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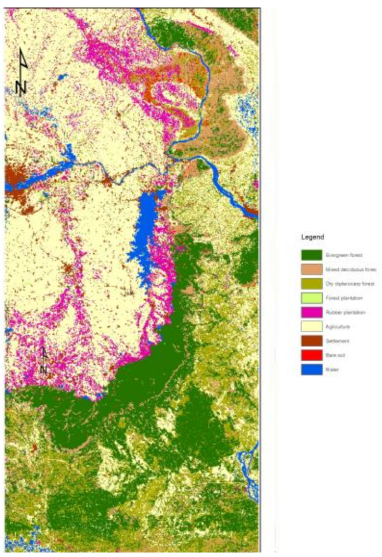
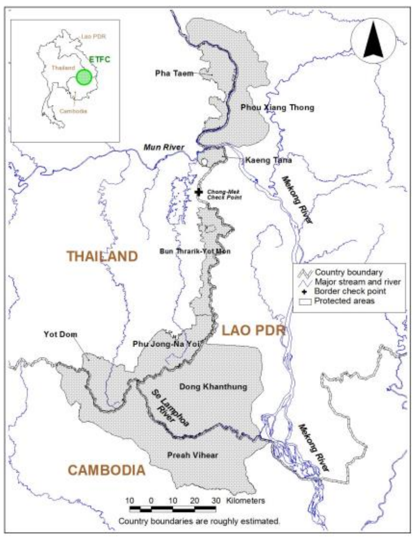
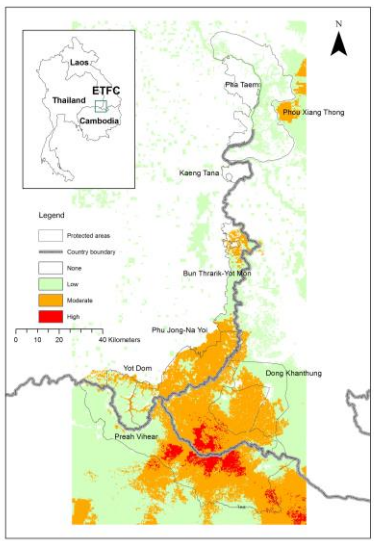
LAND USE CHANGE AND WILDLIFE DISTRIBUTION MODELING IN THE EMERALD TRIANGLE FOREST COMPLEX







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2015

ITTO Project PD 577/10 Rev.1 (F)

Management of the Emerald Triangle Protected Forests Complex to Promote Cooperation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase III)

Host Government

THE GOVERNMENT OF THAILAND

Executing Agency

THE ROYAL FOREST DEPARTMENT OF THAILAND

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ABBREVIATIONS

ADB	Asian Development Bank
AEC	ASEAN Economic Community
ASTER	The Advanced Spaceborne Thermal Emission and Reflection Radiometer
AUC	Area under curve
CLUE	Conversion of Land Use and its Effects
ETFC	Emerald Triangle Forests Complex
FA	Forest Administration
GDP	Gross Domestic Product
GIS	Geographic information system
GLM	Generalized Linear Models
GMS	Greater Mekong Sub-region
GPS	Global Positioning System
ITTO	International Tropical Timber Organization
KU	Kasetsart University
LU/LC	Land-use/Land-cover
MAXENT	Maximum Entropy Method
NBCA	National Biodiversity Conservation Area
PPFC	Pha Taem Protected Forests Complex
PVPF	Preah Vihear Protected Forest for the Conservation of Genetic Resources of Plants and Wildlife
RFD	Royal Forest Department
TBCAs	Trans-boundary Biodiversity Conservation Areas
TORs	Term of References

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ACKNOWLEDGEMENTS

The GIS Consultant would like to thank the Government of Japan and International Tropical Timber Organization (ITTO) to provide financial and technical support for implementation of the Management of the Emerald Triangle Protected Forests Complex to Promote Cooperation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Lao PDR (Phase III) Project number: PD 577/10 Rev. 1 (F), respectively. The kind cooperation and support of all Superintendents and the Emerald Triangle project staff from Thailand, Lao PDR and Cambodia are greatly appreciated during field work, training and preparation of this report. We are grateful to the Mekong River Commission Secretariat, the Department of National Parks, Wildlife and Plant Conservation in Thailand and the Forest Administration in Cambodia for providing the data. Special thanks are given to Mr. Kamol Wisupakan, Mr. Thanet Buakaew, Dr. Naris Bhumpakphan and Dr. Hwan-ok Ma for support and guidance. Finally, the GIS Consultant would like to thank Palle Havmoller for English editing.

Prof. Dr. Yongyut Trisurat
GIS Consultant

EXECUTIVE SUMMARY

After completion of the *Management of the Emerald Triangle Protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II*), PD 289/04 Rev.1 (F), the Royal Forest Department (RFD) of Thailand and Forestry Administration (FA) of Cambodian jointly developed the Project Phase III Proposal. The project scope has extended the implementation to cover Phou Xiang Thong and Dong Khanthung National Biodiversity Conservation Areas in Lao PDR. The project phase III was approved by ITTO and financed by the Government of Japan. It built on the achievements of project phases I and II and resolved some pending issues identified in the evaluation report.

The overall objective was to contribute to the conservation of trans-boundary biodiversity in the Emerald Triangle Protected Forests Complex between Thailand, Cambodia and Laos. The experiences and lessons learned from this project will be used as a model for other potential trans-boundary conservation areas in participating countries and in the Greater Mekong Sub-region. The specific objective of Phase III of the project is to strengthen the protection of trans-boundary habitats of protected wide-ranging wildlife species in the Emerald Triangle.

The RFD has invited the Forestry Research Center of the Faculty of Forestry, Kasetsart University (KU) to render professional services assigned to 1) GIS Consultant and 2) Wildlife Consultant. This technical report presents the main outputs responsible by the GIS Consultant (Dr. Yongyut Trisurat), which include updating the GIS database for trans-boundary biodiversity conservation planning and assisting joint researches on land-use modeling and wide-ranging species distribution in the ETFC. The Land Use Change and Wildlife Distribution Modeling in the Emerald Triangle Forest Complex Report consisted of seven sections, namely Section 1: Introduction; Section 2: Concepts and Backgrounds; Section 3: Study Area; Section 4: Applied Methodology/ Projecting Land Use and Landscape Change; Section 5: Results; Section 6: Conclusions and Recommendations; and Section 7: Implications for Practices.

Section 1: Introduction

Section 1 describes the importance of the Emerald Triangle landscape in the Greater Mekong Sub-region, background of trans-boundary conservation in Thailand, key achievements and pending issues of the project phases I and II. The overall objective and specific objectives of the Management of the Emerald Triangle Protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase III) were also included. At the end roles and responsibilities of GIS consultant were shown.

Section 2: Concept and Background

Section 2 identified six main activities to be implemented by the GIS consultant. In addition, the GIS consultant proposed the processes to achieve the assigned activities, including 1) core GIS dataset, 2) GIS database design and development, 3) collection of wildlife occurrences, 4) prediction of land use change, 5) modeling species distributions and 6) formulating management strategies. The GIS database is intended to be used to support biodiversity conservation and protected areas management and decision-making at both the Pha Taem complex and the Emerald Triangle landscape. Therefore, the GIS database consists of two datasets. The core GIS dataset at scale of 1:50,000 for the PPFC and at scale of 1:250,000 for the Emerald Triangle. Three GIS training modules were proposed to increase capacity of multi-stakeholders and their understanding on spatial data and analyses, namely *1) Introduction of GIS, Map Reading and GPS Mapping*; 2) *Land Use Modeling*; and 3) *Species Distribution Modeling*. The current research used the Dyna-CLUE (Conversion of Land Use and its Effects) model to assess future land-use at the ETFC. In addition, the presence-only species modeling technique (MAXENT model) was selected. The advantages of MAXENT include the following: (1) it requires only presence data and environmental factors, (2) it can utilize both continuous and categorical variables, and (3) it is efficient at determining the algorithms for converging the optimal probability distribution.

Section 3: Project Area

Section 3 presents physical feature, biological feature and socio-economic aspects of the project area derived from the project phases I and II. It is noted that only little information was presented for Laos because most activities were implemented in Thailand and Cambodia in previous phases.

The Emerald Triangle Protected Forest Complex landscape comprises five protected areas, so called the Pha Taem Protected Forest Complex (PPFC). The total area of the complex is approximately 1, 736 km^2. The PPFC adjoins two protected areas in Lao PDR (Phou Xing Thong and Dong Khanthung (NBCA), covering approximately 2,800 km^2, and the Protected Forest for conservation of Genetic Resources of Plants and Wildlife in Preah Vihear Province, Cambodia is about 1,900 km^2. The total area of the eight protected areas is approximately 6,500 km^2.

Three main vegetation types, viz. Dry Evergreen Forest, Mixed Deciduous Forest and Deciduous Dipterocarp Forest.Higher abundance of wildlife species were recorded in Cambodia and Lao PDR and they seasonally migrate across the tri-national boundaries. However, conservation measures in these two countries are weak due to limited financial support and human capacity. Therefore, long-term persistence of wide-ranging and iconic species in this area is largely dependent on close cross-border cooperation between the three countries to maintain integrity of wildlife habitats and to reduce anthropogenic pressures.

Section 4: Applied Methodology

This technical report emphasised methods used for land-use modelling and species distribution modelling. Five steps were conducted to detect land use change between 2003 and 2013 and to predict future land use change at the Emerald Triangle landscape. They consisted of 1) gathering past land-use/land-cover map, 2) preparing current land-use/land-cover map, 3) land-use change detection, 4) land-use modeling and 5) assessing landscape configuration features. Four land-use scenarios in 2030 were defined by multi-stakeholders involved in the project, namely a) low economic decline and localized resource degradation (business as usual), b) unsustainable economic development and serious resource degradation scenario, c) sustainable poverty and stable resources scenario, and d) sustainable development and limited resources degradation scenario.

In addition, the processes for mapping wildlife distributions and determining priority areas for protecting the iconic species in the Emerald Triangle area include four steps: a) collection of wildlife presence points, b) target species selection, c) generation of species distribution models, and d) validation and mapping distributions. The criteria used for selection of target species include: 1) wide distribution in the Emerald Triangle (having trans-boundary territory), 2) regionally and nationally threatened status, 3) adequate observation records (≥10 points) and 4) iconic or flagship for conservation.

Section 5: Results

Forest cover in the entire ETFC and surrounding landscape is predicted to decline from 44.8% in 2013 to 40.2, 36.2, 42.4 and 40.5% in 2030 under these scenarios, respectively. In addition, the CLUE-s model results indicated that dry dipterocarp forest in the north of Dong Khanthung provincial protected forest in Lao PDR and to the west of Pha Taem National Park in Thailand would be threatened by encroachment for agriculture and rubber plantation. If on restriction policy, parts of the Preah Vihear protected forest in Cambodia and Phou Xiang Thong National Biodiversity Conservation Area in Lao PDR would be converted for arable land in 2030. Evergreen forests were predicted as relatively intact at the current stage because they are found either inside protected areas or in steep terrains, thus become natural barriers for human-intervention.

The predicted deforestation would cause negative impacts on wildlife distribution and wildlife hotspots in the Emerald Triangle protected forest complex. The multi-stakeholders from three countries selected 12 species for modeling their distributions. These species include nine mammals: gaur (*Bos gaurus*); banteng (*B. javanicus*); sambar (*Cervus unicolor*); *Eld's* deer (*C. eldii siamensis*); Asian elephant (Elephas maximus); barking deer (*Muntiacus muntjac*); leopard (*Neofelis nebulosa*); tiger (*Panthera tigris*) and wild boar (*Sus scrofa*), and three birds: Sarus crane (*Grus Antigone*); Lesser adjutant stork (*Leptoptilos javanicus*); and Giant ibis (*Pseudibis gigantean).* The model results revealed that the likely suitable habitats for selected wildlife species in 2013 cover approximately 45% of the Emerald Triangle landscape and
the average percentage contribution of protected areas to protecting the focal selected species were more than 80% of the total predicted suitable habitats, especially for gaur, Sambar deer, Asian elephant and tiger. The average percentage of contribution was the lowest (approximately 50%) under the sustainable poverty scenario. This may be due to the fact that more forest areas and contiguous forest patches were predicted outside the protected areas, therefore the selected species are able to inhabit these areas.

High species richness class was predicted along the borders between the PVPF (except the western part) and Dong Kanthung NBCA will be classified as moderate richness. In addition, the remaining areas in Preah Vihear, Yot Dom, Bun Thrarik-Yot Mon and part of Phou Xiang Thong were predicted as low richness of the selected species. The entire areas of Pha Taem and Kaeng Tana National Parks were categorized as none habitat of any of the 12 species.

Three GIS training courses were conducted during the project phase III. They are as follows:

1) *Introduction of GIS, Map Reading and GPS Mapping.* This training course was conducted for park rangers and interested people involved in the project (e.g. patrol border police, RFD officials). The objectives of this course were to refresh GIS skills and to guide how to collect and develop standardized core GIS database among the three countries. It was conducted on November 28th - 29th, 2013 at the Pha Taem National Park. There were approximately 30 participants from five protected areas in the PPFC. Besides, RFD staff, ITTO Project staff and graduate students from Kasetsart University also participated in this training.
2) *GIS Modeling for Forest Land Use Assessment and Prediction.* This training course was jointly organized for GIS staff and park rangers of the three countries who were involved in the project. The objectives of this course were to train participants on CLUE model using default database and to jointly develop land use scenarios for the Emerald Triangle. The second training was conducted in Tbeng Mean Chey Preah Vihear province, Cambodia and the duration of the training workshop was 5 days (March 10-15, 2014). There were all together 50 participants/resource persons. Thirty two participants were from Cambodia, 6 from Laos and 12 from Thailand.
3) *GIS - Wildlife Distribution Modeling*. This training course was conducted for GIS staff, park rangers and wildlife scientists of the three countries who were involved in the project. The training aimed at introducing various spatially explicit species distribution models, advantages and disadvantages, finalizing wildlife species for modeling and jointly generating distributions of selected species in the Emerald Triangle. The 3rd GIS training sessions on GIS-Wildlife

Distribution Modeling was planned for 5 days from October 20-25, 2014). The venue of the training was Toh Saeng Kong chiam Hotel, Ubon Ratchathani Province, Thailand. There were all together 41 participants/resource persons. Eighteen participants were from Cambodia, 5 from Laos and 18 from Thailand.

The training evaluation results of the three courses showed that the contents of training were ranked between highest and good (>80%) and more than 80% of participants appreciated logistic arrangement and facilities offered during the training. The main constraint of the training contents was the period of time allowed for the training. It should be noted that the objectives of the training courses were not aimed to train participants to become experts in GIS modeling. In addition, most participants had basic knowledge on GIS and spatial modeling obtained from previous training courses. Therefore, the identified constraint was unavoidable.

Section 6: Conclusions and Recommendations

This section 6 summarized main findings and recommended key points for the effective trans-boundary biodiversity conservation. It is recommended that the GIS center of the regional office in Ubon Ratchathani province should host and maintain GIS database of the PPFC, while Tbeng Mean Chey Forestry Office in Preah Vihear province and Champasak University in Chapasak province are responsible for updating and maintaining GIS database for Cambodia and Lao PDR, respectively. This is to ensure that the GIS database will be kept in good shape for future uses. The results of land-use prediction indicated that forest cover in the north of Dong Khanthung protected forest in Lao PDR, parts of the Preah Vihear protected forest in Cambodia and to the west of Pha Taem National Park in Thailand would be threatened by encroachment for agriculture and rubber plantation if on restriction policy. This land-use change patterns will restrict the distributions of selected species in small patches across the tri-national borders and cause negative effect of long-term persistence of species having trans-boundary territory. It is recommended that the three countries put collaborative efforts to regularly patrol and prevent deforestation in the risk areas and to protect intact forest and remaining suitable habitats, especially in Laos and Cambodia.

Section 7: Implications for Practices

This section highlighted and discussed the contributions of the research results. Three sub-sections were elaborated, namely integration of scenarios and models, important habitats of selected species and translating research results into concrete actions and contributions to conservation communities.

Prof. Dr. Yongyut Trisurat
GIS Consultant

1. INTRODUCTION

The Southeastern Indochina Dry Evergreen Forest ecoregion is situated in the Greater Mekong across northern and central Thailand, Lao PDR, Cambodia and Vietnam. However, about two-thirds of the original forest of this eco-region has been converted to agricultural areas or seriously degraded (Wikramanayake *et al*., 2000). The largest extensive intact block still remains along the tri-national borders between Thailand, Lao PDR and Cambodia, in the so-called *Emerald Triangle Forests Complex (ETFC).* It is recognized as global outstanding for biodiversity conservation and for important habitats of the large vertebrates in the Greater Mekong Sub-region or GMS (Office of Environmental Center, 2005). According to Bhumpakphan (2003), Cambodian Forest Administration (2009) and Round (1998) the ETFC inhabits more than 50 threatened species. Of this figure, more than 10 species found in the ETFC are categorized either as critically endangered or endangered species such as Asian elephant (*Elephans maximus*), banteng (*Bos javanicus*), *Eld's* deer (*Rucervus eldii siamensis*), Clouded leopard (*Neofelis nebulosa*) and Siamese crocodile (*Crocodylus siamensis*).

