning yellowish green. The impact of the planned road crossing the park is clearly visible, leading to a reduction in Dipterocarp forest (Figure 8B and 8D).

3.1.2. Montane and Mossy Forests (2010 – 2040)

For the montane and mossy forests, the changes between the 2010 map and the 2040 scenario maps (Figure 9) are less pronounced compared to those for lowland Dipterocarp forest (Figure 8). For Montane forests (Figure 8D), there is however a clear reduction along the south-western part outside the park, although the distribution of this forest types in the region remains more or less the same.

For the mossy forests (Figure 8C and 8D), the maps show an increase for areas inside the park and along the northern part, outside the park, whereas in other areas (southern part, outside park) there is a reduction. The former (increase) correspond to areas at higher elevation (see Figure 3B).

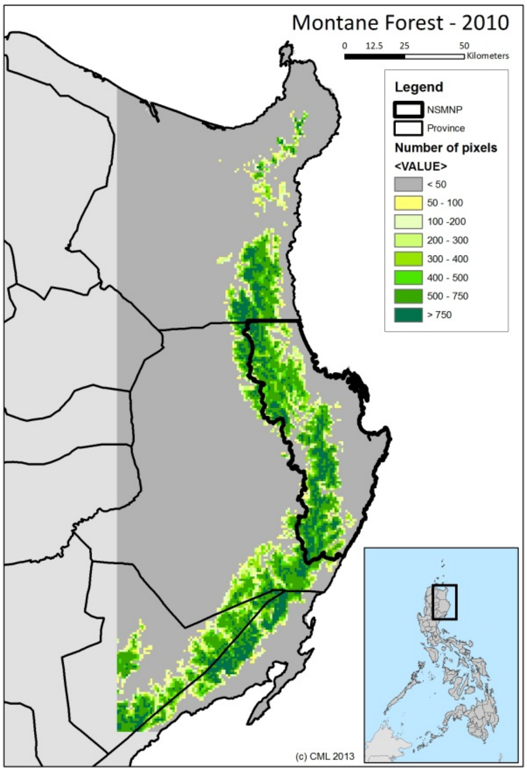
Tables 6A and 6B gives more detailed information on the predicted impacts of climate change on all agricultural and forest land use types including corn, grassland, mosaic landscape (mixture of forest patches, banana, grassland, corn, and rice) and ultrabasic forest, for all scenarios. The summed forest class figures show a considerable decrease in forest, even within the park a decline of ca. 18% (despite an increase for mossy forest) has been predicted for the F1-NR scenario representing climate-only effects. Yet, for agriculture, considerable increases can be observed, particularly for corn, for all land use scenarios. The worst case scenario A1 also shows remarkable increases in grassland, mosaic landscape and rice, in addition to corn, at the costs of forest.



A B

C D

Figure 8: The (projected) distributions of Lowland Dipterocarp forest under present (A) and climate change conditions with (B and C) and without (D) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).



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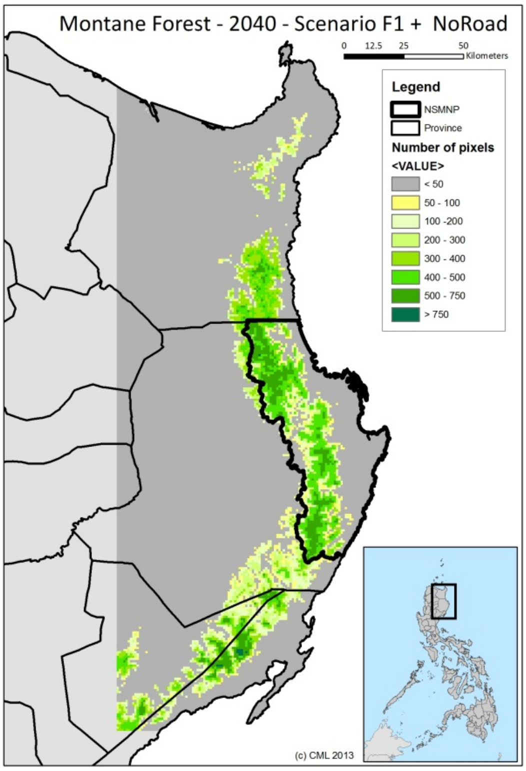

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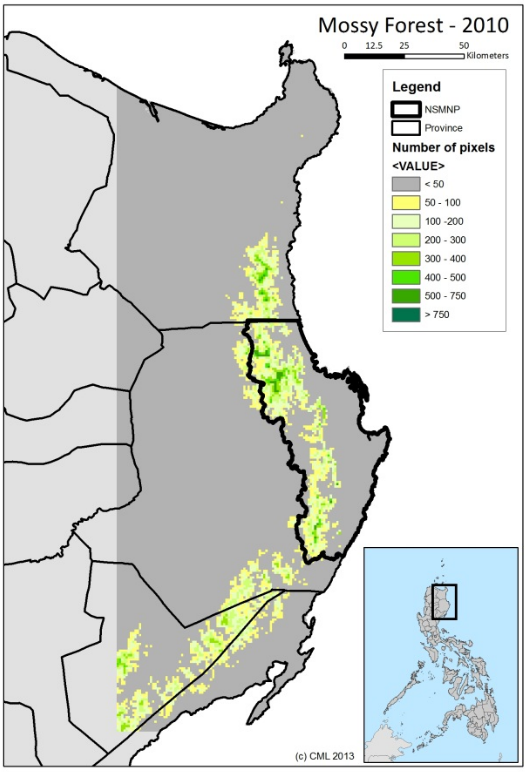

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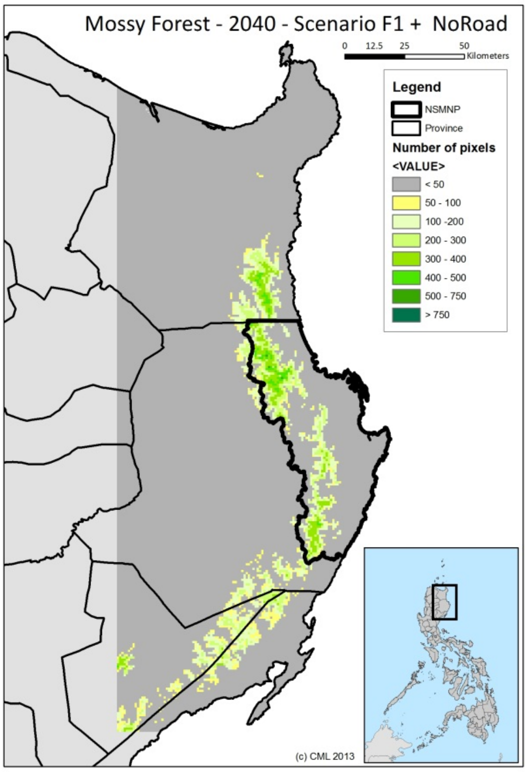

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Figure 9: The (projected) distributions of Montane Forest (A, B) and Mossy Forest (C, D) under present (A, C) and climate change conditions (B, D) without a planned road crossing the park (Scenario F1: forest projected as dominant land use over agriculture in park).