The ETFC landscape contains heterogenuous landscape patterns and different hydrological conditions. The general topography in Thailand is mountaineous and slopes gently towards the southeast. In contrast, the areas in Lao PDR and Cambodia are generally flat and parts of the forested areas are inundated during wet season. As a result of the highly heterogenuous landscape, wide-ranging species seasonally migrate across the tri-national boundaries and some are dependent on strictly limited resources, including permanent waterbodies and lowland forest patches in the dry season (Bhumpakphan, 2003). The resources are scattered in protected areas, while remnant forests outside the reserves are vulnerable to disturbance .

Besides diversity of natural feaures, the disparities of local livelihhod, conservation efforts and human capacity are clearly recognized among the three countries. According to the International Monetary Fund, the Gross Domestic Product (GDP) per capita in 2013 in Thailand was US$ 7,907. In contrast, the average GDP per capital in Lao PDR and Cambodia was US$ 2,054 and US$ 1,818, respectively. Cambodia and Lao PDR have some of the most extensive intact natural forests, but the countries lack sufficient capacity to effectively maintain the remaining forest covers and conserve biodiversity at all levels (Galt *et al*., 2000). In contrast, the Government of

Thailand has deployed a lot of park rangers and facilities to manage and to protect biological resources but Thailand's protected areas contain relatively less biodiversity than protected areas in Lao PDR and Cambodia (Trisurat, 2003). These contrasting economic and biodiversity conservation conditions have resulted in an influx of foreign migrant workers and illegal wild flora and fauna trades into Thailand (Trisurat, 2007).

Therefore, long-term persistence of trans-boundary biodiversity in the ETFC is largely dependent on the cooperation between the three countries to safeguard the remaining habitats and to reduce anthropogenic pressures both inside and in the buffer zones of the protected forests. To address some of these issues, the Government of Thailand has with technical support from the International Tropical Timber Organization (ITTO) and financial support from Japan, Switzerland and USA has initiated the framework of trans-boundary biodiversity conservation in cooperation with Cambodia, and Lao PDR since 2001 (Kalyawongsa and Hort, 2010). The project phase I, *"Management of the Pha Taem Protected Forests Complex to Promote Cooperation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase I),"* in the period 2001-2003 was primarily aimed at initiating a management planning process for the Pha Taem Protected Forests Complex (PPFC) in the framework of trans-boundary biodiversity conservation and establishing cooperation among the three countries. At the end of phase I, Cambodia showed interest and jointly developed a second phase proposal recommending the Preah Vihear Protected Forest for the Conservation of Genetic Resources of Plants and Wildlife (PVPF) to be included in the project area. The project phase II (2008-2010) was directed to strengthening tri-national cooperation and implementing biodiversity conservation activities through the involvement of local communities and improvement of livelihoods of local residents living in or close to the buffer zones of the protected forests (Trisurat, 2007).

In spite of the relative progress of establishing and promoting trans-boundary biodiversity conservation areas (TBCAs) in the ETFC, there were some constraints limiting the achievement and affecting the sustainability of project objectives identified in the evaluation report for the project phase II (Gasana, 2010). These included project design limitations and limited scale of project interventions in the Cambodia component of the program, as well as incomplete establishment of effective partnerships with civil society for long-term sustainability of the project. In addition, approximately 30% of dry dipterocarp forest mainly in the buffer zones and protected areas in Cambodia and Lao

PDR was converted to other land-use classes, including to rubber plantation in Thailand, unsustainable logging concession in Lao PDR and land allocation program for military in Cambodia (Trisurat *et al*., 2014). These issues were overlaid by external constraints associated with the limited participation of Lao PDR in project activities and border disputes between Thailand and Cambodia, which reduced the level of trans-boundary cooperation (Kalyawongsa and Hort, 2010). In respond to those challenges, the Royal Forest Department (RFD) in Thailand and the Forest Administration (FA) in Cambodia, which are the main executing agencies received financial support from the Government of Japan to execute the project phase III (2012-2015). The specific objective of the current phase aims at strengthening the protection of trans-boundary habitats of the protected wide-ranging wildlife species in the ETFC landscape.

The RFD invited the Forestry Research Center of the Faculty of Forestry, Kasetsart University (KU) to render professional services assigned to 1) Geographic information system (GIS) Consultant and 2) Wildlife Consultant. This technical report presents the main outputs from the GIS Consultant (Prof. Dr. Yongyut Trisurat), including updating the GIS database for trans-boundary biodiversity conservation planning and assisting joint researches on land-use modeling and wide-ranging species distribution in the ETFC. It should be noted that this technical report focuses on the second objective using the updated GIS database and involvement of multi-stakeholders participating in the series of training workshops as outlined in the Term of References (TORs) between the RFD and KU.

2. CONCEPTS AND BACKGROUNDS

The Term of References (TORs) has defined six main activities to be implemented by the GIS consultant. The activities are as follows:

- Work with the project team and other consultants to develop additional GIS database as might be required.
- Work with GIS consultants and wildlife scientists in Cambodia and Laos, respectively to ensure that both countries develop GIS using a standardized design.
- Propose mechanism and guidelines for joint research activities on wide-ranging species distribution among the three countries.
- Conduct GIS training for scientists and professional staff of the three countries.
- Predict land use change and its consequences on wildlife distribution in the Emerald Triangle
- Assist in formulating protection a framework to prevent future land use changes.

The processes to achieve these activities include 1) core GIS dataset development, 2) GIS database design and development, 3) collection of wildlife occurrence data, 4) prediction of land use change, 5) modeling species distributions and 7) formulating management strategies as shown in Figure 1.

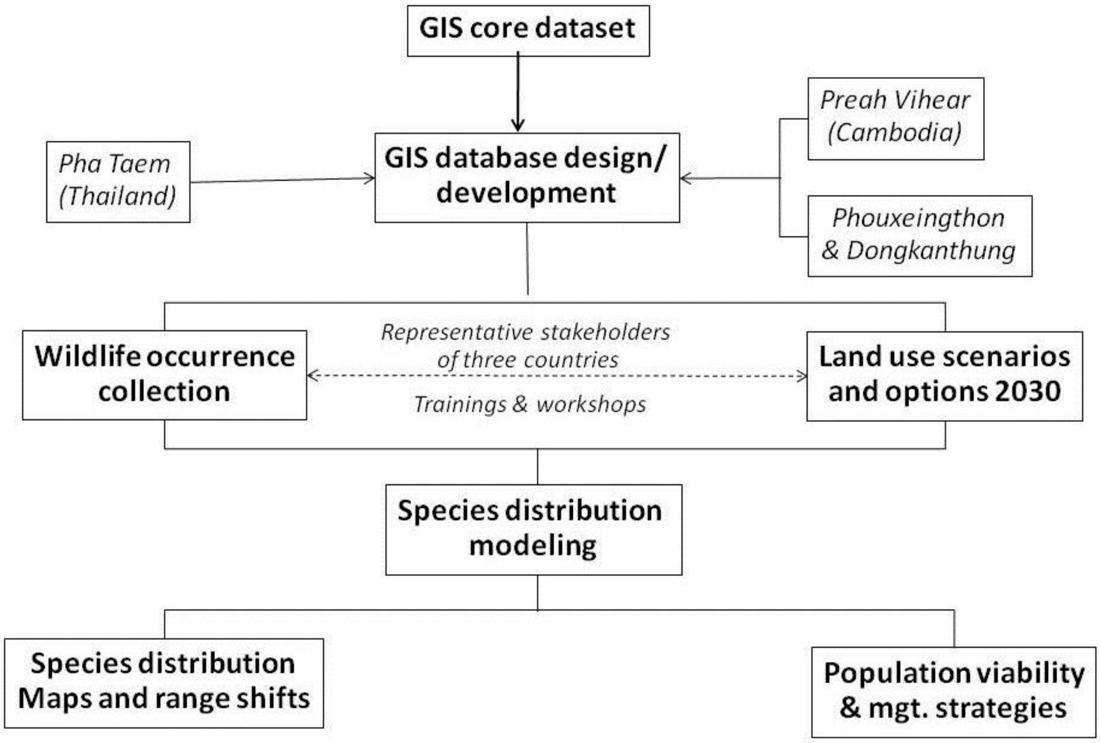


Figure 1 General guidelines for GIS database implementation

2.1 GIS Dataset

To ensure that the three participating countries develop GIS using a standardized design and use the GIS data to enhance trans-boundary biodiversity conservation, the processes of database development can be categorized into three main steps, including 1) defining core GIS database for the PPFC and the ETFC; 2) GIS data catalogue and design; and 3) database development. They are described in details as follows:

2.1.1 Core GIS database

The GIS database is intended to be used to support biodiversity conservation and protected areas management and decision-making at both the PPFC and the ETFC levels. Therefore, the GIS database consists of two datasets. The core GIS dataset at scale 1:50,000 for the PPFC consists of 11 themes and more than 30 layers, including their attributes as shown in Table 2. The spatial extent of the PPFC dataset covers 16 topographic map sheets (Table 1). Basically, they were updated from the project phase II

(Trisurat, 2010). The review of the work to date both at national (Thailand's protected areas and wildlife conservation) and regional levels (Greater Mekong Sub-region) (ADB, 1998) found that the vector-based model (shape file) and the raster-based model (grid), developed by ArcView and ArcGIS soft wares, are commonly used in the region. Therefore, in the context of the Emerald Triangle the spatial elements are largely restored in vector model, but raster data is wherever applicable.

In addition, the project phase III also aimed to develop GIS database for land-use and species distribution modeling at the ETFC. This dataset includes 9 themes and 18 layers (Table 2). Generally, they were gathered from existing databases available in other organizations (e.g., FA-Cambodia, Mekong River Commission, FAO, WorldClim database). Road and stream networks were updated from topographic maps and Landsat-8 TM, and later interpolated to obtain proximity distance to these line features. The pixel resolution of 500 m was selected for land use modeling because it was suitable for landscape scale and generally relevant to original data.

Table 1 Proposed core datasets for the PPFC

Core Dataset	Spatial Layer	Spatial data type	Attribute	Relevant to	
				Land use	**Wildlife**
1. Admin.	Country*	Polygon	Name	NA	NA
	Province*	Polygon	Name	NA	NA
	District*	Point, polygon	Name	Delivery	NA
	Sub-district*	Polygon	Name, population	NA	Threat
	Village*	Point	Name Population	Threat	Threat
2. Biodiversity	Land use types* (present/predicted)	Polygon	Land use class	Baseline	Food and cover
	Wildlife observation	Point	Name, location and date	NA	Occurrence, distribution
	Wildlife habitat suitability 1/*	Polygon	Suitability class	NA	
	Forest inventory plot	Point	Location, sector, tree name	NA	Food
	LTER Plot	Polygon	Site ID	NA	NA
	Tree tagging	Point	Name, ID, girth	NA	NA
3. Geology	Geology	Polygon	Rock type, Lithology class	Parent material	NA
4. Infrastructure	Roads*	Line	Width, surface type	Accessibility	Threat
5. Meteorology	Weather station	Point	Name and measured parameter	Determine vegetation type & specific crop	Water source
	Annual rainfall*	Grid	Amount of rainfall		
6. Protect	Protected area*	Polygon	Name	Restriction area	Protection measure
	Locations of HQ and Ranger Station*	Point	Name	Restriction area	Protection measure
	Attraction location	Point	Name and type	NA	Threat
7. Soil	Soil*	Polygon	Name and texture	Parent material	NA
8. Threats	Encroachment	Polygon	Type of crop	Demand	Threat
	Wildlife poaching	Point	Wildlife name, signs	NA	Threat
	Illegal logging	Point	Tree name	NA	Threat
9. Topography	Contour*	Line	Elevation value	Natural barrier	Natural barrier
	Spot height elevation	Point	Height and name	Natural barrier	Natural barrier
	DEM 2/*	Grid	Altitude	Natural barrier	Natural barrier
	Slope 2/*	Polygon/Grid	Class	Natural barrier	Natural barrier
	Aspect 2/	Polygon/Grid	Class	Suitability	Natural barrier
10. Water	River and stream network*	Line	Name and type	Irrigation	Water sources
	Water body (e.g. reservoir)	Polygon	Name	Irrigation	Water sources
11. Images	Past satellite image	Pixel	Value	Data source	Data source
	Present satellite image	Pixel	Value	Data source	Data source

Remarks: * - primary GIS layer; 1/ derived from spatial analysis; 2/ derived from contour line

Table 2 Proposed core datasets for the entire Emerald Triangle landscape

Theme	Spatial Layer	Spatial data type	Attribute	Scale/ resolution	Source
1. Land use	Land use types (2003)	Grid	Land use class	250 m	MRC[1/]
	Land use types (2013)	Grid	Land use class	250 m	Image interpretation
2. Admin.	Country	Polygon/Line	Name	1:250,000	MRC
	Population density	Polygon/Line	Name	1:250,000	MRC
3. Geology	Geology	Polygon	Rock type	1:250,000	MRC
4. Climate	Bioclim 1	Grid	Mean annual temperature (°C x 10)	1 km	World climate
	Bioclim 12	Grid	Annual rainfall	1 km	World climate
	Bioclim 17		Precipitation of driest quarter	1 km	World climate
	Bioclim 18		Precipitation of warmest quarter	1 km	World climate
5. Protect	Protected area	Polygon	Name	1:50,000	Phase II and Laos
6. Soil	Soil	Polygon/grid	Soil order	1:250,000	FAO & MRC
7. Threats	Distance to main road	Grid	Nearest distance	250	Topo map & image
	Distance to city	Grid	Nearest distance	250	MRC
	Population	Grid	Population density per cell	1:250,000	LandScan
8. Topography	DEM[2/]	Grid	Altitude	100 m	ASTER[3/]
	Slope	Grid	%	100 m	ASTER
	Aspect	Grid	Degree northward	100 m	ASTER
9. Stream	Distant to main stream and river	Grid	Nearest distance	250	Topo maps & interpolation

Remarks: [1/] Mekong River Commission; [2/] Digital elevation model; [3/]Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

2.1.2 Data catalogue and database dictionary

The data catalogue contains information on spatial data and non-spatial data, source of information, date of production and scale. In addition, all detailed database designs are compiled in a database dictionary, which ensures simplicity and integration between data custodians and end-users. The bilingual database dictionary (Thai and English) was produced during the previous project phases (Trisurat, 2003b, 2010) in order to describe all coverage, tables, columns and relationships. It also contains the database object names (e.g. administration, elevation), description, data type, length, etc. Therefore, the project phase III has simply used the existing database dictionary.

2.1.3 Database development

As discussed earlier, the sources for geo-spatial data are probably more numerous and of greater variety than in most other information sets. At the outset, the data, such as those identified as core datasets mentioned above, can be imported/input to GIS from various sources, such as:

- V*arious digital forms*: vectors, raster, database, spreadsheet tables, satellite data, internet, etc.;
- *Non-digital graphics*, such as conventional maps, photographs, sketches, schematic diagrams, and the likes;
- *Conventional documents* in registers and files;
- Compilations in *scientific reports*; and
- Collections *of survey measurements* (expressed in coordinates or other units).

These regional and global data restored in various digital forms were then converted to GIS format (Shapefile or Grid). It should be noted that all GIS layers were developed using map datum WGS84 UTM zone 48 and that the main project execution, especially data conversion was done at the Faculty of Forestry, Kasetsart University in Bangkok.

2.2 GIS Training Courses

Geographic Information System or GIS can be defined as “ a power tool for collecting, storing, retrieving at will, transforming and displaying spatial information from the real-world for a particular set of purposes” (Burrough, 1986). It is information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. The main difference between geographical data or GIS and other data is that the latter helps answer question like, *what?* or *where?* and the former answers both *what?* and *where?* Therefore, GIS has been widely used to support protected areas management (Trisurat, 2007), biodiversity conservation and land-use modeling (Trisurat *et al*., 2010)

GIS contains four main components: computer hardware, computer software, data and human resource. Among these four components, human resource is recognized as the most important component for effective implementation of GIS in a sustainable manner. Therefore, the GIS consultant worked closely with the Project Managers of Thailand Component (Mr. Kamol Wisupakan) and Cambodia Component (Mr. Dany Chheang) to arrange training courses aiming at developing human resources with the skills and technical knowledge necessary to effectively and efficiently obtain, exchange and use core datasets. Three training modules were developed, namely *1) Introduction of GIS, Map Reading and GPS Mapping*; 2) *Land Use Modeling*; and 3) *Species Distribution Modeling*. The proposed objectives, contents and participants are shown in Table 3.

Table 3 Proposed GIS training workshops for the project phase III conducted by the GIS consultant*

Course title	Objective	Participants	Place/date
Introduction of GIS, Map Reading and GPS Mapping	Refresh GIS skills and to guide how to collect and develop standardized core GIS database	Thai park rangers and interested people involved in the project (e.g. patrol border polices, RFD officials)	PPFC field office at Pha Taem National Park, Ubon ratchani Province
International Land Use Modeling	Understand various land-use modeling techniques; develop land-use scenarios in 2030, and be familiar with CLUE-s model using the ETFC database	GIS staff and park rangers of three countries (Thailand, Lao PDR and Cambodia)	Cambodia or Lao PDR (Champasak University)
Species Distribution Modeling	Understand various species distribution models, and emphasis on logistic regression and MAXENT models	GIS staff, park rangers and wildlife scientists of three countries (Thailand, Lao PDR and Cambodia)	Lao PDR (Champasak University) or Cambodia (Forestry Administration).

*excluding contribution to the wildlife monitoring workshop

The GIS Consultant defined qualifications of potential candidates, and worked closely with the two Project Managers and Wildlife Consultants of Thailand and Cambodia, as well as the Cambodian GIS consultant in order to identify suitable participants to the training courses. The project provided facilities and supported participants.

2.3 Land Use Modeling

It is important to understand present and future land-use/land-cover patterns because deforestation is considered to have a large as an important effect on wildlife distribution and biodiversity (Sodhi *et al*. 2004; Corlett 2012). This is due to the fact that deforestation does not only cause habitat loss, but also results in habitat fragmentation, diminishing patch size in core area, and isolates of suitable habitats (MacDonald, 2003). Trisurat and Duengkae (2011) indicated that the predicted occurrence of Black-crested Bulbul (*Pycnonotus melanicterus*) in the Sakaerat Man and Biosphere Reserve in Nakhon Ratchasima Province, Thailand would significantly decrease even if forest cover only slightly declined from 45.3% to 42% of the reserve and otherwise intact habitats would be severely fragmented.

Various models have been develop to forecast future land-use patterns, they range from simple system representations, including a few driving forces, to simulation systems based on a profound understanding of situation-specific interactions among a large number of factors (Verburg *et al*., 2004; Pontius *et al*., 2008). The Markov Chain Model is a simple land use model that uses previous land use trends to predict what will happen in the future. However, it is not capable of addressing land suitability, land demands and government policies (Pontius *et al*., 2008). A Cellular Automata then incorporates spatial components in the traditional Markov Chain Model and can address dynamisms with simple rules (Baker, 1989). It has been applied in a wide range of land-use change applications (Houet, and Hubert-Moy, 2006; Ballestores and Qiu, 2012). Recently, an agent-based model was developed to allow the influence of human decision-making on the environment to be incorporated in a mechanistic and spatially explicit way, also taking into account social interaction, adaptation and decision-making at different levels (Matthews *et al*., 2007).

The current research used the Dyna-CLUE (Conversion of Land Use and its Effects) model (Verburg and Overmars, 2009) to assess future land-use at the ETFC. The Dyna-CLUE model was chosen for this study because it explicitly addresses the dynamics of the different future land demands. In addition, it has been used at both local level (Trisurat *et al*., 2010) and regional level (Verburg and Veldkamp, 2004) and has been proven to be useful for different popular land-use change models (Pontius *et al*., 2008). Specific objectives were (1) to quantify rate of land-use/land-cover change in recent years and (2) to allocate land-use change and land-use patterns across the ETFC based on different demand scenarios of stakeholders from the three participating countries.

2.4 Wildlife Habitat and Species Distribution Modeling

Habitat is the specific place or environment where an organism lives. Hutchinson (1957) and Patton (1992) defined habitat as all factors affecting an animal's chance to survive and reproduce in a specific place. They include not only the abiotic environment but also biotic factors of the respective ecosystem determining the abundance of resources as well as their trophic chain interactions. These specific places are often described by a vegetation type or a topographic feature (e.g., food, water, cover and space) and can be derived from maps. A food map should include shrub areas, location of big trees (i.e. *Ficus* spp.), concentrations of big trees, salt licks and natural openings, while a cover map should include plant canopy, location of caves and trees, etc. A water map should show at least the stream network, water bodies and amphibian habitats.

Ecological niche was developed similar to habitat and broadly classified into three major concepts (Kimmins, 2004). Firstly, it refers to the functional role of a species in an ecosystem and how the species fits into the complex functional processes of the ecosystem and also defined as the relationship of an animal to food and enemies. Secondly, niche refers to the habitat of a species: the range of environments in which it lives. This definition also includes its temporal adaptations to light, temperature, moisture, soil, fires, and the amplitude of these factors. Thirdly, it involves the geographic distribution or range in which a species is found in the landscape.

Species-distribution models are based on the assumption that the relationship between a given pattern of interest (e.g. species abundance or species occurrence) and a set of factors assumed to control and can be quantified (Guisan and Zimmermann, 2000).

Basically, there are two approaches for developing species distribution maps: the deductive approach and the inductive approach, and the selection of these approaches is dependent on objectives and data availability (Stoms *et al*., 1992). The *deductive approach* extrapolates known habitat requirements or expert judgments to the spatial distributions of habitat factors. If the habitat requirements are not well known, the distribution map can be derived from a sample of observations of the species locations to one or more habitat factors. This method is named *inductive approach*. Based on these two general approaches, the existing species distribution models are categorized into three modeling techniques, namely (1) cartographic overlay, (2) species modeling using presence-absence data, and (3) species modeling using presence-only data. The elements of each approach are illustrated in sections below.

2.4.1 Cartographic overlay

A Habitat Suitability Index (HIS) is one deductive approach that has been developed using cartographic overlay technique (Patton, 1992). Once the species has been selected a habitat suitability index based on research data and expert opinions is calculated. The assumption is that the HIS, a numeric value summarizing habitat suitability based on ranking habitat quality (e.g., 0.0-1.0 or 1-3), can be developed for the selected species. There are a series of HIS equations as follows:

$HIS = [V_1 + V_2 + V_3]/3$ Compensatory Model

$HIS = [2V_1 + V_2 + V_3]/4$ Weighted Mean

$HIS = [V_1 \times V_2 \times V_3]^{1/3}$ Geometric Mean

Where HIS = habitat Index Suitability

V_i = habitat factors (e.g., food, cover, water, space).

A large number of habitat suitability indices have been developed for both terrestrial and aquatic habitats. In operation, a Geographic Information System (GIS) is used to create habitat factors, assign numeric values based on habitat quality, overlay all these layers and calculate suitability classes.

To proceed this method, the required wildlife habitat factors were first reclassified according to their attributes and their suitability for each species (e.g., 3-suitable, 2-

moderate and 1-not suitable). For instance, during the project phase I, dry evergreen forest was assigned as 3 because it is preferred by elephant. Meanwhile, score 2 is assigned for deciduous forest and scrub while score 1 is given to the remaining classes which are dominated by human activities (Trisurat, 2010). The weighting scores for each factor may be included to determine their importance for species distribution. For example, altitude and proximity to a stream are more important than vegetation for elephant distribution because they normally roam in low altitude, flat terrain and prefer to remain close to water sources. Therefore, the proposed weighting scores may be 4, 4 and 2 with the total of 10.

2.4.2 Species distribution modeling using presence–absence data

A range of species distribution models have been developed for binary response variables (presence/absence) such as Generalized Additive Models ((Hastie and Tibshirani, 1990) and Generalized Linear Models (GLM). Logistic regression modeling, a particular branch of GLM, is a multivariate statistical technique that is used to predict a binary dependent variable (presence or absence) from a set of variables (Atkinson and Massari, 1998). It is an inductive approach in which the result is derived from the statistical relationship between a sample observation and related variables. The advantage of logistic regression is that the variables may be either continuous or discrete, or any combination of both types, and they do not necessarily have normal distributions. Therefore, it is not necessary to categorize explanatory factors before entering them in the model. The algorithm of logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not). In this way, logistic regression estimates the probability of a certain event occurring (Lee and Nelder, 1996; Atkinson and Massari 1998). The logistic regression model is:

$$\text{Prob}_{event} = \frac{e^{Zi}}{1+e^{Zi}}$$

Where Z_i is the linear combination model of species I as follows:

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$$

βI = coefficient

Xi = independent variables (habitat factors)

The probability values derived from the regression models range from 0.0-1.0. The higher the value, the greater the likelihood of occupancy of the target species. A cut-off value of 0.5 was used for binary classification. Any pixel containing the probability values equal to or greater than 0.5 was categorized as presence, otherwise as absence. In some cases, the cut-off value for binary classification may be adjusted (0.4, 0.45, 0.50, 0.55 and 0.60) to maximize the fit for sample data based on prior knowledge (Neter *et al.*, 1996; Trisurat *et al*., 2010).

The logistic regression model remains the most widely used model for predicting the potential distributions of species (Guisan and Zimmermann, 2000). For example, Trisurat *et al*. (2011) employed this method to predict distributions of key mammal species in the Western Forest Complex in Thailand. In addition, Phrommakul (2003) used the same method to estimate seasonal distribution of tiger in the Thung-Yai-Huai Kha Khaeng world heritage site in Thailand.

2.4.3 Species distribution modeling using presence-only data

Reliable species distribution information on various scales is needed for both biogeographic and conservation purposes. Species distribution data from herbarium and museums, taxonomic literature, ecological communities, inventory data and field observations that were documented in databases and GIS can provide information relevant to the development of prediction maps (Dennis and Hardy, 1999; Chefaoui and Lobo, 2008). However, these heterogeneous data sources generally do not indicate the locations where the species have been found after a sufficiently intense collection effort as pseudo-absences can decrease the reliability of prediction models (see Anderson, 2003; Loiselle *et al*., 2003).

There are many methods that use presence-only data for modeling species distributions. For instance, BIOCLIM predicts suitable conditions in a bioclimatic envelope, consisting of a rectilinear region in environmental space and representing the range of observed presence values in each environmental dimension (Busby, 1986). In addition, DOMAIN predicts the suitability index by computing the minimum distance in environmental space to any presence record (Carpenter *et al*., 1993) Environmental-Niche Factor Analysis (ENFA, Hirzel *et al*., 2002) uses presence localities together with environmental data for the entire study area, without requiring a sample of the background to be treated like absence. It is similar to principle components analysis

(Jolliffe, 2002), involving a linear transformation of the environmental space into orthogonal marginality and specialization factors. Then, environmental suitability is modeled as a Manhattan distance in the transformed space. In addition, the maximum entropy method (MAXENT) uses entropy as the means to generalize specific observations of presence of a species, and does not require or even incorporate absence points within the theoretical framework (Peterson *et al*., 2001).

The idea of MAXENT is to estimate a target probability distribution by searching the probability distribution of maximum entropy (i.e., the distribution that is most spread out, or closest to uniform), subject to a set of constraints that represent our incomplete information about the target distribution. The information available about the target distribution often presents itself as a set of real-valued variables, called “features”, and the constraints are that the expected value of each feature should match its empirical average (i.e., average value for a set of sample points taken from the target distribution). When MAXENT is applied to presence-only species distribution modeling, the pixels of the study area make up the space in which the MAXENT probability distribution is defined. Pixels with known species occurrence records constitute the sample points, and the features can be climatic variables, elevation, soil category, vegetation type or other environmental variables and functions.

The advantages of MAXENT include the following: (1) it requires only presence data and environmental factors, (2) it can utilize both continuous and categorical variables, and (3) it is efficient at determining the algorithms for converging the optimal probability distribution (Philips *et al*., 2006). According to Tognelli *et al*. (2009), MAXENT was one of the strongest performing methods among four groups of modeling techniques (artificial neural networks, - BIOCLIM, classification and regression trees, - DOMAIN, generalized additive models,-GARP and generalized linear models, - MAXENT), particularly for species sampled from a relatively low number of localities. Therefore, it was used to estimate the probability distribution of selected species in the project phase III. The advantages and disadvantages of the three species distribution approaches are presented in Table 4.

Table 4 Comparisons of species distribution models

Model	Advantages	Disadvantages
Cartography overlay	Simple to understand; Applicable for all species either with or without occurrence data.	Normally overestimates the distribution range Largely depending on expert knowledge.
Logistic regression model	The relative importance of different predictor variables in determining species distribution can be assessed	Requires large input dataset in order to obtain a meaningful model.
Maximum entropy model	Uses only presence data to run, easy to obtain. The relative importance of different predictor variables in determining species distribution can be assessed. Can effectively model species distribution from small dataset.	Predicted distribution might be biased due to non-systematic samplings and can be overestimated or underestimated due to the sampling scheme.

Source: Trisurat *et al.* (2011)

3. STUDY AREA

3.1 Geographical Location

The Emerald Triangle Protected Forests Complex (ETFC) comprises the Pha Taem Protected Forests Complex (PPFC) in Thailand, the Preah Vihear Protected Forest for the Conservation of Genetic Resources of Plants and Wildlife (PVPF) in Cambodia and two national biodiversity conservation areas (NBCA) in Lao PDR. The total protected areas encompass approximately 6,500 km^2. The study area of this research also covers surrounding areas of protected areas located within the rectangular extent covering all together approximately 25,800 km^2 (Figure 2).

The PPFC is located between latitudes 14° 12.5′ and 15° 13.9′ North and longitudes 104° 58.5′ and 105° 8.5′ East in Ubon Ratchathani province. It comprises five protected areas, namely Pha Taem National Park, Kaeng Tana National Park, Phu Jong-Na Yoi National Park and Yot Dom and Bun Thrik-Yot Mon Wildlife Sanctuary. The collective area of the complex is approximately 1, 736 km^2 with a perimeter of 730 km. Some 317 km, or 43% of its total border, adjoins Lao PDR (298 km, or 40.96%) and Cambodia (18 km, or 2.5%) (Table 1). Currently, 26 ranger stations (including Headquarters) have been established to manage biological resources and facilitate tourism activities. The number of park officials and employees varies from time to time.

The PVPF is a part of the Northern Plains of Cambodia and is located in Preah Vihear Province. It is situated south of the Yot Dom Wildlife Sanctuary between latitudes 13º51’ and 14º25’ north and longitudes 104º52’ and 105º47’ east. The PVFP covers an area of approximately 1,900 km^2 and its total perimeter is 386 km. Approximately 186 km or 48% of the total border length is adjoining Thailand (72 km or 18.65%) and Laos (114 km or 29.53%) (Table 5).

There are two protected areas in Lao PDR located in the ETFC, namely Phou Xeing Thong National Biodiversity Conservation Area and Dong Khanthung proposed National Biodiversity Conservation Area. The Phou Xeing Thong National Biodiversity Conservation Area located in Saravan Province, Lao PDR has an area of approximately 1,015 km^2. Dong Khanthung proposed National Biodiversity Conservation Area is situated in Champasak Province between latitudes 14º5’ and 14º30’ north and longitudes 105º12’ and 105º45’ east. It has an area of approximately 1,828 km2 (Figure 2). It borders both Thailand and Cambodia. Dong Khanthung is sub-divided into three zones, namely protected forest along the national border, core zone and sustainable use zone. The areas of these three zones are 88,384, 40,602 and 53,873 ha, respectively (Table 5). The official boundary of Dong Khanthung is not available. Therefore, it was digitized from the report on Wildlife, Habitats and Priorities for Conservation in Dong Khanthung Proposed National Biodiversity Conservation Area, Champasak Province, Lao PDR (Round, 1998). It is noted that there is no information about number of park rangers and staff working in the ground for both Cambodia and Lao PDR.