Table 6A: Predicted area for various land use types under conditions of climate change, modeled for three land use change scenarios (F1 – NR: no planned (park-crossing) road and forest predominates; F1:with planned road and forests predominates; A1: with planned road and agriculture predominates)

(Predicted) area in km2	2010		2040 F1 - NR		2040 F1		2040 A1	
	Park	Buffer	Park	Buffer	Park	Buffer	Park	Buffer
Corn	31,2	98,7	508,0	1289,3	427,1	1278,1	1074,2	1278,1
Grassland	55,9	524,6	56,5	597,5	151,8	602,7	302,2	602,7
Mosaic Landscape	40,3	768,1	56,9	498,8	151,2	516,8	299,4	516,8
Rice	23,6	124,0	51,3	358,2	84,4	354,7	183,6	354,7
Lowland Dipterocarp Forest	1316,3	1200,6	1062,6	368,5	929,2	362,7	345,3	362,7
Montane Forest	929,9	669,8	658,9	311,6	680,1	309,5	418,9	309,5
Mossy Forest	204,5	100,2	225,4	121,1	198,1	120,5	137,2	120,5
Ultrabasic Forest	376,9	43,1	376,9	26,8	376,9	26,9	237,9	26,9
Sum 4 Forest classes	2827,5	2013,8	2323,8	827,9	2184,3	819,6	1139,3	819,6
Sum 4 Agriculture classes	150,9	1515,4	672,7	2743,8	814,5	2752,3	1859,4	2752,3
Total (including other classes, e.g. urban)	3078,2	3702,6	3078,2	3702,6	3078,2	3702,6	3078,2	3702,6

Table 6B: Predicted change (%) in area for various land use types under conditions of climate change, modeled for three land use change scenarios (F1 – NR: no planned (park-crossing) road and forest predominates; F1: with planned road and forests predominates; A1: with planned road and agriculture predominates)

Change in percentage from 2010	2040 F1 - NR		2040 F1		2040 A1	
	Park	Buffer	Park	Buffer	Park	Buffer
Corn	1530,3	3820,8	1270,6	3784,9	3347,6	3784,9
Grassland	1,2	130,6	171,7	139,8	440,9	139,8
Mosaic Landscape	41,0	-667,8	275,0	-623,2	642,6	-623,2
Rice	117,6	992,3	257,6	977,7	677,9	977,7
Lowland Dipterocarp Forest	-19,3	-63,2	-29,4	-63,7	-73,8	-63,7
Montane Forest	-29,1	-38,5	-26,9	-38,8	-55,0	-38,8
Mossy Forest	10,2	10,2	-3,1	9,9	-32,9	9,9
Ultrabasic Forest	0,0	-4,3	0,0	-4,3	-36,9	-4,3
Sum 4 Forest classes	-17,8	-41,9	-22,7	-42,2	-59,7	-42,2
Sum 4 Agriculture classes	345,7	813,8	439,6	819,4	1131,8	819,4
Total (including other 4 classes)	0,0	0,0	0,0	0,0	0,0	0,0

3.2. Impact of climate change and land use on bird species distribution

Figure 10, 11 and 12 show the predicted 2040 outcome of the species distributions for the three bird species categories (forest bird species, endemic species and red list species) and the three climate and land use change scenarios. Table 7 summarizes the predicted changes for the period 2010 - 2040. The results are discussed per category in the section below.

3.2.1. Forest bird species

Scenario A1 shows a large decrease in forest bird species: over 60% and 70% for the park and buffer zone respectively. For the scenarios with a planned road crossing the park, reduction in forest species is visible along both sides of the new road. The climate-only effects, as represented by scenario F1-NR in Figure 10C, correspond to a bird species reduction of 20% within the park (Table 7). Yet outside the park, where factors other than climate play a role as well, reductions are considerably larger, i.e., up to 73%. These differences within and outside the park suggest, however, that park protection still matters although reductions by climate change do occur!

3.2.2. Endemic bird species

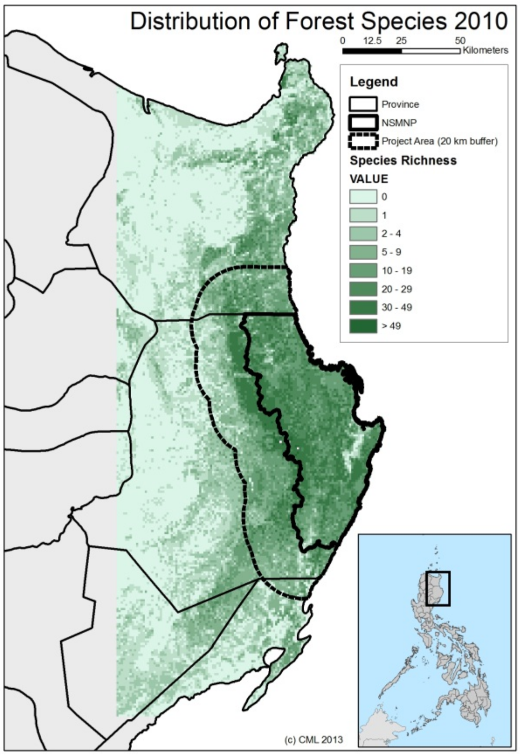
The results of the endemic species distributions are comparable to those of the forest bird species described above, with most species occurring within the boundaries of the forested park, for all scenarios.

3.2.3. Red list bird species

For the Red list species, it is evident that the models predict very few species outside the park by 2040 (a decrease of over 90%). In the case of the A1 scenario, also within the park the occurrence of red list species is limited. In addition, the F1-NR and F1 scenarios (Figure 12C and D) show a clear effect of climate change within the park boundaries: red list species move slope upward

3.2.4. All species

Tables 8 and 9 further show the bird species with the highest increase and the highest decline for the A1 scenario. In the first Table, it becomes evident that the highest decline occurs among forest and endemic species, with 4 of the 23 species listed expected to be recorded as “Red list” species by 2040. When compared to the F1-NR (climate –only) scenario, it becomes evident that also in the case of climate change only the species are predicted to reduce in numbers (although to a more limited extent). Table 9 lists the species with the highest incline for the same A1 scenario. It is evident that almost all are non-forest species, i.e., species that typically occur in open areas or areas with various habitats. When comparing the A1 with the F1-NR scenario, most (except 4) species are predicted to increase although for a much lower number of gridcells.



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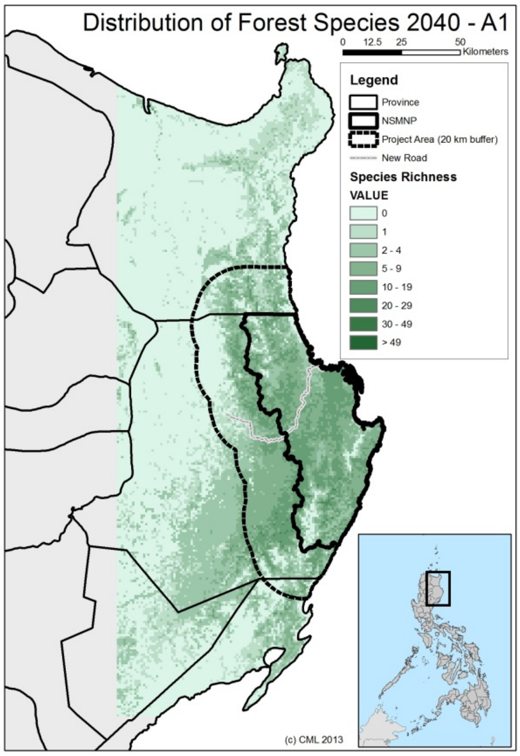

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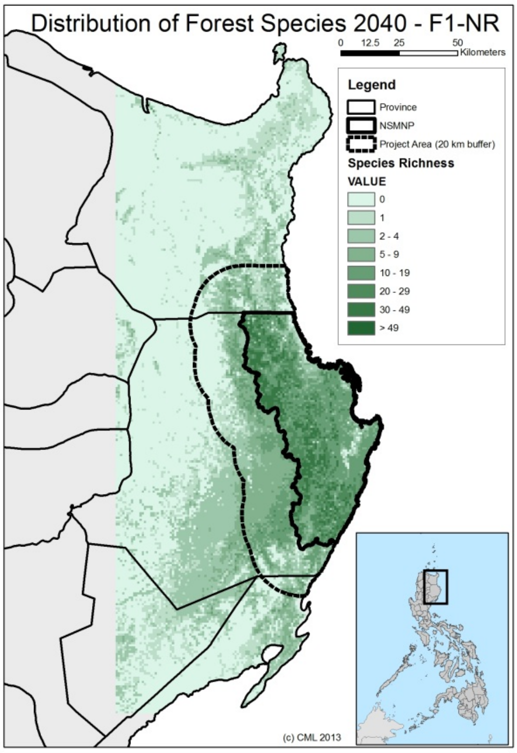