Table 5 Summary of key features of the Emerald Triangle Protected Forests Complex

Name	Established [1/]	Area (km^2) [2/]	Perimeter (km) [2/]	Country bound. Km (%) [4/]	Ranger Station/HQ	Officials [5/]
Thailand						
Pha Taem NP	1991	353.16	242.67	63.32 (27%)	6	3/100
Kaeng Tana NP	1981	84.62	62.52	29.96 (48%)	6	2/90
Phu Jong Na Yoi NP	1987	697.38	215.88	93.87 (43%)	7	1/90
Yot Dom WS	1977	235.93	88.21	33.21 (37%)	5	1/60
Bun Thrik-Yot Mon	Proposed	365.86	186.15	96.40 (52%)	2	1/15
Sub-total		1736.95	730.04 [3/]	316.76 (43%)	26	8/355
Cambodia						
Preah Vihear Protected Forest	1993	1899.27	386.24	186.48 (48.28%)	na	na
Laos						
Phouxeingthong NBCA	1993	1015.00	226.99	64.93 (28.60%)	na	na
Dong Khanthung	Proposed NBCA	1828.60	237.34	163.93 (69.07%)	na	na
- Border protected forest		883.84				
- Core zone		406.02				
- Sustainable use		538.72				
Sub-total		2,843.60	464.33	228.86 (49.29%)	na	na
Total		6,479.82				

Notes: 1/ Royal Gazette; 2/ Calculated by GIS; 3/ Excluding shared border; 4/ Length of country boundary; 5/ Government Official/employee

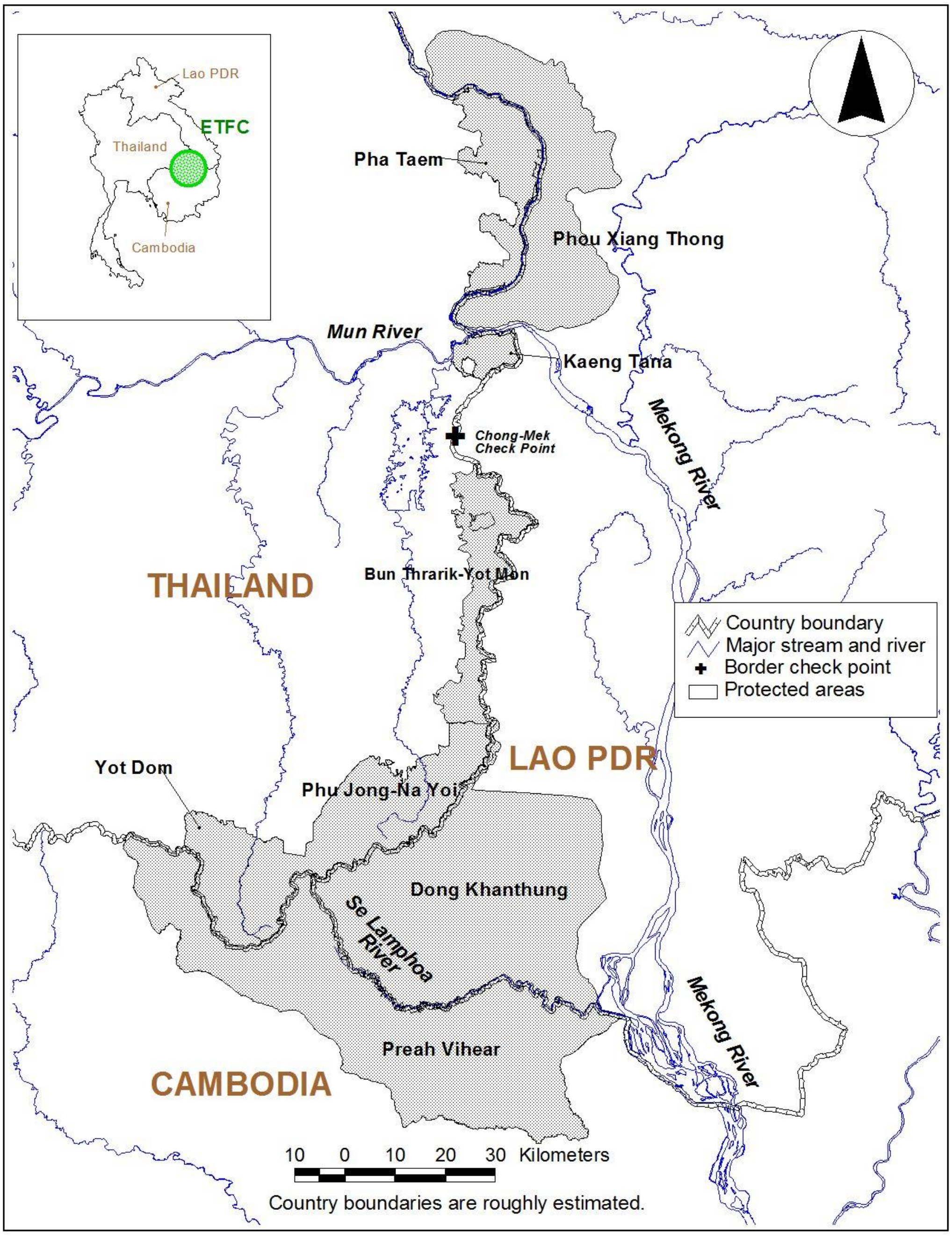


Figure 2 Location of the Emerald Triangle protected forests complex along the borders of Thailand, Lao PDR and Cambodia.

3.2 Environmental Aspects

The terrain of the PPFC is flat to undulating with elevations ranging from 100 m to 732 m above sea level. The terrain in the west and northwest is relatively low and then rises to the east and south before declining to the Mekong River (Trisurat, 2003a). The rivers and streams that have their origin in the PPFC provide the primary water resources for two hydro-power reservoirs.

Three main vegetation types have been described based on the interpretation of satellite imagery in 2002 in the PPFC. They are dry evergreen forest, mixed deciduous forest, and dry dipterocarp forest. More than 288 tree species have been identified (Marod, 2003) and at least 49 mammals, 145 birds, 30 reptile and 13 amphibian species have been recorded, but large wildlife species such as Asian Elephant (*Elephas maximus)*, banteng (*Bos javanicus)*, freshwater crocodile and tiger have only been observed along the tri-national borders (Bhumpakphan, 2003).

The Preah Vihear Protected Forest (PVPF) in Cambodia is situated within the Indo-Burma Biodiversity Hotspot, which is one of twenty five Hotspots that are recognized globally. According to the forest cover assessments that were conducted in 2002 and 2006, forest land represents 96.78% of the total surface area of the PVPF, with dry deciduous forest the dominant forest type, representing almost 67% of its total surface area. There are two primary rivers, the Mekong and the Ro Pov, located to the northeast of the PVPF, which have an important role in the region, not only for transportation, but also for the social and economic sectors.

The area is home to 57 mammal species and about 255 species of birds, 58 species of reptiles and numerous species of amphibians, including several globally-threatened species. It is probably the most important site globally for the critically-endangered Giant ibis (*Pseudibis gigantean)* and the most important site in south-east Asia for three critically-endangered vultures. It also has important populations of the Asian elephant, banteng, *Eld's* deer (*Rucervus eldii siamensis),* fishing cat *(Prionailurus viverrinus)*, dhole (*Cuon alpinus)* and white-winged duck (*Cairinia scutata)*, all of which are endangered. Other threatened species that may be seen in the PVPF include the gaur (*Bos gaurus),* the Bengal slow Loris *(Nycticebus bengalensis)*, the northern pig-tailed macaque (*Macaca leonine)*, the Malayan sun bear *(Helarctos malayanus)*, the green peafowl (*Pavo muticus)* and the Sarus Crane (*Grus antigone)*. The primary biodiversity value of the PVPF is its populations and unique assemblages of large mammals and water birds.

Since 1998, the Forestry Administration, in cooperation with Cat Action Treasury and the Wildlife Conservation Society (since 1999) have conducted biodiversity conservation surveys in Preah Vihear. The results of those surveys have documented an impressive list of fauna, probably unique in south-east Asia for its representation of species from dry dipterocarp forests and related habitats, many of which are in rapid decline elsewhere.

3.3 Social and Cultural Aspects

There are more than 80 villages situated within three kilometers of the boundaries of the PPFC in Thailand with a total estimated population of approximately 89,000. The livelihood choices of local people often impact biodiversity conservation through potential conflicts of interest between those livelihood choices and the conservation of protected forest areas. This may lead to forest encroachment to support unsustainable agriculture practices, the introduction of cow and buffalo into protected forest areas, and wildlife poaching.

The majority of local households (70%) are engaged in agriculture as their primary occupation, followed by fisheries (10%). The average annual household income of local communities is US$ 1,070, which is only about one-third of that in Ubon Rachathani city. Sixty-four percent of the local population believes that their incomes are insufficient (Tanakajana, 2003) to cover expenses for food and basic services. Less than half of the local populations (40%) have received a primary school education, while only 30% have received a secondary school education.

Currently, there are four communities situated inside the Pha Taem National Park. These communities settled there long before the establishment of the national park. There have been no substantive reports of conflicts between local people and park rangers, however, since local people agreed to stop their practice of shifting cultivation. Considering the political situation and the improved relationship between the local people and park rangers, no resettlement programs have been planned.

While social conditions inside protected areas and in the buffer zone in Lao PDR are apparently difficult, reliable statistics are currently unavailable. In Cambodia, the province of Preah Vihear is sparsely populated with about 130,000 primarily poor, rural residents. Until 1998, it was primarily accessible only by air because of its remoteness and since large areas were still insecure and most roads remained mined. As a consequence, the province has not generally benefited from the economic development that has been occurring throughout the country. There are seven districts in the province, but four of them are cut off in the wet season by the Steung Saen River. Security concerns, as well as access to most parts of the province, have improved (Royal Government of Cambodia, 2000), but while some socio-economic information is available, it has yet to be completely assessed, especially with regard to those living in and around the PVPF.

Within and surrounding the PVPF are 3,042 families with the total population of 14,189. Some 3% of that population consists of minority ethnic groups. Life expectancy is increasing and is now 58 years for women and 54 years for men (SCW, 2006). The low population density, less than 8 persons/km^2, in the project area is primarily due to the inaccessibility that results from flooding in the wet season, the lack of water in the dry season, undeveloped roads and other infrastructure, and the relatively small land area that is suitable for intensive agriculture, although some irrigated agriculture is practiced in areas that are inundated in the rainy season. There is, as a result, a low level of development with very few employment opportunities. While no specific surveys on family income generation within the PVPF have been conducted, an estimate of average domestic income per person in 2001 was about USD$259 (Cambodia Forest Administration, 2009). Indeed, a large segment of the population in Preah Vihear province lives under the poverty line.

On the basis of statistics compiled by the Seila rural development program in 2004, the percentage of the population between 6-17 years of age attending school in the project area in Preah Vihear was 21% and the percentage of 14-15 years old attending school was 5%. Moreover, illiteracy in the project area is high, especially for women. Female illiteracy at age 15 included 8,442 of 17,208 women (49%), while the comparable figure for males at age 15 was 6,630 of 16,237 men (41%).

4. APPLIED METHODOLOGY

This section emphasises methods used for land-use modelling and species distribution modelling. They are presented in the following subsections.

4.1 Land Use Modelling

Basically, there are four main steps to detect land-use/land-cover (LU/LC) change and modeling as shown in Figure 3. These steps are described as follows:

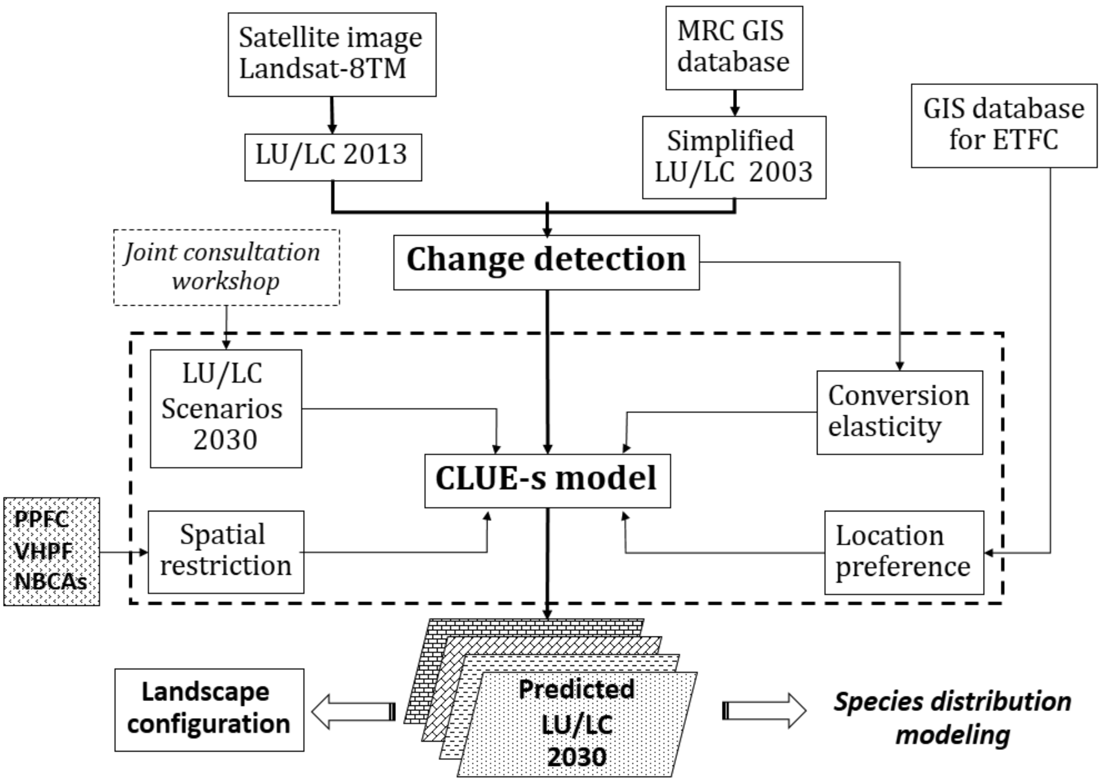


Figure 3. Main steps of land-use change detection and prediction

4.1.1 Gathering past land-use/land-cover map

The raster LU/LC map of 2003 with a resolution of 250 m covering the entire study area was obtained from the Mekong River Commission Secretariat (MRC). The original LU/LC map comprised 14 classes, namely 1) moist evergreen forest, 2) dry evergreen forest, 3) hill evergreen forest, 4) mixed deciduous forest, 5) dry deciduous forest, 6) forest plantation, 7) rubber plantation, 8) oil palm plantation, 9) cash crop, 10) paddy field, 11) settlement and infrastructure, 12) bare soil and miscellaneous land uses, 13) rock outcrop and 14) water body. The original 14 LU/LC classes were generalized into 9 classes as a result of combining some classes renamed as evergreen forests (moist, dry and hill evergreen forests), arable land (paddy, cash crop and oil palm) and bare soil & rock outcrop. This is because the current Dyna-CLUE version is applicable to not more than 11 classes (Verburg and Overmars, 2009) for land-use transitions at landscape level. It was found during field reconnaissance that oil palm was recently introduced and mainly planted in paddy fields in small patches (less than 250-m resolution). Thus, both classes show similar image signatures and they are difficult to discriminate.

4.1.2 Preparing current land-use/land-cover map

The current LU/LC map of 2013 was interpreted from satellite images. The relatively cloud-free Landsat-8 TM imageries were downloaded from USGS (United States Geological Survey Department - http://earthexplorer.usgs.gov/). A sub-scene of images path/row 126/49 and 126/50, dated 8 October 2013 and 26 October 2013, respectively, was extracted and geometrically registered to the UTM coordinate system WGS Zone 48 using the topographic map at scale 1:50,000. Then, these two sub-scenes were mosaicked using ERDAS Imagine software and false color composite images (band combination 4 5 3 – R G B) were produced for visual interpretation based on tone, shape, size, pattern, texture, shadow and association (Lillesand *et al*., 2004). Due to unavailability of reference data from the NBCAs in Lao PDR, key image features of LU/LC types were sampled from the PPFC in Thailand and the PVPF in Cambodia.

The current research used the contingency table or classification matrix to quantify the agreement between the interpreted classes and the known classes of LU/LC map (Foody, 2002). Omission and commission errors for each LU/LC class, overall accuracy, and the kappa statistic were calculated for the assessment (Jensen, 1996). A number of samples classified in preliminary LU/LC classes were selected using stratified random sampling scheme. The total number of sample locations for arable land, rubber plantation, forest plantation, dry dipterocarp forest, mixed deciduous forest, dry evergreen forest, settlement and others classes were 238, 38, 14, 43, 42, 61, 53 and 19, respectively.

4.1.3 Land-use change detection

The LU/LC maps of 2003 and 2013 were overlaid and change detection between LU/LC classes was evaluated using transition matrix. In addition, the annual rate of LU/LC change was determined by using the deforestation rate (DR) equation from year P (start) until year N (end year) (Trisurat, 2009), as below:

$$\text{DR (\%)} = -\left[1-\left(\frac{LUyearN}{LUyearP}\right)^{1/t}\right] x100$$

where	DR	=	Annual rate of change
	N	=	Land-use of end year
	P	=	Land-use of start year
	t	=	Time period; t2 – t1 (10 years)

4.1.4 Land-use change modeling

The Dyna-CLUE model requires four inputs to allocate a set of conditions and possibilities of LU/LC patterns: (1) land-use requirements, (2) location characteristics, (3) spatial policies and restrictions, and (4) land-use type-specific conversion settings (Verburg and Overmars, 2009). Land use requirements were calculated at the aggregate level jointly defined by 50 multi-stakeholders of the three participating countries attending the Joint Training Workshop on GIS Modeling for Forest Land Use Planning during 10-15 March 2014 in Cambodia. Superintendents of protected areas, government officials, NGOs representatives and lecturers from universities participated in the workshop.

Using a two dimensional matrix to develop the LU/LC scenarios (Van der Heijden, 1996), the workshop participants identified *population growth as an important factor* and *economic growth* as a result of the *ASEAN Economic Community (AEC) in 2015 scheme as a critical uncertainty* to drive four LU/LC . In addition, they jointly defined the four LU/LC scenarios for the period from 2003 to 2030 (Figure 4).

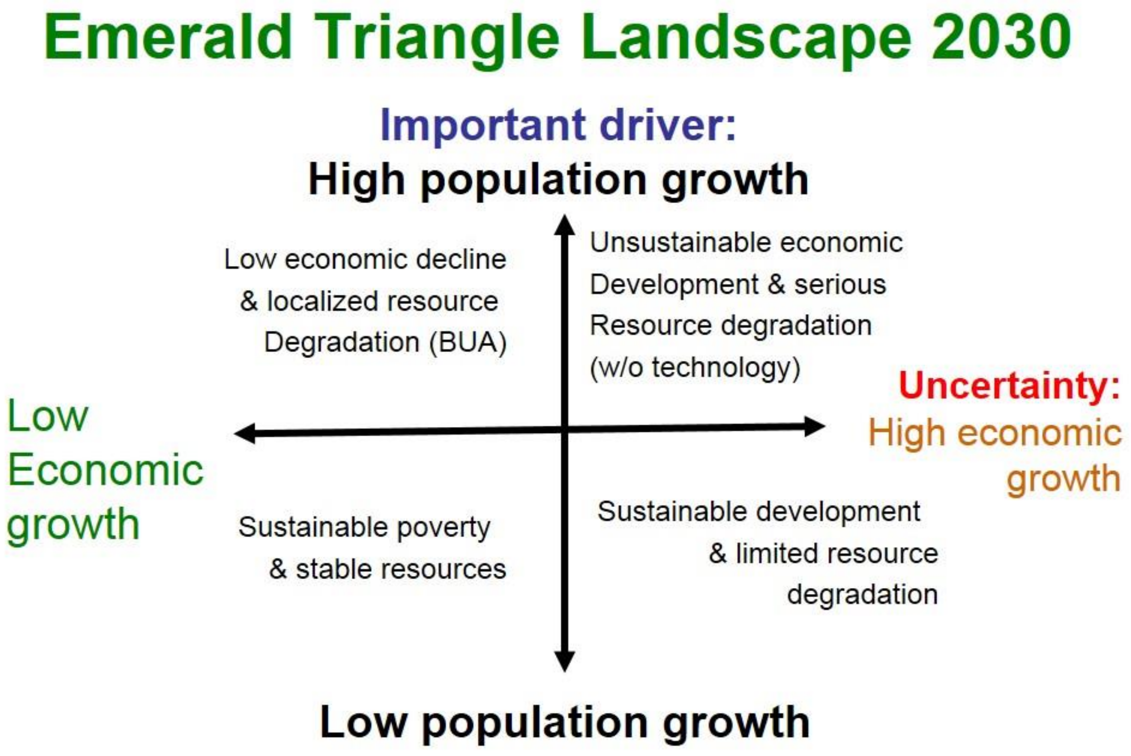


Figure 4 Land use/land cover scenarios of the Emerald Triangle

The definitions of the scenarios are detailed as below:

a) Low economic decline and localized resource degradation (business as usual). A continuation of land transformation of recent years (2003-2013) is foreseen. The recent land-use change detection revealed that only limited encroachment was observed inside the PPFC (Protected Areas Region 9, personal communication). Therefore, this scenario defines the PPFC as restriction areas.

b) Unsustainable economic development and serious resource degradation scenario. It is predicted that the continuous high rubber prices and high population growth make it profitable to transform large forest land and bare soil to paddy field and economic crops.

c) Sustainable poverty and stable resources scenario. A lower rate of land conversion is assumed due to low population growth and the delay of the AEC scheme, meaning limited deforestation. In addition, this scenario anticipates effective protection of remaining forest in all existing and proposed protected areas.

d) Sustainable development and limited resources degradation scenario. A relative land conversion rate applies for rubber plantation. Limited forest encroachment for agriculture outside protected areas and along inner and outer buffer zones of Dong Khanthung is assumed due to low population growth.

The estimated land demands for each land use class under 4 scenarios are shown in Figure 5.

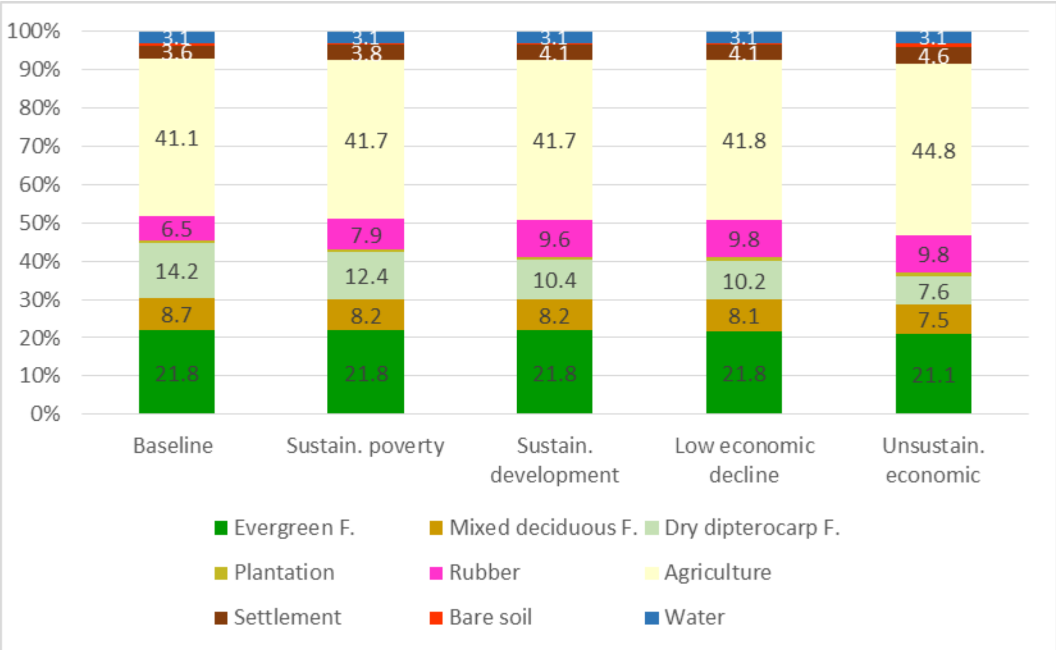


Figure 5 Land allocations for four scenarios from 2013-2030

The Dyna-CLUE model determines the location preferences of the different LU/LC classes based on logistic regression models (Verburg nd Veldkamp, 2004), which define the relation between occurrence of a particular LU/LC type and the physical and socio-economic conditions of a specific location (location factors):

$$Logit(p_i) = \ln (p_i)/(1-p_i) = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$$

where, p_i is the probability of a grid cell for the occurrence

$\beta 0$ = constant value

βi = estimated through logistic regression

X_i = explanatory factors (physical and socio-economic factors)

The physical factors that indicate the preference for a specific type of land use were altitude, slope, aspect, distance to available water, annual rainfall, rainfall in wettest quarter, rainfall in the driest quarter and soil characteristics. In addition, the socio-economic factors influencing land-use change were distance to district, population density and distance to main road. Topographic variables were gathered from Advanced Space Thermal Emission and Reflection Radiometer (ASTER) archive of 100-m resolution (http://asterweb.jpl.nasa.gov/data.asp). Road and stream networks, and district location were updated from topographic maps at scale 1:50,000 and Landsat-8 TM, and later they were interpolated to obtain proximity to road, proximity to stream and proximity to city, respectively.

Climatic variables of approximately 1-km resolution were downloaded from the World climate database (http://www.worldclim.org/download), while soil map and population density were obtained from the MRC. The pixel resolution of 100 m was selected for this research because it was suitable for landscape scale and relevant to the original LU/LC map in 2003 and the driving factors. In addition, the goodness-of-fit of a logistic regression model was evaluated using the receiver operating characteristic (Hosmer and Lemeshow, 2000). The value of the area under curve (AUC) ranges between 0.0 (completely unfit) and 1.0 (perfect fit), where AUC 0.5 is completely random.

Generally, the elasticity values are estimated based on capital investment and expert judgment, ranging from 0 (easy conversion) to 1 (irreversible change) (Verburg and Veldkamp, 2004). In this study, the elasticity values were obtained from the probability transition matrix of land-use between 2003 and 2013. In addition, water body and settlement & infrastructure classes were assigned not possible to be transformed. A minimum of 10 years was assigned in the transition-setting as a requirement for the natural succession of reforestation to forest class and 20 years were specified for succession from abandoned agriculture back to forest cover, based on a previous study (Sahunaru *et al.*, 1993) and image signature.

When all inputs were provided, the Dyna-CLUE model calculated the total probability for each grid cell of each land use type based on the suitability of location derived from the logit model, the conversion elasticity and the competitive advantage of the location. The total allocated area of each land use equals the total land requirements specified in the scenario (Verburg and Veldkamp, 2004).

4.1.5 Assessing landscape configuration features

The FRAGSTATS ver. 3.0 software (McGarigal and Marks, 1995) was used to assess landscape structure and fragmentation indices of forest classes, arable land and rubber plantation in 2013 and 2030 in terms of total area, number of patches, mean patch size, largest patch index, shape index, total core area and mean core area. An eight-neighbor rule was used to identify patch in the landscape. In addition, a core area was assigned from 1 km from perimeter. These landscape indices imply direct and indirect impacts of forest fragmentation on biodiversity (Turner *et al*., 2001; Trisurat and Duengkae, 2011).

4.2 Species Distribution Modelling

The processes for mapping wildlife distributions and determining priority areas for maintaining viable population in the Emerald Triangle area include four steps: a) collection of wildlife presence points, b) target species selection, c) generation of species distribution models, and d) validation and mapping distributions (Figure 6).

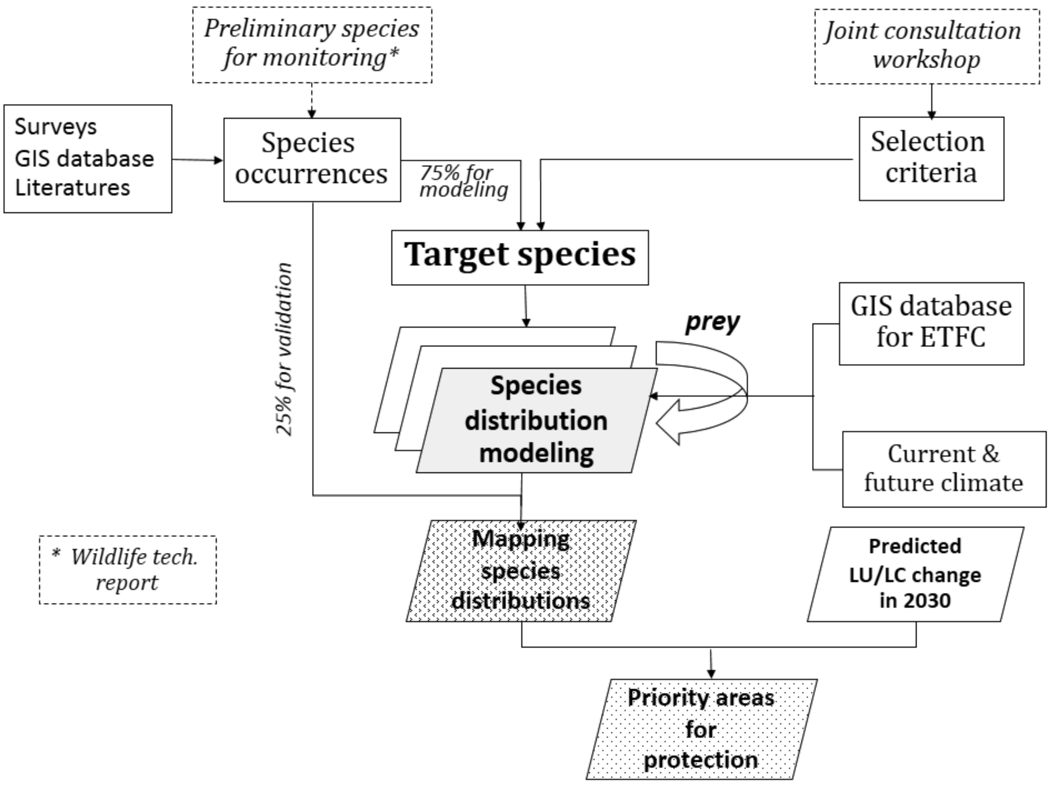


Figure 6. Main steps of species distribution modeling

4.2.1 Collection of wildlife occurrences

Wildlife occurrence data in the ETFC were obtained from three methods, namely ground survey, existing GIS database and literature review. Details of these methods are available in Wildlife Technical Report written by Bhumpakphan (in press). Each method is detailed as follows:

a) Ground survey

Additional ground surveys were conducted in the PPFC in Thailand and Dong Khanthung NBCA in Lao PDR by the Wildlife Consultant (Dr. Naris Bhumpakphan), scientists (lecturers from Champasak University), and park rangers. It is noted that the scientists and park rangers were trained in how to identify tracks and signs of wildlife before the actual survey. The training workshop on Wildlife and Landscape Training was held in Lao PDR on December 11st – 15th, 2013. After the training, the project provided guide books (*e.g.*, Lekagul and McNeely, 1988; Lekagul and Round, 1991; Das, 2010), Global Positioning System (GPS), camera and infra-red camera trapping to assist field survey. In addition, local market survey and interview were included to obtain information on bush meat to confirm the actual presence of wildlife species on the ground.

b) *Existing GIS database*

The existing geo-referenced wildlife locations were combined from the GIS database developed during the PPFC project phases 1 and 2 and from the GIS database of the PVPF. The later data were collected during 2000-2010 by the Forestry Administration, in cooperation with Cat Action Treasury and with the Wildlife Conservation Society for biodiversity conservation surveys in the Preah Vihear Northern Plain (Dany Chheang, personal communication). Besides the environmental factors used in the CLUE-s model, four additional layers were added to determine wildlife habitats, namely deciduous forest patch size, evergreen forest patch size, precipitation of the wettest quarter and precipitation of the driest quarter.

c) Literature review

Besides actual survey, wildlife occurrence data in Dong Khanthung NBCA were also obtained from the report on *Wildlife, Habitats, and Priorities for Conservation in Dong Khanthung Proposed National Biodiversity Conservation Area, Champasak Province, Lao PDR* (Round, 1998). The secondary wildlife data from available literature (e.g., country reports, Duckwort et al. (1999), scientific articles, and internet-based information) were reviewed for Phou Xiang Thong NBCA.

4.2.2 Target species selection

Fifteen potential target species for monitoring were proposed by Bhumpakphan (in press) based on habitat uses, slope gradient, IUCN conservation status and distribution range. Those wide-range species or landscape species that relate to large habitat area of the ETFC landscape include elephant, gaur, banteng, sambar deer, Siamese *Eld*'s deer, tiger, leopard, Sarus crane, Lesser adjutant stork, vultures and freshwater crocodile. These species were further reviewed for modeling and mapping during the *Joint Training Workshop on Species Distribution Modeling* held in Ubon Ratchathani province on 21-24 October 2014. The criteria used for selection of target species include: 1) wide distribution in the Emerald Triangle (having trans-boundary territory), 2) regionally and nationally threatened status (IUCN Redlist in 2013, Nabhitabhata and Charn-ard, 2005), 3) adequate observation records (≥10 points; Wisz *et al*., 2008) and 4) iconic or flagship species for conservation (Beazley and Cardinal, 2004).

4.2.3 Generation of species distribution models

The species distribution maps for selected species were generated using the logistic regression model and maximum entropy method (MAXENT) (Phillips *et al.*, 2006) according to the number of observations and distribution patterns of occurrence data. If there were limited observations and they were clumpy distributed the MAXENT model was chosen, otherwise the logistic regression was used. In addition, Geographic Information System (ArcGIS) was used to convert between raster GIS and ASCII data derived from the distribution model. For each species, occurrence data were divided into two datasets. Seventy-five percent of the sample point data was used to generate a species distribution model, while the remaining 25% was kept as independent data to test the accuracy of each model.

It is noted that species distributions were conducted at the ETFC level. Therefore, environmental variables that were previously identified as direct or indirect factors affecting the patterns of abundance and distribution of wildlife at the regional and national levels (Lekagul and McNeely, 1977; Bonilla-Sanchez *et al*., 2010; Trisurat *et al*., 2010) were developed or extracted from the existing GIS database. For medium-and large sized carnivore species, an additional prey species was included because it is recognized as an important factor for large carnivore distribution. This layer was obtained by combining key prey species previously derived from the species distribution models. Prey species for leopard consisted of wild boar, barking deer, Sambar deer and *Eld's* deer. Banteng and gaur were included for tiger (Simcharoen *et al*., 2007). All environmental variables were converted to GIS raster format to perform spatial analyses. The pixel resolution of 250 m was chosen because it was relevant to the minimum mapping unit of the land use derived from visual interpretation and most of environmental factors.

4.2.4 Validation and mapping species distributions

The continuous probability of occurrence of each model output (0.00-1.00) was transformed into a binary prediction by applying the commonly used thresholds for predicting species distributions (Liu *et al*., 2005). If the probability value is equal or greater than this threshold value, it will be classified as presence, otherwise absence. In addition, the performance of each model was evaluated by using the area under curve (AUC) of the receiver operating characteristic (Hosmer and Stanley, 2000) and the predicted maps were validated using omission & commission errors and a contingency matrix by comparing the predicted presence-absence with independent presence-absence occurrences (25% of total occurrence data). The logistic threshold derived from the MAXENT model that yield the highest overall accuracy and provide optimum omission & commission errors was selected to map species distribution. On the other hand, the cut-off value of 0.5 was selected to reclassify probability values derived from the logistic regression model. It is noted that the predicted LU/LC maps derived from land use scenarios and future climatic variables in 2050 (http://www.worldclim.org/download) were replaced by the existing LU/LC map and current climatic variables to obtain future distribution maps. The analyses were conducted accordingly as present distribution.

5. RESULTS

5.1 Land Use

5.1.1 Land use/land cover 2013

Preliminary land use/land cover in 2013 was visually interpreted from Landsat-8 TM satellite images based on tone, shape, size, pattern, texture, shadow, and association (Lillesand and Kiefer, 1987). The GIS Consultant used stratified random sampling to determine the number of samples classified in preliminary land use classes and compared them with the actual (known) classes during field validation. The total number of sample locations for paddy, rubber plantation, forest plantation, dry dipterocarp forest, mixed deciduous forest, dry evergreen forest, settlement and others classes were 232, 38, 14, 43, 42, 59, 59 and 21 respectively.