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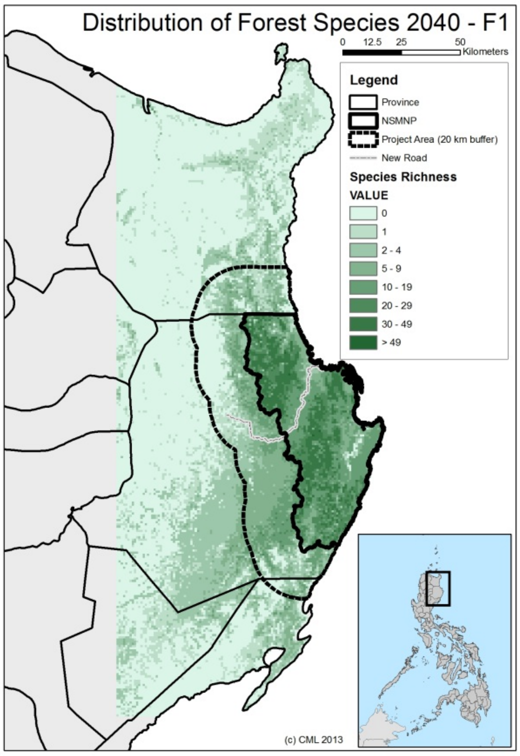
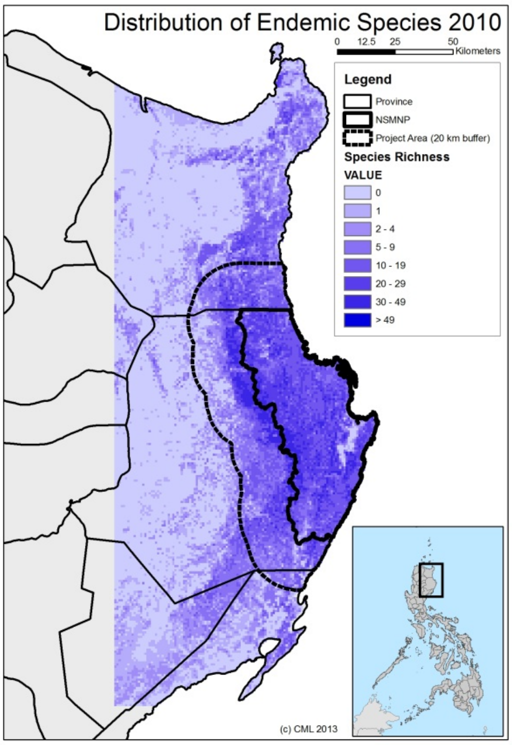


D

Figure 10: The (projected) forest bird species distributions under present (A) and climate change conditions with (B, D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).



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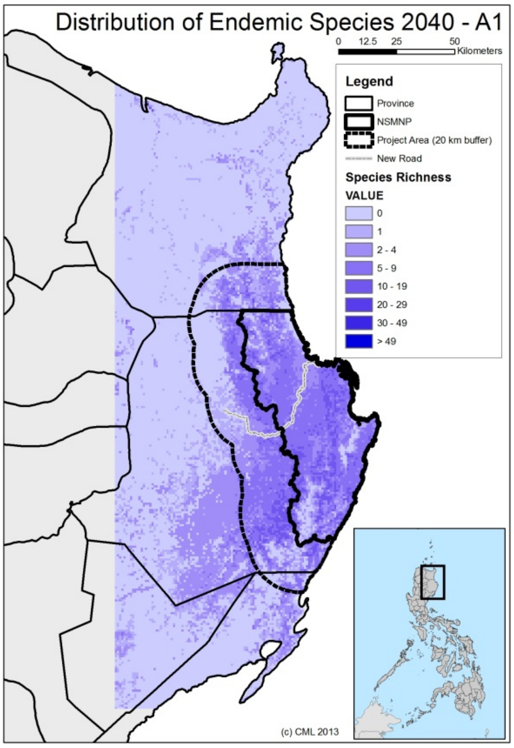

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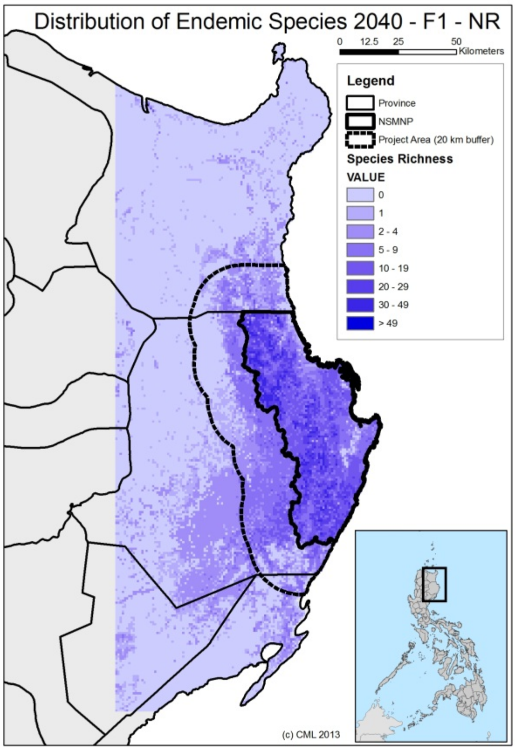

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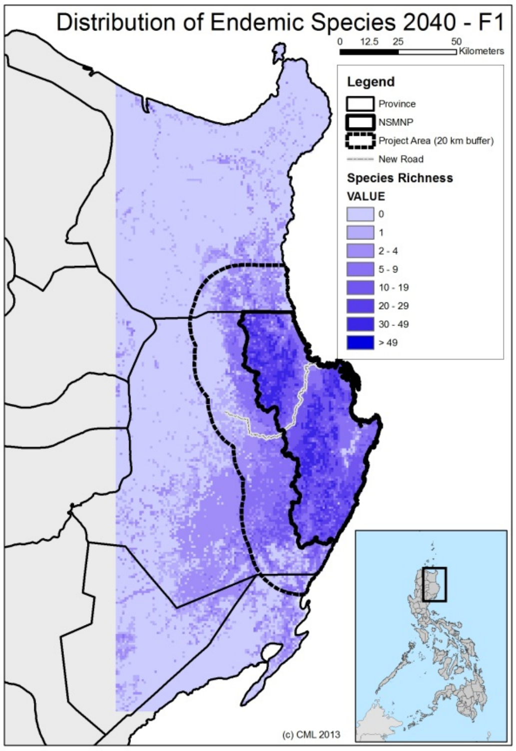


D

Figure 11: The (projected) endemic bird species distributions under present (A) and climate change conditions with (B, D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).

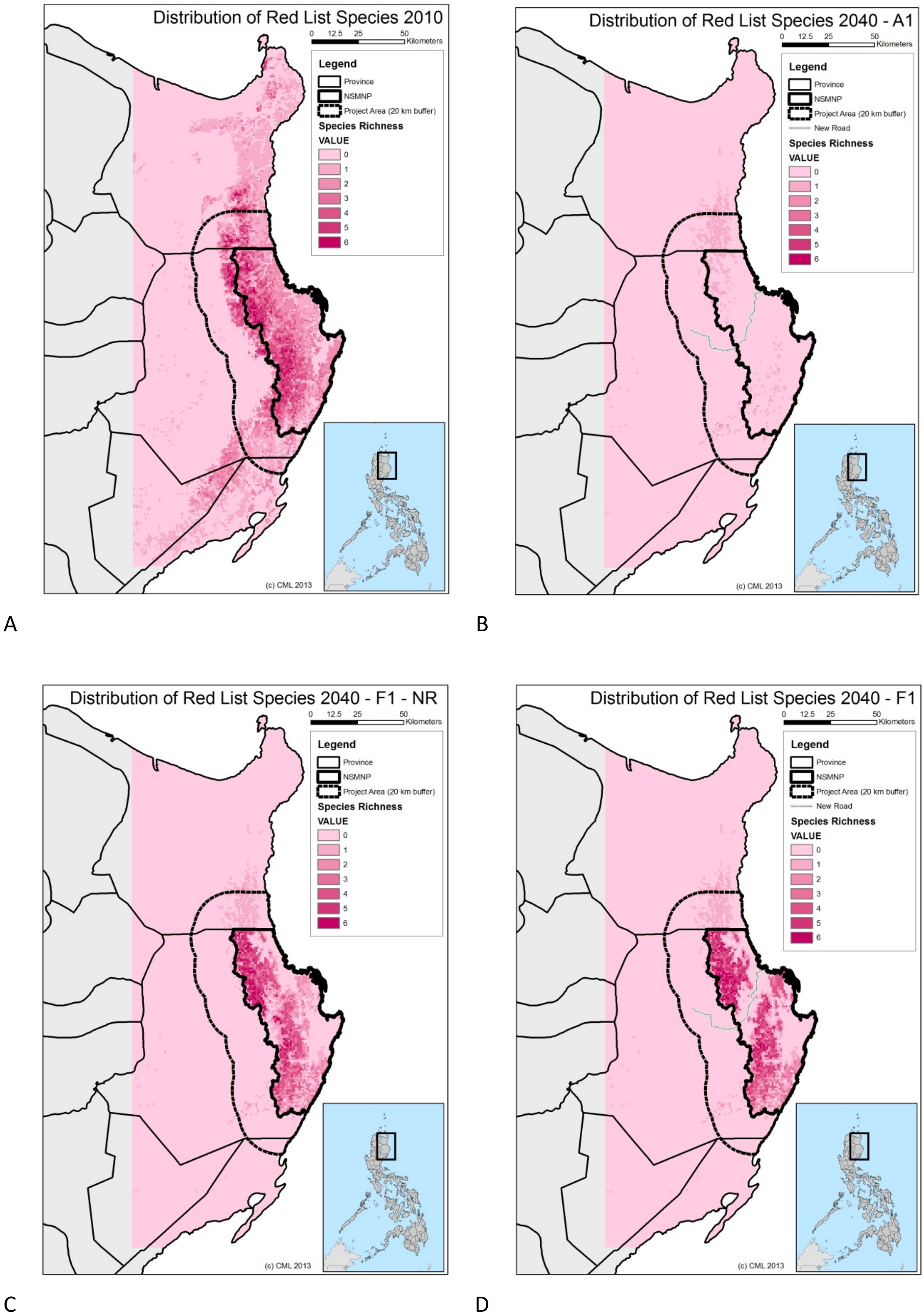


Figure 12: The (projected) red list bird species distributions under present (A) and climate change conditions with (B,D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).

*Table 7: Percentage of change during 2010-2040 in species-index**

Category	2040 F1 – NR		2040 A1	
	Park	Buffer	Park	Buffer
Forest species	-20,0	-73,5	-65,2	-73,2
Endemic species	-21,9	-76,9	-69,6	-76,8
Red List Species	-22,6	-96,2	-97,2	-96,3

**species index = sum of the species richness per grid cell for each category*

Table 8: Species with highest decline in predicted presence in NSMNP for the 2010 - 2040 period

SPECIES	English Name	Habitat	Endemism	Red List	Present 2010 (No of cells)*	A1 2040 (No of cells)*	A1 2010 - 2040 (% change)	F1 - NR 2040 (No of cells)*	F1-NR 2010 - 2040 (% change)
325	Philippine Trogon	F	E	LR	2839	0	-100	1305	-54
395	Yellow-wattled Bulbul	F	E	LR	2574	0	-100	768	-70
591	Bicolored Flowerpecker	F	E	LR	1955	0	-100	1134	-42
329	Indigo-banded Kingfisher	F	E	LR	1944	0	-100	929	-52
414	Philippine Fairy-Bluebird	F	E	LR	1914	0	-100	1047	-45
423	Stripe-headed Rhabdornis	F	E	LR	1760	0	-100	854	-51
297	Philippine Hawk-Owl	F	E	LR	1738	0	-100	663	-62
302	Great Eared Nightjar	V	NOE	LR	1671	0	-100	698	-58
293	Philippine Scops-Owl	F	E	LR	1664	0	-100	1559	-6
422	Sulphur-billed Nuthatch	F	E	LR	1587	0	-100	1240	-22
576	Flaming Sunbird	F	E	LR	1520	0	-100	853	-44
355	Rufous Hornbill	F	E	NT	1484	0	-100	1168	-21
223	Cream-bellied Fruit-Dove	F	E	NT	1352	0	-100	1076	-20
436	Golden-crowned Babbler	F	E	NT	1328	0	-100	1111	-16
545	Yellow-bellied Whistler	F	E	LR	1312	0	-100	1084	-17
357	Philippine Pygmy Woodpecker	F	E	LR	1107	0	-100	620	-44
604	Yellowish White-eye	F	E	LR	1092	0	-100	601	-45
361	White-bellied Woodpecker	F	NOE	LR	1074	0	-100	521	-51
416	Slender-billed Crow	F	NOE	LR	1037	0	-100	874	-16
272	Rusty-breasted Cuckoo	F	NOE	LR	985	0	-100	343	-65
528	Blue-breasted Flycatcher	F	E	LR	953	0	-100	684	-28
362	Greater Flameback	F	NOE	LR	644	0	-100	225	-65
368	Whiskered Pitta	F	E	VU	426	0	-100	417	-2

**: number of predicted grid cells in which bird species present*

Table 9: Species with highest incline in predicted presence in NSMNP for the 2010 - 2040 period

Species	English Name	Habitat	Endemism	Red List	Present 2010 (No of cells)*	A1 2040 (No of cells)*	A1 2010 - 2040 (% change)	F1 - NR 2040 (No of cells)*	F1 - NR 2010 - 2040 (% change)
617	Scaly-breasted Munia	O	NOE	LR	13	922	6992	69	431
499	Bright-capped Cisticola	O	NOE	LR	10	660	6500	66	560
240	Spotted Dove	O	NOE	LR	5	313	6160	81	1520
458	Pied Bushchat	O	NOE	LR	27	927	3333	101	274
373	Barn Swallow	V	NOE	LR	25	857	3328	45	80
530	Mangrove Blue Flycatcher	V	NOE	LR	30	769	2463	171	470
481	Great Reed-Warbler	O	NOE	LR	27	546	1922	22	-19
484	Tawny Grassbird	O	NOE	LR	5	80	1500	10	100
239	Red Turtle-Dove	O	NOE	LR	8	91	1038	27	238
485	Striated Grassbird	O	NOE	LR	18	126	600	61	239
574	Olive-backed Sunbird	V	NOE	LR	107	687	542	166	55
554	White-breasted Wood-swallow	O	NOE	LR	94	569	505	57	-39
615	White-bellied Munia	V	NOE	LR	191	1014	431	742	288
557	Brown Shrike	V	NOE	LR	182	913	402	611	236
386	Pied Triller	V	NOE	LR	75	335	347	34	-55
618	Chestnut Munia	O	NOE	LR	243	1072	341	514	112
394	Yellow-vented Bulbul	V	NOE	LR	302	1320	337	1156	283
539	Black-naped Monarch	F	NOE	LR	318	1360	328	780	145
555	Long-tailed Shrike	O	NOE	LR	9	38	322	46	411
595	Red-keeled Flowerpecker	V	E	LR	119	388	226	30	-75
387	Ashy Minivet	F	NOE	LR	94	301	220	46	-51
337	White-throated Kingfisher	V	NOE	LR	698	2137	206	1401	101
568	Coleto	F	E	LR	880	2055	134	2091	138
241	Zebra Dove	O	NOE	LR	64	144	125	271	323

**: number of predicted grid cells in which bird species present*

3.3. Impact of climate change and land use on individual bird species: some examples

Figures 13, 14 and 15 show distributions of individual bird species for 2010 and the three climate and land use scenarios. Two species typically occur in a forest environment, i.e., the montane species Luzon Racquet Tail (*Prioniturus montanus*) and the lowland forest Rufous Coucal (*Centropus unirufus)*, and one species is characteristic for open and mosaic landscapes: the Spotted Dove (*Stigmatopelia chinensis).*

The Luzon Racquet Tail in Figure 13 has clearly a preference for montane forest areas in the NSMNP. Under the A1 scenario, this bird species is predicted to completely disappear from the park, whereas for other two F1 scenarios this is not the case. The Rufous Coucal in Figure 14 is also predicted to decrease under the A1 scenario. Under the F1 scenarios, the species remains present particularly in lowland Dipterocarp forest areas. The F1 scenario (Figure 14D) shows that the species is predicted to be extremely vulnerable to the planned road. The Spotted Dove, typically occurring in mosaic landscapes, hardly occurs within the park in 2010, yet, under scenarios A1 (Figure 15B) and F1 (Figure 15D) the bird species is predicted to follow the planned road, making use of opened up areas.