The contingency table or classification matrix (Table 6) shows that classification accuracy of most land use classes, except cassava and oil palm was greater than 80%. The overall accuracy for land use interpretation was approximately 91% and kappa accuracy was 86%, which is acceptable for most remote sensing scientists. Five sample locations of paddy field were misclassified as dry dipterocarp forest. This is because some shrubs still remain in the paddy field. In addition, the classification between oil palm and paddy, as well as paddy and cassava was difficult. This is due to the fact that oil palm was recently introduced and mainly planted in paddy fields. Crown cover of young oil palm covered only small areas. To avoid omission and commission errors, cassava and oil palm were later merged with paddy and renamed as agriculture class (Figure 7).

Table 6 Contingency table resulting from field validation

	Land use/ land cover class	Interpretation																
		Paddy field	Cassava	Para rubber	Oil palm	Plantation	Bare soil	Dry dipterocarp forest	Mixed dipterocarp forest	Dry evergreen forest	Hill evergreen forest	Moist evergreen forest	Rock outcrop	Water	Settlement & infra	Total	Producer's Accuracy (%)	Omission error (%)
Ground truth	Paddy	210						5								215	98	2
	Cassava	5	4													9	44	56
	Para rubber	7		35		1										43	81	19
	Oil palm	3			2											5	40	60
	Plantation			3		13										16	81	19
	Bare soil						2									2	100	0
	Dry diptercarp forest	7						38	2							47	81	19
	Mixed deciduous forest								40	7						47	85	15
	Dry evergreen forest									52						52	100	0
	Hill evergreen forest										1					1	100	0
	Moist evergreen forest											1				1	100	0
	Rock outcrop												6		1	7	86	14
	Water													10		10	100	0
	Settlement & Infra														53	53	100	0
	Total	232	4	38	2	14	2	43	42	59	1	1	6	10	54	508	92	8
	Commission error (%)	9	0	8	0	7	0	12	5	12	0	0	100	100	98			
	User's accuracy (%)	91	100	92	100	93	100	88	95	88	100	100	0	0	2			

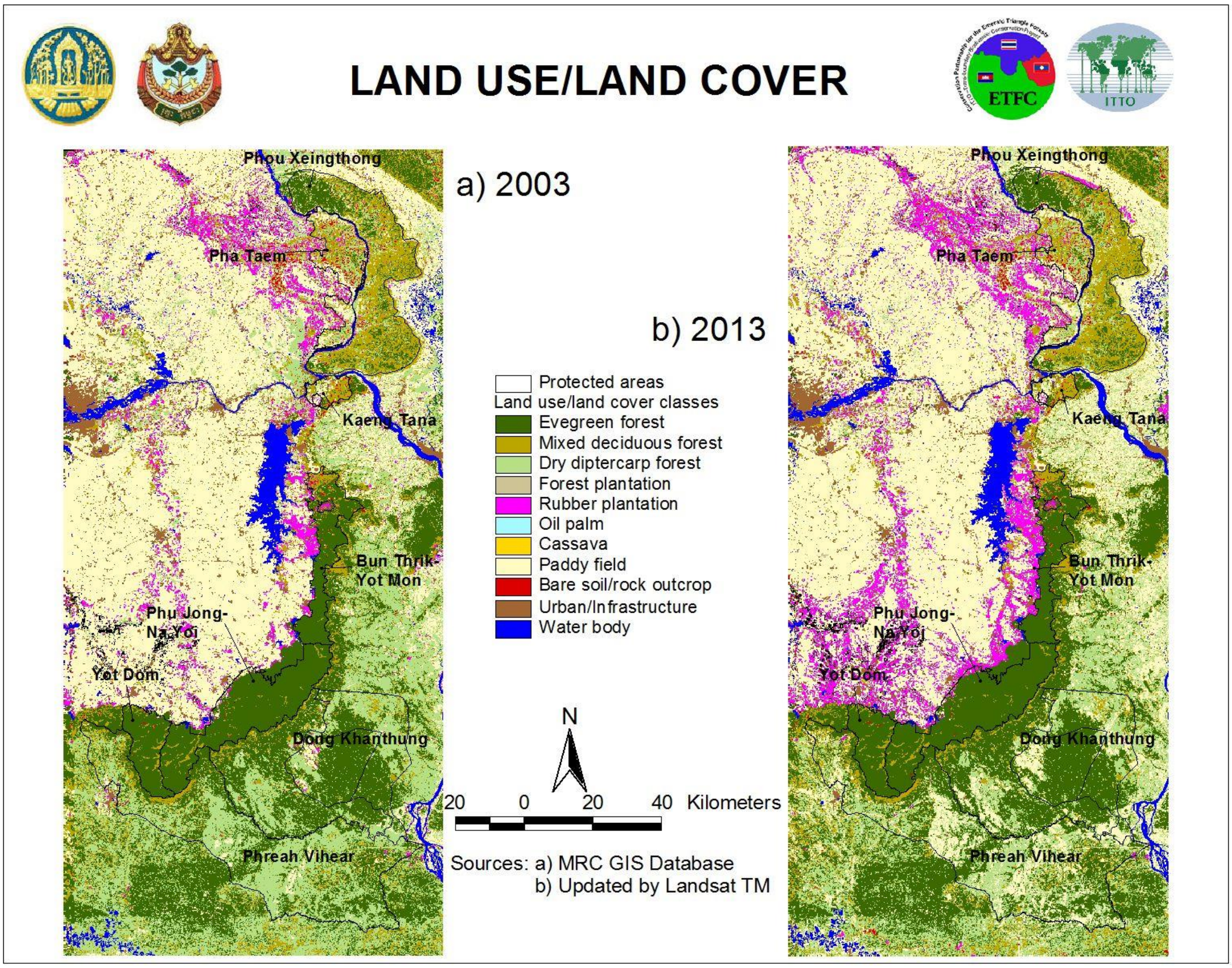


Figure 7 Land-use/land-cover in 2003 and 2013 in the Emerald Triangle Protected Forest Complex

5.1.2 Land use/land cover change between 2003 and 2013

Land use/land cover maps in 2003 and 2013 were overlaid. Based on spatial and static analyses, the results are shown in Table 7.

Table 7 Land use/land cover classes in 2003 and 2013 in the Emerald Triangle Protected Forest Complex (ha)

Type of land-use	2003		2013		Change	Change in %	
	ha	%	ha	%	ha (+/-)	10 yrs.	Yearly
Moist evergreen forest	1,150	0.04	1,081	0.04	-69	-6.00	-0.62
Dry evergreen forest	546,750	21.15	555,823	21.50	9,073	1.66	0.16
Hill evergreen forest	4,212	0.16	4,200	0.16	-12	-0.29	-0.03
Mixed deciduous forest	245,412	9.49	226,573	8.77	-18,839	-7.68	-0.80
Dry dipterocarp forest	540,687	20.92	374,337	14.48	-166,350	-30.77	-3.61
Forest plantation	9,850	0.38	13,475	0.52	3,625	36.80	3.18
Para rubber	85,456	3.31	164,225	6.35	78,769	92.18	6.75
Oil palm	600	0.02	1,075	0.04	475	79.16	6.00
Paddy	951,556	36.81	1,040,444	40.25	88,888	9.34	0.90
Cash crop	12,931	0.50	17,317	0.67	4,386	33.92	2.96
Settlement	77,700	3.01	80,365	3.11	2,665	3.43	0.34
Bare soil	14,281	0.55	12,587	0.49	-1,694	-11.87	-1.26
Rock outcrop	11,268	0.44	10,706	0.41	-562	-4.99	-0.51
Water body	83,050	3.21	82,697	3.20	-353	-0.43	-0.04
Total	2,584,903	100.00	2,584,903	100.00	0.00	0.00	0.00

Moist and hill evergreen Forest: In the ETFC, moist evergreen forest is found along stream networks where soil moisture is high all year round. Hill evergreen forest normally occurs in elevation higher than 1,000 m above mean sea level. Accessibility to this vegetation type is difficult, therefore the area of hill evergreen forest was similar. In 2003, moist evergreen forest covered approximately 1,150 ha or 0.04% of the ETFC, and it slightly declined to 1,081 ha or 69 ha in 2013.

Dry evergreen forest is dominant among evergreen forest classes and mainly found in Phu Jong-Na Yoi National Park, Yot Dom Wildlife Sanctuary and the core area of Dong Khanthung. According to remote sensing and GIS analysis, dry evergreen forest covered an area of 546,750 ha or 21.15% of the ETFC landscape in 2003, and it slightly increased to 555,823 ha or 21.50% in 2013. Approximately 9,000 ha were added possibly due to different image signature. The land-use/land-cover map in 2013 was interpreted from Landsat-8 TM taken in October 2013 which was early dry season. Therefore, there might be commission errors as the results of the signature of dense mixed deciduous forest and flooded dry dipterocarp forest situated in Dong Khanthung (Table 6). Therefore, they were wrongly interpreted as dry evergreen forest.

Mixed deciduous forest basically exists in Phou Xing Thong NBCA, Pha Taem National Park, Kaeng Tana National Park, along the escarpment between Thailand and Lao PDR and patchy scatters in the south part of the ETFC landscape. This forest class covered 245,412 ha in 2003 and declined to 226,573 ha in 2013. The reduction rate was 7.68% in 10 years or 0.80 annually.

Dry dipterocarp forest usually occurs on dry shallow and lateritic soils. It used to be abundant along the buffer zone of PPFC but has been converted to agriculture. It is now dominant in Phreah Vihear and Dong Khanthung. In 2003, dry pipterocarp forest covered an area of 540,678 ha or 20.92%. The existing area in 2013 was estimated at 374,337 ha or 14.48%. Thus approximately 116,350 ha or 30.77% of the total area had been converted to agriculture and other uses in the last decade or it has declined 3.61% annually. Sobon (2014) reported that dry dipterocarp forest in the Phreah Vihear northern plain of Cambodia was largely converted to paddy field and settlement under a land allocation program for military.

Forest plantations are mainly established and managed by both the Forest Industrial Organization and Department of National Park, Wildlife and Plant Conservation for economic purpose and natural rehabilitation, respectively. Small scale plantation by villagers is also practiced. *Eucalyptus* sp. is a common species for plantation by the Forest Industrial Organization and villagers. Most of the eucalyptus plantations are sited in Bun Thrarik District between the Bun Thrarik-Yot Mon Proposed Wildlife Sanctuary and the Sirinthon Reservoir. Remote sensing analysis reveals that in 2003 there were about 9,850 ha and that increased to 13,475 ha in 2013 or accelerates 3.18% annually.

Para rubber plantation: Para rubber cultivation is a new agricultural practice in the Emerald Triangle landscape. However, it has increased rapidly in the last decade in the three countries. Rubber plantation covered an area of 85,456 ha in 2003 and rapidly increased to 164,225 ha in 2013 or nearly doubled during 10 years. The annual increment rate was 6.75%, which was the highest among 14 classes. Most plantations are situated in the buffer zones of Bun Thrarik, Phu Jong-Na Yoi and Yot Mon. A few patches are observed inside Bun Thrarik-Yot Mon Wildlife Sanctuary.

Oil palm is determined as a new economic agricultural crop recently found in the PPFC landscape. The areas in 2003 (600 ha) and 2013 (1,075 ha) were not large, but the increment rate (6% annually) was ranked as the second after rubber plantation. Based on land suitability, it is anticipated that the extent of oil palm would not cover large area as rubber or other economic crops due to constraint of soil characteristics and climatic conditions. Because oil palm requires soil moisture all year round and high rainfall.

Paddy and cash crops are widespread in the ETFC landscape. In the PPFC landscape, these two classes constituted nearly 28.72% in 2002 and substantially increased to 30.12% in 2008 (Trisurat, 2010). According to the land use/land cover map 2013 it was found that some paddy and cash crop patches were converted to rubber plantation. On the other hand, agriculture areas in Lao PDR and Cambodia increased substantially. The aggregate areas of paddy and cash crop increased 88,888 ha and 4,386 ha, respectively.

Bare soil and rock outcrops: This land cover class includes a drawdown zone along the river bank and rock out crop in the marginal land or unfertile soil. The areas of 1,694 ha of bare soil and 562 ha of rock outcrop were changed to other classes such as seasonally agriculture or water body in the wet season.

Build-up area: As discussed in the previous section, there are 82 villages situated within a 3-km buffer of the PPFC and 4 villages are located inside the PPFC. In the last 10 years (2003–2013), human settlements had expanded and the number of local residents substantially increased from 49,324 to 65,016 individuals. In addition, new settlements for Cambodian military staff were established in Phreah Vihear province. Therefore, the settlement area in the Emerald Triangle landscape have increased approximately 2,670 ha in the last decade.

Water bodies: This class includes reservoirs, ponds and major rivers. In 2003, the overall water surface covered 83,053 ha. Based on remote sensing analysis, it was found that the water body covered 82,697 ha in 2013 or decreased 353 ha. This may be due to the fluctuation of water level during wet and dry season.

5.1.3 Predicted land use/land cover in 2030

It should be noted that the current CLUE-s model version is applicable to not more than 11 classes. In addition, the classification matrix (Table 8) shows that the classification between oil palm and paddy, as well as paddy and cassava was difficult and their classification accuracies were low. In addition, the CLUE-s model was developed for modeling land use at landscape level (Verburg and Veldkamp 2004). . To avoid omission and commission errors, the original classes (14 classes) were generalized to 9 classes, namely 1) evergreen forest (moist, dry and hill evergreen forests), 2) mixed deciduous forest, 3) dry deciduous forest, 4) forest plantation, 5) rubber plantation, 6) agriculture (paddy, cash crop and oil palm), 7) settlement and infrastructure, 8) bare soil and rock outcrop and 9) water body. In addition, the transition matrix of these land use classes between 2003 and 2013 is shown in Table 8. It is noted that water body was not modeled because it was determined as stable in the land demand scenarios (Figure 5).

The significant factors and coefficients of the logistic regression models that determine the location suitability of the eight LU/LC classes are shown in Table 9. It is noted that each driving factor contributed to different LU/LC types. High altitude, steep slope, high annual rainfall and further distance from city and stream, as well as difficult to access by road were positively correlated to remaining evergreen forest. In contrast, areas that were close to the stream and main city, situated on fertile soil, accessible from main roads, and at low altitude were a prime target for agriculture. Aspect is a considerable factor only for rubber plantation in the logistic regression model. In general, rubber trees can grow in all aspect directions (Ranst *et al*., 1996) but the model results indicated that the greater degree from clock-wise direction is more suitable for rubber. This is due to the fact that most existing rubber plantation areas are situated in the buffer zones of the PPFC (Figure 7). The areas to the east of PPFC are mountainous landscapes.

Table 8 Transition matrix of land use/land cover classes between 2003 and 2013

Land use/land cover Year 2003 (column) Year 2013 (row)	Evergreen forest	Mixed deciduous forest	Dry dipterocarp forest	Forest plantation	Rubber	Agriculture	Settlement	Bare soil/rock	Water	**Grand Total**
Evergreen forest	**83.60**	5.70	7.08	0.03	0.44	2.86	0.12	0.06	0.10	100.00
Mixed deciduous forest	15.57	**56.19**	11.92	0.08	2.34	12.89	0.43	0.32	0.27	100.00
Dry dipterocarp forest	9.38	6.18	**48.45**	0.11	1.97	32.28	0.59	0.60	0.44	100.00
Forest plantation	0.96	1.28	1.16	**58.00**	15.48	17.28	4.56	0.13	1.16	100.00
Rubber	2.00	4.30	5.68	1.14	**62.54**	20.69	2.82	0.31	0.52	100.00
Agriculture	0.96	1.66	3.11	0.56	8.90	**82.22**	1.79	0.04	0.75	100.00
Settlement	0.49	0.65	0.78	0.47	2.61	14.64	**79.52**	0.01	0.82	100.00
Bare soil/rock	2.15	4.99	15.13	0.68	13.26	23.17	16.55	**23.04**	1.01	100.00
Water	0.56	0.76	1.37	0.13	0.83	10.77	1.20	0.02	**84.37**	100.00
Grand Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 9 Beta values of significant location factors for regression models related to each land use type.