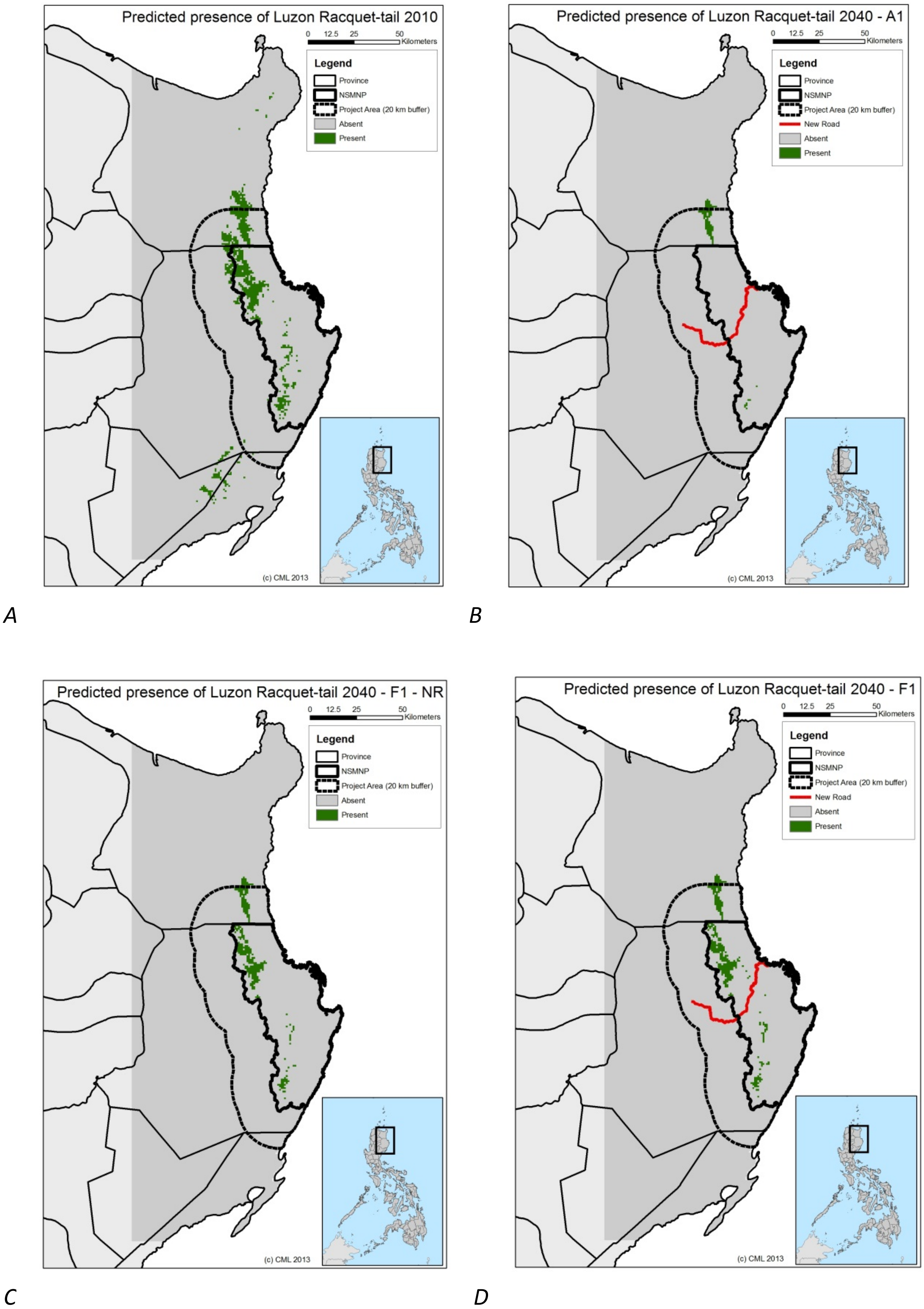
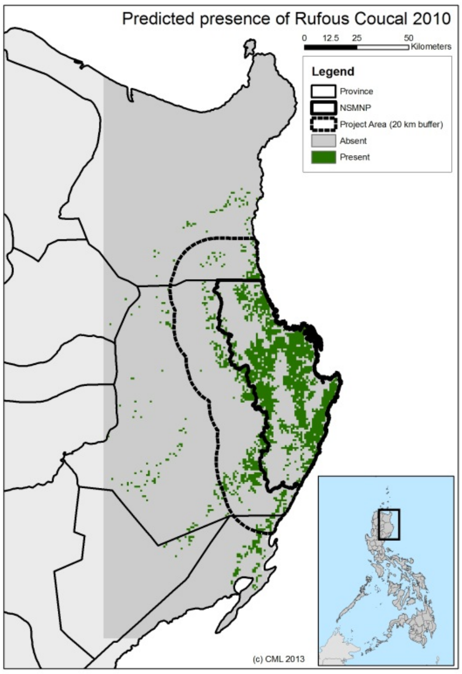
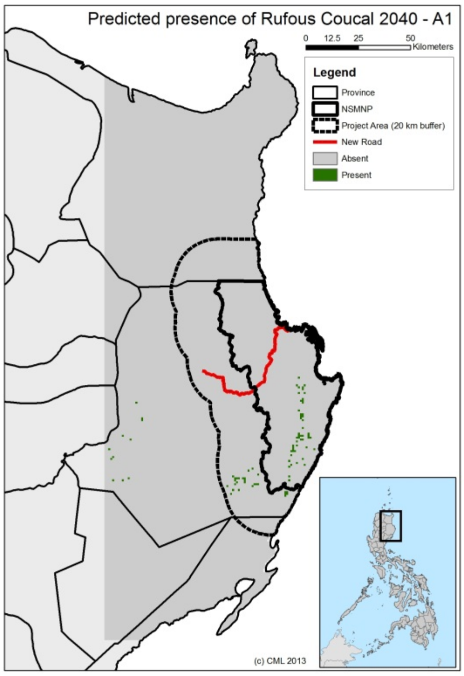


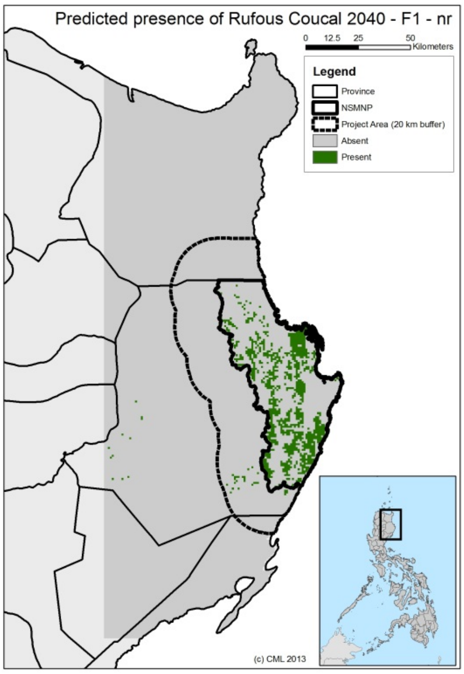
Figure 13: The (projected) distributions of the Luzon Racquet Tail (Prioniturus montanus; montane forest bird) under present (A) and climate change conditions with (B,D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).



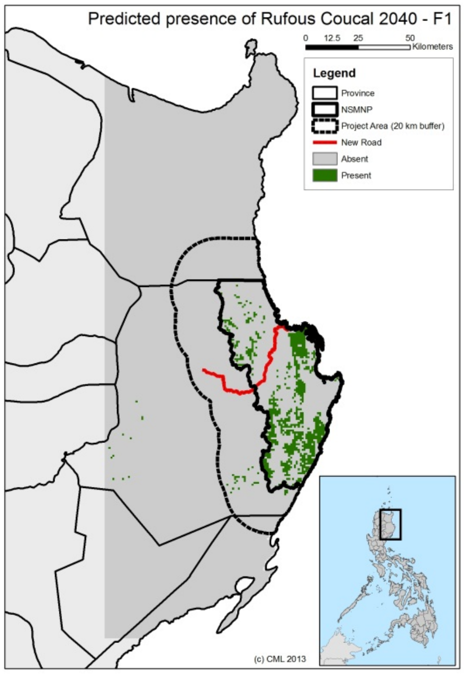
A



B



C



D

Figure 14: The (projected) distributions of the Rufous Coucal (Centropus unirufus; lowland forest bird) under present (A) and climate change conditions with (B,D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).

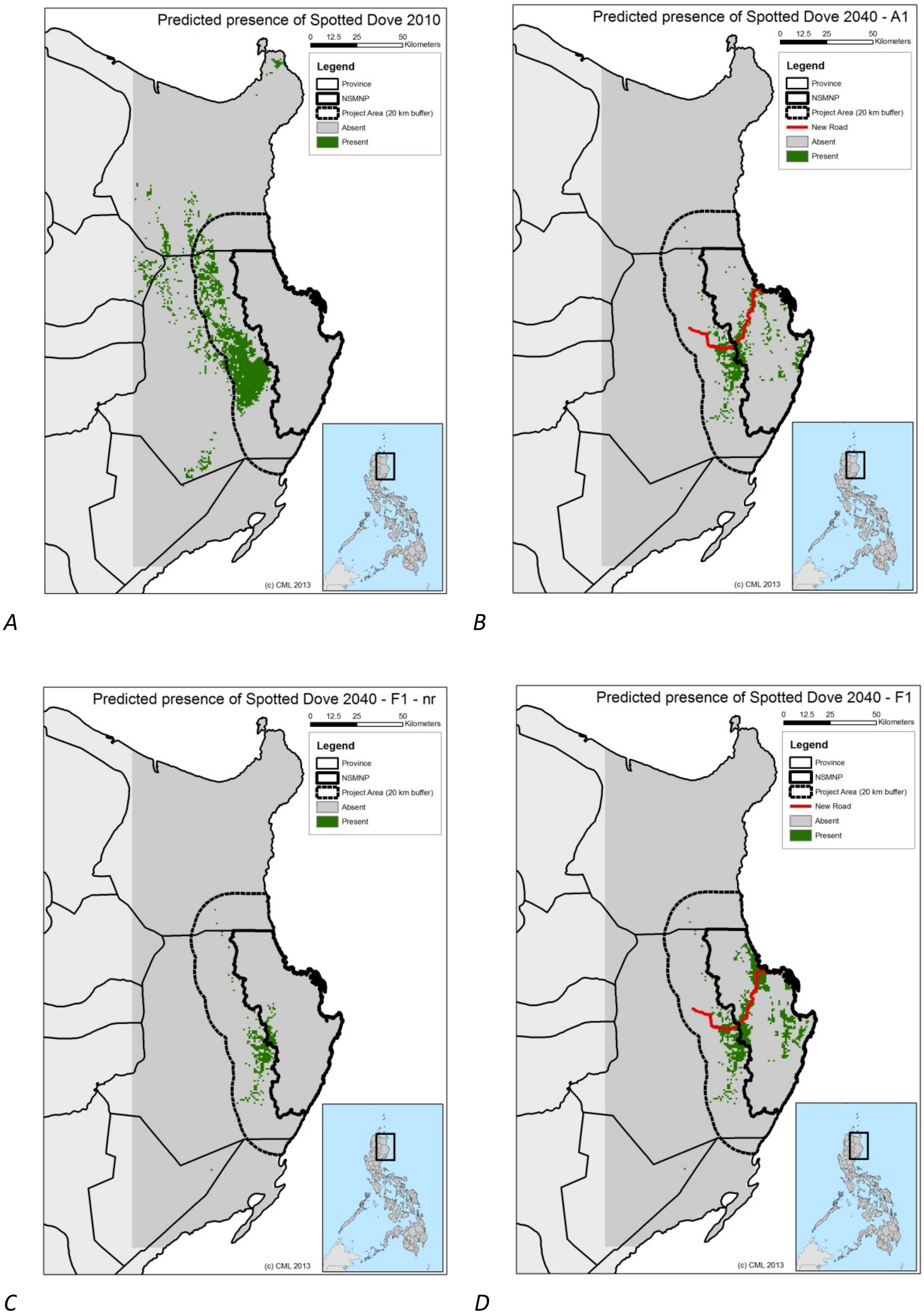


Figure 15: The (projected) distributions of the Spotted Dove (Stigmatopelia chinensis; non-forest bird) under present (A) and climate change conditions with (B,D) and without (C) a planned road crossing the park (Scenario A1: agriculture dominant over forest in park; F1: forest dominant over agriculture in park).

4. Conclusions and discussion

This study focused on the consequences of projected climate change by 2040 for nature in the Northern Sierra Madre Natural Park and surroundings, especially forest types and bird species. Climate change is projected to not only influence the distribution of bird species but also possible land use, like agriculture. So, larger parts of the high-altitude region may become more suitable for agriculture and on the lower parts there are shifts in agricultural land use to be expected. Also the planned construction of a main road crossing the Northern Sierra Madre Mountain Range and dissecting the park is expected to have a major influence on land use, creating easy new access points for logging and land transitions: a turn over from natural areas to anthropogenically influenced areas. Climate change further influences the distribution of forest bird habitats, especially the mountainous forest types, which shift upwards due to increasing temperature.

So, climate change not only influences bird species directly, but also indirectly by changing land use and shifts of habitats. This was investigated by modeling the impacts of climate and land use change under three scenarios: A1: agricultural land use is dominant over forest habitat types even within the NSMNP plus the impact of a new main road; F1: forest habitat types are dominant within the NSMNP (but not outside) plus the moderate impact of a planned new main road and finally; F1-nr: the same as F1 but without the new main road. It has to be stressed that the complete agricultural dominance approach for A1 is a worst case scenario (in which the park is not protected at all against agricultural development) whereas the forest protection approach for F1 can be considered as the “standard” case scenario for the park.

The results show that in all scenarios lowland Dipterocarp forest is strongly declining probably because of transitions of natural forested areas into (climate-change induced) agricultural land use and distance to road-effects.. A decline will also happen within large parts of the NSMNP under scenario A1 (agriculture first). The mountainous forest types showed an upward shift and, for the montane forests, a slight decline in area in scenario F1 (forest first). The scenario with and without planned road crossing the mountain ridge shows the strong effects of the road construction and its radiating effects on land use.

The effects of climate and land use changes on bird species distribution are partly following the changes in forest habitats: under the A1 scenarios, the models predict a considerable decrease in most forest bird species. The same is true for the endemic and the red list bird species. For the F1 scenarios, with forest dominant over agriculture within the park, the changes are less severe. In fact most of the forest species are predicted to survive inside the NSMNP where they are protected against land use changes. Yet, the construction of the planned new road will be clearly visible in terms of reduced bird species. In case of no road construction in the park, climate change effects are still predicted to reduce bird species, but to a lower extent, and cause red list species to move slope upward.

This study includes for the first time the effects of (climate-induced) changed land use on forest habitats and includes the impact of (climate-induced) habitat changes on birds. In most studies the consequences of potential infrastructural works are not included, as done in this study that uses an overall innovative approach to model a realistic future scenario. It could be assumed that forest habitats should (largely) be protected in protected areas but the daily practice is that this is often not the case (e.g., Van der Ploeg et al 2011). Hence, the F1 scenario (forest first) for the NSMNP is probably too positive on the future protection of forest habitats within the park boundaries

It might be surprising that the decline of mountainous forest is not large or even absent (mossy forest) but this has several reasons. In the first place, the forest shows persistence (ecological inertia) against changes. In the second places, mountainous areas are in absolute area much smaller than the lowland areas. Finally, scenarios used in this study are for the nearby future, 2040. Other studies used often 2100 for their scenarios with much larger changes to expect. Future climate change after 2040 will result in a stronger decrease because the potential areas will become progressively smaller.

When building models all sorts of assumptions have to be made, which are described in the materials and methods section. We provide here some suggestions to improve the modeling of the impact of climate change on forest habitats and birds in the NSMNP and Northern Luzon.

During bird modeling we assumed that the distribution of forest bird species for the area modeled was not biased. Further modeling should check this assumption. There are two common solutions to bias, 1) using a part of the region for background sampling and 2) using all the bird sampling points as background sampling. Only option 1 will be applicable because the number of bird sampling sites is relatively low.