Variables	Evergreen forest	Mixed deciduous forest	Dry dipterocarp forest	plantation	Rubber	Agricul-ture	Settlement	Bare soil
DEM (m) 0	0.0020	ns	-0.0130	0.0152	0.0111	-0.0033	0.0028	0.0075
Slope (%) 1	ns	0.1033	ns	-0.0962	-0.1185	-0.1200	ns	-0.0347
Aspect 2	ns	ns	ns	ns	0.0007	ns	ns	ns
Population density (person/km2) 3	-0.0388	-0.0011	-0.0004	-0.0007	-0.0006	-0.0002	0.0017	ns
Annual rainfall (mm) 4	0.0087	-0.0064	-0.0027	0.0191	-0.0064	-0.0067	0.0076	-0.0148
Rainfall in the wettest quarter (mm) 5	-0.0074	0.0081	0.0066	-0.0233	0.0083	0.0059	-0.0111	0.0160
Rainfall in the driest quarter (mm) 6	-0.0448	0.1519	0.2902	-0.3836	-0.1795	-0.1019	-0.1217	ns
Distance to road (m) 7	0.0002	8.9E-05	5.7E-05	-0.0014	-0.0005	-0.0003	-0.0029	-0.0001
Distance to stream (m) 8	8E-05	0.6E-05	5.1E05	-0.0004	-0.0006	-0.0001	-0.0001	ns
Distance to city 9	3.8E 05	-0.3.2E-05	1.1E-05	ns	ns	1.6E-05	-3.0E-05	-3.4E-05
Acrisol soil 10	3.2217	0.4374	2.3320	0.7626	0.6666	1.5903	-0.3665	0.7441
Arenosol soil 11	1.5034	ns	1.3106	0.7348	ns	2.1740	-0.5131	ns
Cambisol/Plinthosol soil	3.5029	0.5725	2.4457	ns	-1.5936	1.3835	-0.6280	ns
Ferralsol soil 13	3.5540	ns	Ns	-1.8358	0.8336	1.1610	ns	ns
Gleysol/Fluvisol soil	2.1677	0.9295	1.9162	ns	Ns	1.8357	-1.1610	ns
Leptosol soil 15	4.7861	ns	2.0991	ns	Ns	1.9332	ns	ns
Lixixol soil 16	2.8929	ns	Ns	ns	1.6638	1.6729	ns	ns
Luvisol/Solonetz soil	2.4951	ns	3.0006	ns	-2.4466	1.7767	ns	ns
Slope complex 18	2.4752	ns	4.2447	ns	1.7360	ns	-0.7401	2.2224
Rock 19	3.6601	ns	3.5119	-3.3545	-1.3257	ns	-1.7182	0.9972
constant	-11.2522	-0.2324	-8.3067	-5.1757	4.1205	7.5319	1.4886	8.0077
AUC	0.902	0.758	0.767	0.837	0.802	0.815	0.903	0.797

AUC = area under curve; ns = not statistically significant

According to Hosmer and Lemeshow (2000), the predicted models were outstanding for evergreen forest and settlement (AUC>0.9), excellent for forest plantation, rubber plantation and agriculture ($0.8 \leq AUC < 0.9$) and acceptable for mixed deciduous forest, dry dipterocarp forest and bare soil & rock outcrop ($0.7 \leq AUC < 0.8$) (Hosmer and Lemeshow, 2000). This is due to the fact that evergreen forest and human settlement were mainly restricted and clustered in certain areas, while other classes were widely distributed in the ETFC landscape. The gradient of AUC values showed similar agreement with the accuracy assessment of the interpreted LU/LC classes (Table 6).

The simulated LU/LC maps in 2030 for the four scenarios are shown in Figure 8. The results of the *low economic decline and localized resource degradation (business as usual)* scenario with restriction policy in the PPFC show that future deforestation for agriculture was predicted in the remnant forests situated in the buffer zones of the PPFC and areas close to the Chong-Mek border check point (Figure 8a). In addition, substantial areas of forest cover in the Phou Xiang Thong and to the north of Dong Khanthung were predicted to be converted to rubber plantations. In Thailand, expansion of rubber plantation was predicted in the west outside the Pha Taem national park and close to road network currently covered by cash crop and mixed deciduous forest.

The *unsustainable economic development and serious resource degradation* scenario predicted a lot of land conversion to arable land and rubber plantation. The area of mixed deciduous and dry dipterocarp forests was predicted to decline from 22.9% of the entire ETFC in 2013 to 15.1% in 2030. In contrast, rubber plantation area was anticipated to increase 50% from the current status (Figure 5). Figure 8b shows that new arable land is also predicted in the west of PVPF, which is close to the Preah Vihear Temple cultural world heritage site.

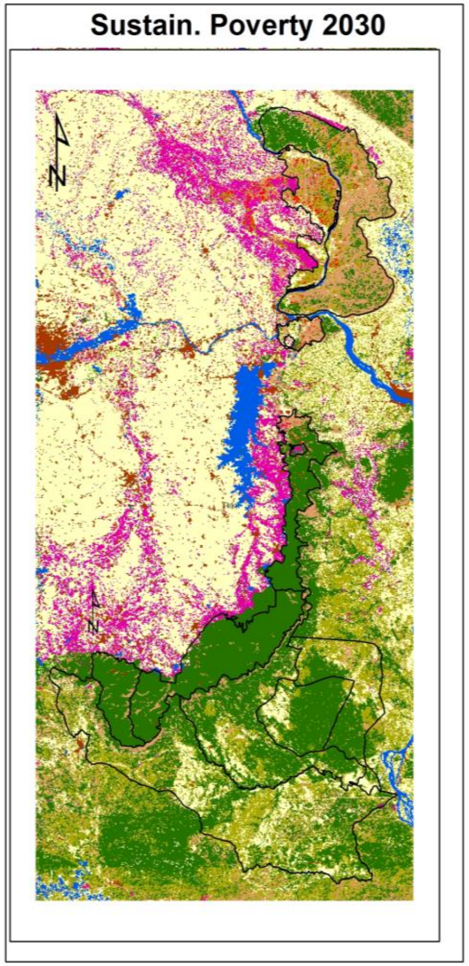


Figure 8 a) Predicted land uses *for sustainable poverty and stable resources* scenario

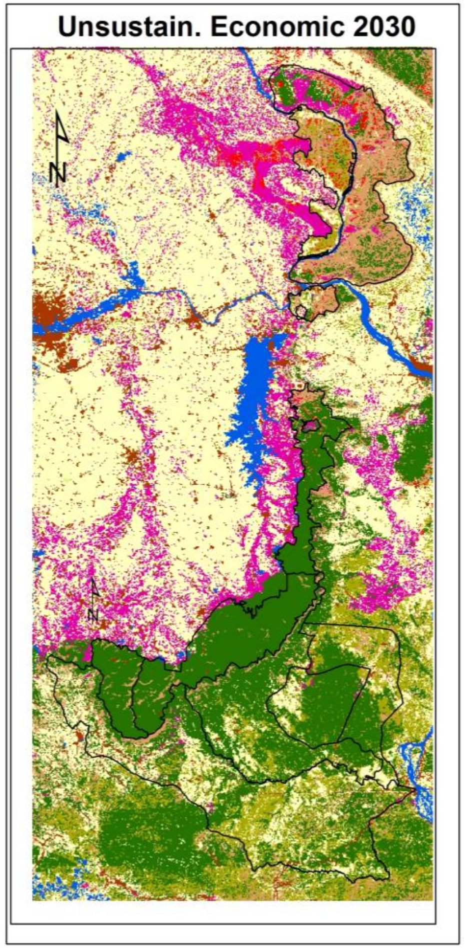


Figure 8 b) Predicted land uses *for Unsustainable economic development and serious resource degradation*

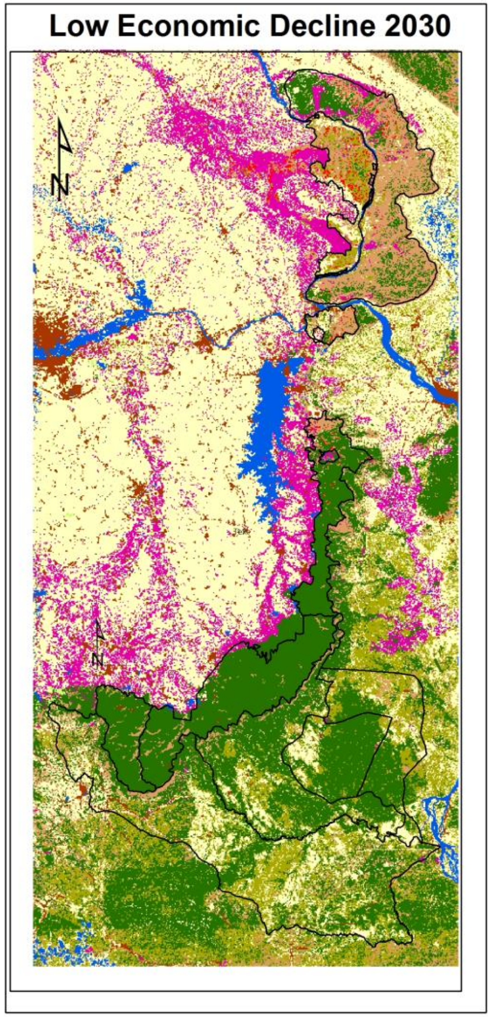


Figure 8 c) Predicted land uses *for Low economic decline and localized resource degradation*

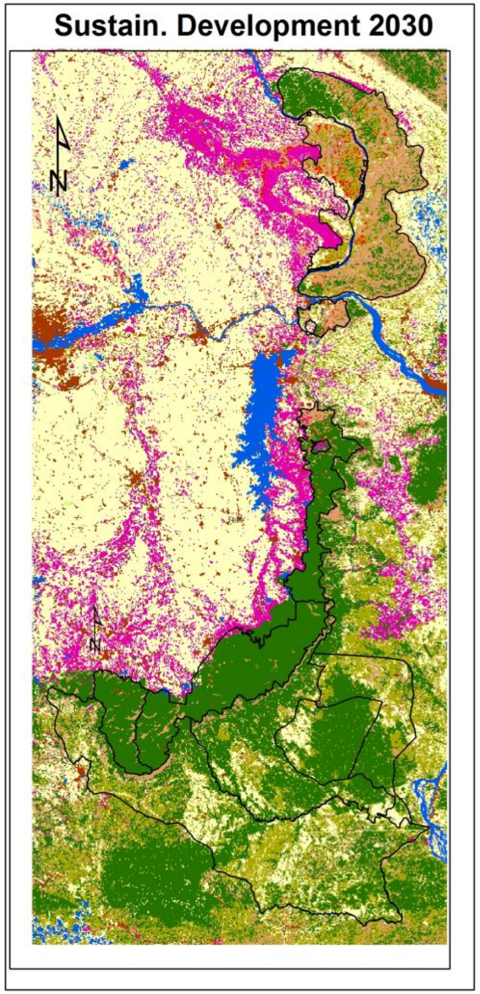


Figure 8 d) Predicted land uses *for sustainable development and limited resources degradation*

The *sustainable development and limited resources degradation* scenario (Figure 8d) predicted similar land-use patterns as the business as usual scenario (Figure 8a). High deforestation was found in the north of Dong Khanthung and to the west of Pha Taem, but limited deforestation was in all protected areas. Finally, the *sustainable poverty and stable resources scenario* showed different land-use patterns than the other scenarios. This scenario assumed less demand for agriculture and rubber plantations due to low population growth and the delay of AEC implementation scheme, leading to limited deforestation. A small amount of land conversion to rubber plantation was expected outside all existing and proposed protected areas (Figure 8c). In addition**,** the predicted deforestation maps in 2030 derived from the four scenarios are shown in Figure 9.

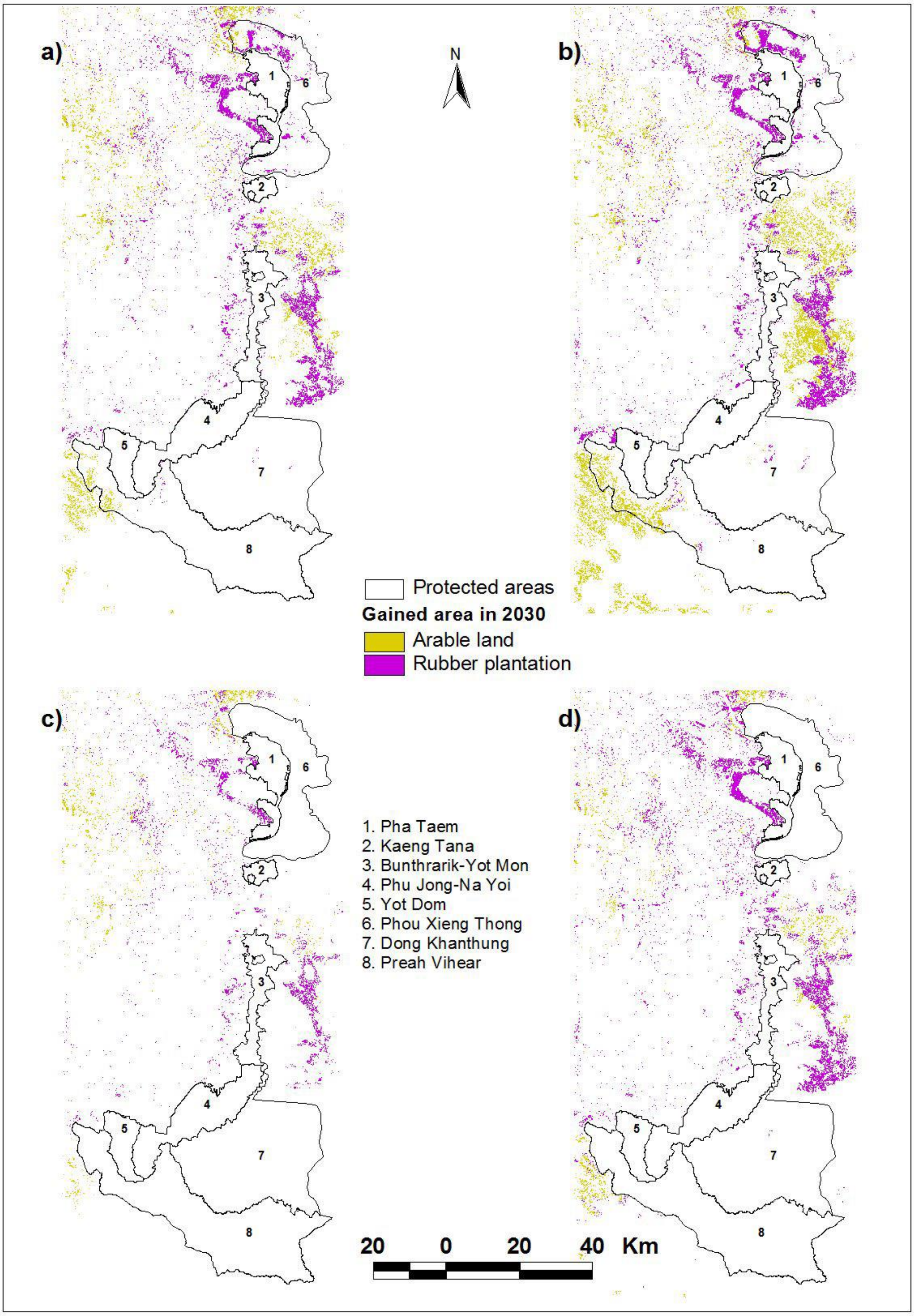


Figure 9 Predicted new areas for arable land and rubber plantation in 2030

5.2 Wildlife Distributions

5.2.1 Selected wildlife species

Wildlife occurrence data in the ETFC were obtained from three methods, namely ground survey, existing GIS database and literature review. Based on the criteria used for selection of target species, multi-stakeholders participating in the *Joint Training Workshop on Species Distribution Modeling* held in Ubon Ratchathani province on 21-24 October 2014, selected 12 species for modeling, their distributions in the ETFC landscape (Table 10). Those wide-range species include elephant, gaur, banteng, sambar, Siamese *Eld's* deer, barking deer, tiger, leopard, Sarus crane, Lesser adjutant stork, Giant ibis and wild boar. Indian muntjac or barking deer had more than 900 records. A high number of observations was also available for gaur, banteng, *Eld's* deer, Asian elephant, barking deer, Sarus crane, Lesser adjutant stork, Giant ibis and wild boar. A minimum record was recorded for tiger and Siamese crocodile. There were a few sightings for vultures in Dong Khanthung and Preah Vihear, but geo-reference locations were not available.

It should be noted that Siamese crocodile, vultures and pileated gibbon were not included although they are classified as threatened species because there were limited records for Siamese crocodile and vultures. Pileated gibbon was reported along the tri-national borders but current distribution is mainly restricted in the Phreah Vihear and along the border between Dong Khanthung and Bun Thrarik-Yot Mon. A herd of Pileated gibbon (3-6 individuals) has an average home range of less than 1 km^2 (Srikosamatara, 1984). Thus, it is not recognized as a landscape species. In contrast, wild boar and barking deer were added for modeling because they are main prey species for tiger (Simcharoen *et al*., 2007) and leopard (Reed *et al*., 2012) in the ETFC landscape.