A lot of effort has been put into bird surveys, which form the basis of the modeling. Despite that, it is clear from the bird survey locations map (Figure 1) that the number of bird sampling plots is relatively low, especially at higher elevations. Future bird surveys will have to focus on these difficult to reach areas.

Besides birds as response variables in the modeling, also some possible improvements for the environmental explanatory variables are possible. The climate data from Bioclim does not take into account the rain- shadow effects of the Sierra Madre mountain ridge. . On the NE monsoon side of the ridge the precipitation should be much higher and on the lee side (west) lower. In addition, the Bioclim data are based on only a few weather stations that are present in the region and hence fail to correctly represent the locally variable bioclimatic conditions of the study area. Also information on soil types was difficult to obtain. The presence of ultra-basic soils had to be derived from the presence of ultra-basic forests. Forest type mapping was now based on the interpretation of satellite images, but in future modeling the use of representative national forest type maps should be in place.

For the modeling of the impact of climate-induced land use we assumed absolute dominance of agriculture above forests. This is clearly a worst case approach. In future modeling the possibilities to use a more realistic sub dominance of agriculture above forests should be worked out.

5. Conservation recommendations

The results in this study once again stress the need to protect the forest habitats of the NSMNP and its surroundings for bird species and biodiversity conservation. Likewise, the integration of (a diversity of) trees in nearby buffer zone and agricultural areas will help avoid a worst case scenario in terms of habitat conversion and species decline, as sketched by the A1 scenario in this study. Whereas national and regional governments have the task to create a policy framework and an environment conducive to park protection, the implementation and monitoring of conservation measures strongly depends on the local government units (LGUs) and communities living in, near and close to the protected area. The activities conducted by the Mabuwaya Foundation as counterpart organization in the same project on *Mainstreaming Climate Change in Biodiversity Planning and Conservation in the Philippines* have been designed to help formulate climate-change adaptation strategies including measures for enhancing biodiversity conservation and to assist in building local capacity for doing so. Workshops for municipal governments covering the NSMNP were organized with the aim to develop climate change mitigation and adaptation plans. Likewise recommendations for follow up activities are defined including technical advice and support for integrating the municipal plans into the management plan of the NSMNP and also on-the-ground activities aimed at tree planting and reforestation through rainforestation and agroforestry plantations, integrating trees into farming systems.

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Appendix 1: Predicted changes and characteristics for all107 bird species encountered in the NSMNP and buffer zone

ID	English Name	Scientific Name	Habitat	Endemism	Red List	Present 2010 (No of cells)*	A1 2040 (No of cells)*	F1 2040 (No of cells)*	F1 - NR 2040 (No of cells)*	A1 2010-2040 (% change)	F1 2010-2040 (% change)	F1- NR 2010-2040 (% change)
27	Intermediate Egret	Mesophoyx intermedia	W	NOE	LR	93	0	2	9	-100	-98	-90
29	Little Egret	Egretta garzetta	W	NOE	LR	322	55	91	653	-83	-72	103
35	Cattle Egret	Bubulcus ibis	W	NOE	LR	8	0	0	0	-100	-100	-100
40	Cinnamon Bittern	Ixobrychus cinnamomeus	W	NOE	LR	649	0	10	9	-100	-98	-99
76	Brahminy Kite	Haliastur indus	O	NOE	LR	583	224	79	101	-62	-86	-83
87	Philippine Serpent-Eagle	Spilornis holospilus	F	E	LR	638	2	802	338	-100	26	-47
93	Philippine Hawk-Eagle	Spizaetus philippensis	F	E	VU	2188	185	1529	1705	-92	-30	-22
94	Philippine Falconet	Microhierax erythrogenys	F	E	LR	1442	537	1133	1519	-63	-21	5
101	Red Junglefowl	Gallus gallus	F	NOE	LR	1733	1495	1900	1911	-14	10	10
125	Plain Bush-hen	Amaurornis olivacea	O	NE	LR	1005	35	818	699	-97	-19	-30
126	White-breasted Waterhen	Amaurornis phoenicurus	V	NOE	LR	931	1271	1410	1337	37	51	44
218	White-eared Brown-Dove	Phapitreron leucotis	F	E	LR	1422	2813	2841	1845	98	100	30
219	Amethyst Brown-Dove	Phapitreron amethystinus	F	E	LR	2378	160	1493	1579	-93	-37	-34
223	Cream-bellied Fruit-Dove	Ptilinopus merrilli	F	E	NT	1352	0	1347	1076	-100	0	-20
224	Yellow-breasted Fruit-Dove	Ptilinopus occipitalis	F	E	LR	1244	1	786	604	-100	-37	-51
237	Philippine Cuckoo-Dove	Macropygia tenuirostris	F	NE	LR	368	3	1008	260	-99	174	-29
239	Red Turtle-Dove	Streptopelia tranquebarica	O	NOE	LR	8	91	244	27	1038	2950	238
240	Spotted Dove	Stigmatopelia chinensis	O	NOE	LR	5	313	508	81	6160	10060	1520
241	Zebra Dove	Geopelia striata	O	NOE	LR	64	144	349	271	125	445	323

ID	English Name	Scientific Name	Habitat	Endemism	Red List	Present 2010 (No of cells)*	A1 2040 (No of cells)*	F1 2040 (No of cells)*	F1 - NR 2040 (No of cells)*	A1 2010-2040 (% change)	F1 2010-2040 (% change)	F1- NR 2010-2040 (% change)
242	Common Emerald Dove	Chalcophaps indica	F	NOE	LR	417	607	1399	1022	46	235	145
250	Guaiabero	Bolbopsittacus lunulatus	F	E	LR	731	8	443	367	-99	-39	-50
259	Luzon Racquet-tail	Prioniturus montanus	F	E	NT	405	8	258	236	-98	-36	-42
262	Colasisi	Loriculus philippensis	F	E	LR	353	7	832	287	-98	136	-19
267	Hodgson's Hawk-Cuckoo	Cuculus fugax	F	NOE	LR	132	277	72	27	110	-45	-80
272	Rusty-breasted Cuckoo	Cacomantis sepulcralis	F	NOE	LR	985	0	294	343	-100	-70	-65
276	Common Koel	Eudynamys scolopaceus	F	NOE	LR	700	1048	1257	1102	50	80	57
277	Scale-feathered Malkoha	Phaenicophaeus cumingi	F	E	LR	924	1624	1538	1545	76	66	67
279	Red-crested Malkoha	Phaenicophaeus superciliosus	F	E	LR	1665	418	1684	1722	-75	1	3
282	Lesser Coucal	Centropus bengalensis	O	NOE	LR	373	3	234	160	-99	-37	-57
283	Philippine Coucal	Centropus viridis	V	E	LR	442	766	1363	1016	73	208	130
285	Rufous Coucal	Centropus unirufus	F	E	NT	1526	51	851	1028	-97	-44	-33
293	Philippine Scops-Owl	Otus megalotis	F	E	LR	1664	0	1403	1559	-100	-16	-6
297	Philippine Hawk-Owl	Ninox philippensis	F	E	LR	1738	0	306	663	-100	-82	-62
302	Great Eared Nightjar	Eurostopodus macrotis	V	NOE	LR	1671	0	579	698	-100	-65	-58
308	Grey Swiftlet	Collocalia amelis	V	NE	LR	425	0	0	0	-100	-100	-100
314	Glossy Swiftlet	Collocalia esculenta	V	NOE	LR	2175	16	1679	1791	-99	-23	-18
319	Purple Needletail	Hirundapus celebensis	V	NOE	LR	1771	3	766	801	-100	-57	-55
325	Philippine Trogon	Harpactes ardens	F	E	LR	2839	0	1233	1305	-100	-57	-54
329	Indigo-banded Kingfisher	Alcedo cyanopectus	F	E	LR	1944	0	836	929	-100	-57	-52
337	White-throated Kingfisher	Halcyon smyrnensis	V	NOE	LR	698	2137	1657	1401	206	137	101
341	Spotted Wood-Kingfisher	Actenoides lindsayi	F	E	LR	2244	931	1915	1724	-59	-15	-23
343	Blue-throated Bee-eater	Merops viridis	O	NOE	LR	127	2	441	50	-98	247	-61
344	Blue-tailed Bee-eater	Merops philippinus	O	NOE	LR	48	1	4	5	-98	-92	-90
346	Luzon Hornbill	Penelopides manillae	F	E	LR	1701	255	1840	1569	-85	8	-8

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355	Rufous Hornbill	Buceros hydrocorax	F	E	NT	1484	0	1364	1168	-100	-8	-21
356	Coppersmith Barbet	Megalaima haemacephala	F	NOE	LR	920	248	1143	994	-73	24	8
357	Philippine Pygmy Woodpecker	Dendrocopos maculatus	F	E	LR	1107	0	1102	620	-100	0	-44
359	Sooty Woodpecker	Mulleripicus funebris	F	E	LR	1931	141	1671	1281	-93	-13	-34
361	White-bellied Woodpecker	Dryocopus javensis	F	NOE	LR	1074	0	620	521	-100	-42	-51
362	Greater Flameback	Chrysocolaptes lucidus	F	NOE	LR	644	0	825	225	-100	28	-65
368	Whiskered Pitta	Pitta kochi	F	E	VU	426	0	607	417	-100	42	-2
373	Barn Swallow	Hirundo rustica	V	NOE	LR	25	857	380	45	3328	1420	80
375	Striated Swallow	Hirundo striolata	O	NOE	LR	4	2	3	0	-50	-25	-100
379	Bar-bellied Cuckoo-shrike	Coracina striata	F	NOE	LR	2394	208	1630	1799	-91	-32	-25
380	Blackish Cuckoo-shrike	Coracina coerulescens	F	E	LR	1131	739	1624	687	-35	44	-39
385	Black-and-white Triller	Lalage melanoleuca	F	E	LR	1175	208	1020	1296	-82	-13	10
386	Pied Triller	Lalage nigra	V	NOE	LR	75	335	67	34	347	-11	-55
387	Ashy Minivet	Pericrocotus divaricatus	F	NOE	LR	94	301	82	46	220	-13	-51
394	Yellow-vented Bulbul	Pycnonotus goiavier	V	NOE	LR	302	1320	1508	1156	337	399	283
395	Yellow-wattled Bulbul	Pycnonotus urostictus	F	E	LR	2574	0	694	768	-100	-73	-70
399	Philippine Bulbul	Ixos philippinus	F	E	LR	2040	1016	2261	1735	-50	11	-15
407	Balicassiao	Dicrurus balicassius	F	E	LR	2428	1528	2521	2189	-37	4	-10
411	White-lored Oriole	Oriolus albiloris		E	LR	1613	348	1438	1414	-78	-11	-12
412	Black-naped Oriole	Oriolus chinensis	V	NOE	LR	326	555	740	736	70	127	126
414	Philippine Fairy-Bluebird	Irena cyanogastra	F	E	LR	1914	0	1469	1047	-100	-23	-45
416	Slender-billed Crow	Corvus enca	F	NOE	LR	1037	0	1020	874	-100	-2	-16
417	Large-billed Crow	Corvus macrorhynchos	O	NOE	LR	629	320	193	66	-49	-69	-90
419	Elegant Tit	Parus elegans	F	E	LR	984	36	1517	723	-96	54	-27
422	Sulphur-billed Nuthatch	Sitta oenochlamys	F	E	LR	1587	0	1141	1240	-100	-28	-22

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423	Stripe-headed Rhabdornis	Rhabdornis mystacalis	F	E	LR	1760	0	750	854	-100	-57	-51
436	Golden-crowned Babbler	Stachyris dennistouni	F	E	NT	1328	0	1138	1111	-100	-14	-16
438	Chestnut-faced Babbler	Stachyris whiteheadi	F	E	LR	361	0	203	222	-100	-44	-39
447	White-browed Shortwing	Brachypteryx montana	F	NOE	LR	297	0	351	213	-100	18	-28
452	Oriental Magpie-Robin	Copsychus saularis	F	NOE	LR	500	138	151	213	-72	-70	-57
453	White-browed Shama	Copsychus luzoniensis	F	E	LR	2474	2904	3158	2650	17	28	7
458	Pied Bushchat	Saxicola caprata	O	NOE	LR	27	927	760	101	3333	2715	274
477	Arctic Warbler	Phylloscopus borealis	F	NOE	LR	2742	3170	3162	2999	16	15	9
481	Great Reed-Warbler	Acrocephalus arundinaceus	O	NOE	LR	27	546	163	22	1922	504	-19
484	Tawny Grassbird	Megalurus timoriensis	O	NOE	LR	5	80	143	10	1500	2760	100
485	Striated Grassbird	Megalurus palustris	O	NOE	LR	18	126	390	61	600	2067	239
489	Philippine Tailorbird	Orthotomus castaneiceps	F	E	LR	1582	1777	2531	1847	12	60	17
499	Bright-capped Cisticola	Cisticola exilis	O	NOE	LR	10	660	409	66	6500	3990	560
528	Blue-breasted Flycatcher	Cyornis herioti	F	E	LR	953	0	1009	684	-100	6	-28
530	Mangrove Blue Flycatcher	Cyornis rufigastra	V	NOE	LR	30	769	675	171	2463	2150	470
532	Pied Fantail	Rhipidura javanica	V	NOE	LR	413	780	468	543	89	13	31
534	Blue-headed Fantail	Rhipidura cyaniceps	F	E	LR	1297	1133	2148	1104	-13	66	-15
539	Black-naped Monarch	Hypothymis azurea	F	NOE	LR	318	1360	1385	780	328	336	145
545	Yellow-bellied Whistler	Pachycephala philippinensis	F	E	LR	1312	0	1203	1084	-100	-8	-17
546	Grey Wagtail	Motacilla cinerea	V	NOE	LR	939	1	215	86	-100	-77	-91
547	Yellow Wagtail	Motacilla flava	O	NOE	LR	485	890	448	429	84	-8	-12
550	Paddyfield Pipit	Anthus rufulus	O	NOE	LR	655	5	31	23	-99	-95	-96
554	White-breasted Wood-swallow	Artamus leucorynchus	O	NOE	LR	94	569	303	57	505	222	-39
555	Long-tailed Shrike	Lanius schach	O	NOE	LR	9	38	315	46	322	3400	411
557	Brown Shrike	Lanius cristatus	V	NOE	LR	182	913	651	611	402	258	236

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568	Coleto	Sarcops calvus	F	E	LR	880	2055	2252	2091	134	156	138
569	Crested Myna	Acridotheres cristatellus	O	NOE	LR	653	1021	510	510	56	-22	-22
572	Plain-throated Sunbird	Anthreptes malacensis	V	NOE	LR	150	0	38	37	-100	-75	-75
574	Olive-backed Sunbird	Nectarinia jugularis	V	NOE	LR	107	687	422	166	542	294	55
575	Purple-throated Sunbird	Nectarinia sperata	V	NOE	LR	1018	73	693	682	-93	-32	-33
576	Flaming Sunbird	Aethopyga flagrans	F	E	LR	1520	0	645	853	-100	-58	-44
591	Bicolored Flowerpecker	Dicaeum bicolor	F	E	LR	1955	0	995	1134	-100	-49	-42
595	Red-keeled Flowerpecker	Dicaeum australe	V	E	LR	119	388	113	30	226	-5	-75
598	Orange-bellied Flowerpecker	Dicaeum trigonostigma	V	NOE	LR	782	2	241	245	-100	-69	-69
604	Yellowish White-eye	Zosterops nigrorum	F	E	LR	1092	0	1027	601	-100	-6	-45
615	White-bellied Munia	Lonchura leucogastra	V	NOE	LR	191	1014	937	742	431	391	288
617	Scaly-breasted Munia	Lonchura punctulata	O	NOE	LR	13	922	564	69	6992	4238	431
618	Chestnut Munia	Lonchura atricapilla	O	NOE	LR	243	1072	783	514	341	222	112

*: number of predicted grid cells in which bird species present

1: Habitat: W= water; O= open area; F= forest; V= various;

2: Endemism: E= endemic; NOE= not endemic; NE= near endemic;

3: Red List: LR= lower risk; NT= near-threatened; VU= vulnerable;