Table 10. Selected wildlife species for modeling in the Emerald Triangle landscape

Scientific name	Common name	Distribution[1/]			IUCN status[2/]	ETFC Iconic	No. of records[3/]	Y/N[4/]
		T	L	C				
Bos gaurus	Gaur	x	x	x	VU		203	Y
Bos javanicus	Banteng	x	x	x	EN	√	228	Y
Cervus unicolor	Sambar	x	x	x	VU		20	Y
Rucervus eldii siamensis	*Eld's* deer		x	x	EN	√	142	Y
Crocodylus siamensis	Siamese crocodile	x	x	x	CR		9	N
Elephas maximus	Elephant	x	x	x	EN	√	356	Y
Gyps bengalensis	White-backed vulture		?	x	CR		?	N
Gyps indicus	Long-billed vulture		?	x	CR		?	N
Grus antigone	Sarus crane		x	x	VU	√	272	Y
Hylobates pileatus	Pileated gibbon	x	x	x	EN		30	N
Leptoptilos javanicus	Lesser Adjutant stork	?	x	x	EN	√	310	Y
Muntiacus muntjac	Indian muntjac, Barking deer[5/]	x	x	x	LC		927	Y
Neofelis nebulosa	Leopard	x	x	x	NT		44	Y
Panthera tigris	Tiger	x	x	x	EN	√	10	Y
Pseudibis gigantea	Giant ibis		x	x	CR	√	291	Y
Sarcogyps calvus)	King or red-headed vulture		?	x	CR		?	N
Sus scrofa	Wild boar[5/]	x	x	x	LC		326	Y

Notes: [1/] T, Thailand; C, Cambodia; L, Lao PDR (Bhumpakphan, in press)
[2/] EN, Endangered species; CR, Critical Endangered species;
VU, Vulnerable species; NT, Near threatened species (IUCN, 2013)
LC, Less Concern species
[3/] Number of records compiled from surveys, literatures and GIS database
[4/] Y, selected for modeling; N, not selected for modeling
[5/] Important prey species for the selected carnivores
x, existing; ?, need to be confirmed/limited records

High occurrences were recorded in the Preah Vihear, Cambodia and followed by Dong Khanthung. This phenomena resulted from the dissimilarity of survey efforts in the study areas. Since 1998, the Forestry Administration, has in cooperation with Cat Action Treasury and with the Wildlife Conservation Society since 1999 conducted biodiversity conservation surveys in the Preah Vihear. The results of those surveys have documented an impressive list of fauna. The wildlife occurrences found in the Preah Vihear were more than 3,000 points from the total points of 3,500 accumulated from the three countries. The number of total points recorded in the Dong Kanthung was approximately 200 points (Round, 1998) while the lowest number of 60 points was observed in the PPFC (Bhumpakphan, in press). This is due the fact that wildlife surveys in Lao PDR and Thailand were conducted by rapid assessment and conducted only one time.

5.2.2 Used distribution models and logistic thresholds

Based on the bias surveys and the patterns of occurrence distributions discussed above, the MAXENT model was used to generate distribution of sambar deer, leopard and tiger because there were limited number of records for these species. In addition, the logistic model was used for the remaining species. It is noted that annual rainfall was excluded in the model due to high correlation with the precipitation in the wettest quarter months (Annex 1).

The results of logistic regression indicated that land use did not contribute to the species distribution for the nine modeled species and only slightly contributed to the distribution of sambar, leopard and tiger. This may be due to the fact that all twelve species are recognized as landscape species meaning they are able to inhabit all vegetation types in the landscape. Distance from city was positively correlated with most species distributions due the fact that they are sensitive to human pressures, but distance was non-considerable for Lesser adjutant stork and barking deer. In contrast, altitude was negatively correlated for many species. This implied that the selected species, especially large mammals prefer to live in low altitude.

It should be noted that environmental variables affected the distributions of selected species differently. The coefficient values derived from the logistic regression showing how environmental variable affects the prediction for each species are found in Table 11. The coefficient value showed that the precipitation in the wettest quarter months was positively correlated for elephant, but it was considered as a negative factor for the remaining species. Basically, most species prefer large forest patches, except bird species (Sarus crane, Lesser adjutant stork and Giant ibis) and *Eld's* deer that most likely live in open-woodland.

Table 11 Relative contributions of the environmental variables to spatial distribution model of each wildlife species

Species	Constant	City distant	LU/LC	Population	DEM	Slope	Stream-dist	Road-dist	Wet_Q _rain	Dry_Q _rain	Deciduous patch size	Evergreen patch size	Prey	AUC	Accuracy
Logistic regression															
Gaur	-3.5711	0.0001							-0.0088	0.5227		0.0006		0.83	67/80/74
Banteng	4.3376	0.0001			-0.015			0.0002	-0.0058			0.0007		0.84	68/83/76
Eld's deer	-12.215	0.0001				-0.701	0.0009	-0.0003		0.4853		-0.002		0.96	86/92/90
Elephant	-23.8579	0.0002			-0.008	-0.214	-0.0004	0.0003	0.0075	0.6834	0.0009	0.0006		0.91	76/89/83
Sarus crane	4.533	0.0002		0.0173			0.0006		-0.0282	1.0253	-0.0023	-0.0017		0.95	86/93/90
Lesser adjutant stork	-13.267				-0.042		0.0003			0.9544	-0.0011			0.89	75/84/79
Barking deer	8.9072			-0.0386	-0.018				-0.0036	-0.1414	0.0007	0.0006		0.81	62/87/75
Giant ibis	2.0501	0.0002					0.0002		-0.0281	1.1752		-0.001		0.96	79/92/86
Wild boar	11.3316	8.20E-05		-0.0549	-0.023			-0.0001	-0.0044	-0.2783	0.0015	0.0007		0.86	73/88/81
MAXENT model															
Sambar	NA	29.1	2.3	<0.1	6.0	0.1	0..2	0.4	1.0	1.4	<0.1	1.6	NA	0.96	89/90/90
Leopard	NA	15.1	0.3	3.5	8.1	0.5	2.0	3.6	1.2	24.8	3.0	10.5	246	0.95	83/91/87
Tiger	NA	48.1	5.0	<0.1	<0.1	<0.1	0.3	0.2	<0.1	<0.1	0.2	<0.1	46.2	0.96	NA

Remarks: Annual rain 2000: 1864 mm (1,469-3,247); driest quarter 2000: 16 mm (11-41); wettest quarter 2000: 1119 mm (847-2054)
Annual rain 2050: 1779 mm (1,381-3,081); driest quarter 2000: 12.3 mm (8-33); wettest quarter 2000: 1048 mm (787-1922)
AUC, area under curve; NA, not applicable

Table 12 Selected species and accuracy assessment of the predicted distributions derived from used logistic thresholds

No.	Species name	10PT[1] and accuracy			EQ[2] and accuracy			MTS[3] and accuracy			EQT[4] and accuracy			MTST[5] and accuracy			AUC[7]	Used threshold
		Threshold	Omm./ Comm.	Accur.	Threshold	Omm./ Comm.	Accur.	Threshold	Omm./ Comm.	Accur.	Threshold	Omm./ Comm.	Accur.	Threshold	Omm./ Comm.	Accur.		
1	Sambar	0.42	11/10	89	0.18	11/70	58	0.42	11/10	89	0.51	28/0	89	0.56	28/0	89	0.96	10PT/MTS
2	Leopard	0.36	17/9	87	0.33	17/27	78	0.29	17/45	79	0.24	8/45	74	0.24	8/45	74	0.95	10PT
3	Tiger	0.21	NA	NA	0.21	NA	NA	0.21	NA	NA	0.48	NA	NA	0.48	NA	NA	0.96	10PT

[1] 10 percentile training presence; [2] EQ, Equal training sensitivity plus specificity; [3] MTS, Maximum training sensitivity plus specificity; [4] EQT, Equal test sensitivity plus specificity; [6] MTST, Maximum test sensitivity plus specificity; AUC, area under curve

In addition, the response curves derived from the MAXENT model reflect the dependence of predicted suitability both on the selected variable and on species occurrences induced by correlations between the selected variable and other variables. The confusion matrix (Table 12) indicate that the overall accuracy derived from the 10PT approach was the highest among the five logistic thresholds. It was therefore selected to reclassify the probability values for mapping distributions of sambar, leopard and tiger.

5.2.3 Extent of present distributions

The predicted distributions of barking deer cover an area of 7,612 km^2 or 30.37% of the Emerald Triangle landscape, the highest of any of the 12 species. It is followed by wild boar (25.55%), elephant (20.46%) and banteng (15.58%) (Table 13). Although, elephant is classified as an endangered species, but it is also recognized as a landscape species and requires a larger territories. In addition, elephant inhabits various habitats both intact and degraded forests. Barking deer and wild boar are medium-sized mammals and classified as common species. Their habitat covers various ranges of ecosystems.

In contrast, potential habitats for Sambar deer, *Eld's* deer, leopard, tiger and Giant ibis cover less that 10% of the Emerald Triangle landscape and mainly concentrate in the protected areas. These species are listed as endangered or vulnerable species. Table 13 shows that more than 70% of the total suitable habitat for these species (except Sarus crane) were predicted to be in protected areas. Figures 10-21 show the species occurrences and distribution maps for the 12 selected species.

5.2.4 Extent of future distributions

This research determined the consequences of land-use change and combination of land-use and climate changes on the distributions of selected species. The results indicate that future land-use change (less forest cover) will slightly increase suitable habitats for Sarus crane, gaur, banteng, sambar deer and tiger (Table 13; Annex 2). This is due to the fact that gaur, banteng and sambar deer are browser species and they are main prey species for tiger (Simcharoen *et al*., 2007). In addition, crane prefers to inhabit open areas such as paddy field, open woodland close to water bodies (Purchkoon *et al.,* 2014). In contrast, future land-use change negatively affects habitat for elephant, especially under the sustainable development scenario. The suitable habitat was predicted to decrease from 20.46% at present to approximately 14% in 2030.

Table 13. Predicted suitable distributions for each mammal species in 2013 in the Emerald Triangle landscape

Species name	Area (km^2)	%	Low Econ without CC	Low_Econ	Sus. Pov without CC	Sus Pov	Sus Devl without CC	Sus Devl	Unsus Dev. without CC	Unsus Devl.
Gaur	3,664	14.62	14.66	8.51	14.79	8.52	15.37	8.55	15.19	8.99
Banteng	3,905	15.58	15.81	19.00	15.98	19.13	16.32	19.32	16.19	16.20
Sambar	1,008	4.02	3.78	3.84	4.02	3.11	3.90	3.86	3.90	3.99
Eld's deer	1,511	6.03	6.00	2.59	6.02	2.60	5.98	2.60	5.90	2.52
Elephant	5,128	20.46	20.05	7.74	19.48	7.72	14.01	7.82	20.07	8.13
Sarus crane	3,018	12.04	12.72	10.67	13.41	4.83	12.66	4.62	12.73	4.61
Lesser adjutant stork	4,542	18.12	18.36	0.85	19.03	0.86	18.34	0.85	18.54	0.85
Barking deer	7,612	30.37	30.75	42.01	30.09	41.16	31.01	42.24	30.74	41.74
Leopard	1,524	6.08	5.92	6.09	6.08	6.59	5.96	6.16	5.87	6.07
Tiger	1,856	7.41	7.60	6.81	7.26	4.37	7.29	7.27	8.13	7.08
Giant ibis	2,042	8.15	8.15	0.45	8.14	0.45	8.14	0.45	8.13	0.45
Wild boar	6,403	25.55	24.79	41.39	23.45	39.87	25.35	41.66	24.67	40.81
Maximum	7,612	30.37	30.75	42.01	30.09	41.16	31.01	42.24	30.74	41.28
Minimum	1,008	4.02	3.78	0.45	4.02	0.45	3.90	0.45	3.96	0.45
Average	3,518	14.04	14.05	12.50	14.76	11.67	13.70	12.12	14.10	11.79
Richness class										
None	13,600	54.27	54.71	44.18	56.04	50.75	53.86	49.24	54.97	50.14
Low (1-4 species_	7,283	29.06	28.43	48.10	28.41	40.12	31.74	41.08	27.79	40.28
Moderate (5-8 species)	3,839	15.32	15.63	6.92	14.58	9.13	13.03	9.68	15.94	9.58
High (9-12 species)	339	1.35	1.24	0.00	0.92	0.00	1.38	0.00	1.29	0.00
Total habitat[4]	11,461	45.73	45.29	45.73	43.96				79.21	
Total area	25,061						6,513			

[1] percentage of distribution range to the northern region; [2] percentage of the remaining habitat in year 2006 to the northern region; [3] shift in species distribution compared with year 2006; [4] predicted suitable habitats for all taxa, excluding overlapped areas

Table 14. Contribution of protected areas to conserve selected mammal species in the Emerald Triangle landscape

Species name	Baseline		Low Econ without CC		Low_Econ		Sus. Pov without CC		Sus Pov		Sus Devl without CC		Sus Devl		Unsus Dev. without CC		Unsus Dev.	
	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)	Area	Cont. (%)
Gaur	41.06	73.00	41.27	73.18	30.28	92.52	30.19	53.07	30.19	92.20	41.37	69.94	30.31	92.25	42.59	72.90	32.04	92.72
Banteng	41.41	69.06	42.11	69.24	49.13	67.24	49.11	79.90	49.11	66.78	42.33	67.40	49.26	66.31	43.10	69.20	43.10	69.20
Sambar	15.41	99.52	14.43	99.18	14.64	99.02	15.14	97.99	15.14	99.20	14.90	99.38	14.74	99.40	15.18	99.54	15.23	99.11
Eld's deer	13.79	59.44	13.68	59.26	6.35	63.87	6.46	59.65	6.46	64.51	13.77	59.81	6.44	64.35	13.29	58.56	6.10	62.95
Elephant	56.11	71.26	55.48	71.94	25.13	84.47	53.26	71.08	25.01	84.31	37.94	70.38	25.20	83.85	55.52	71.91	26.54	84.92
Sarus crane	16.46	35.51	17.03	35.10	5.42	13.32	3.76	35.20	3.76	20.43	17.11	35.44	3.61	20.50	16.93	34.88	3.53	20.08
Lesser adjutant stork	27.14	38.91	27.13	38.42	0.08	2.42	0.08	0.11	0.08	2.41	2.71	3.84	0.08	2.42	27.53	38.60	0.08	2.42
Barking deer	56.68	48.49	57.53	48.63	72.32	44.77	69.73	60.24	69.73	44.06	58.07	48.67	73.04	44.97	57.64	48.74	71.86	44.77
Leopard	16.91	72.27	16.65	73.14	16.69	71.25	16.93	72.36	17.89	70.59	16.80	73.29	16.95	71.52	16.33	72.36	16.53	70.78
Tiger	25.72	90.26	26.52	90.70	24.02	91.76	25.21	90.24	16.16	96.20	25.25	89.99	25.01	89.41	25.36	91.36	25.22	92.60
Giant ibis	15.25	48.63	15.23	48.58	0.00	0.00	0.00	0.00	0.00	0.00	15.25	48.70	0.00	0.00	15.16	48.44	0.00	0.00
Wild boar	53.61	54.53	53.15	55.73	71.71	45.06	67.75	75.09	67.75	44.20	53.82	55.19	72.66	45.36	52.89	55.72	70.76	45.10
Maximum	56.68	99.52	57.53	99.18	72.32	99.02	69.73	97.99	69.73	99.20	58.07	99.38	73.04	99.40	57.64	99.54	71.86	99.11
Minimum	13.79	35.51	13.68	35.10	0.00	0.00	0.00	0.00	0.00	0.00	2.71	3.84	0.00	0.00	13.29	34.88	0.00	0.00
Average	31.63	63.41	31.68	63.59	26.31	56.31	28.14	52.69	22.85	50.16	28.28	60.17	26,44	56.69	31.79	63.52	25.92	57.50
Richness class																		
None	20.79	9.97	21.61	10.28	19.77	11.64	23.63	50.75	23.42	23.42	19.14	9.24	19.16	10.13	22.19	10.50	20.92	10.86
Low (1-4 species_	32.65	29.19	31.30	28.64	56.04	30.31	31.52	40.12	45.26	45.26	42.51	34.84	47.71	30.23	29.96	28.04	46.46	30.02
Moderate (5-8 species)	42.10	71.41	42.75	71.14	24.17	90.90	41.46	9.13	31.32	31.32	33.85	67.58	33.12	89.04	43.37	70.75	32.62	88.57
High (9-12 species)	4.46	85.83	4.34	91.31	0.00	NA	3.39	NA	0.00	NA	4.50	85.13	0.01	NA	4.48	90.04	0.00	NA

[1] percentage of distribution range to the northern region; [2] percentage of the remaining habitat in year 2006 to the northern region; [3] shift in species distribution compared with year 2006

It should be noted that the predicted distributions for most species, except banteng barking deer and wild boar significantly declined when future climatic conditions (precipitation in the wettest quarter months and precipitation in the driest quarter months) were added. In contrast, the predicted habitats for banteng barking deer and wild boar significantly increased (Table 13; Annex 3).

5.2.5 Contribution of protected areas

All protected areas in the Emerald Triangle landscape cover approximately 6,500 km^2 or 26% of the total area. Noticeably, not all of the protected areas were defined as suitable habitat for selected species. The average extent of suitable habitats was 63% at present and ranged between 50-64% in 2030. The results also show that the average contributions of protected areas under the combination of land-use and climate change were less than under land-use change only.

It should be noticed that more than 80% of the total current and future suitable habitats for gaur, Sambar deer, Asian elephant and tiger are predicted to be in protected areas. The contributions of protected areas to protecting the focal selected species were moderate for banteng, *Eld's* deer, barking deer, leopard and wild boar and were low for Sarus crane, Lesser adjutant stork and Giant ibis. Table 14 also shows that the contributions of protected areas to protecting the selected species in the future are less than the current status for most species, except elephant and tiger. The average percentage of contribution was the lowest (approximately 50%) under the sustainable poverty scenario. This may be due to the fact more forest areas and contiguous forest patches were predicted outside the protected areas, therefore the selected species are able to inhabit these areas.

5.2.6 Concentration of selected wildlife species

The probability values for 12 species generated from the species distribution models were overlaid using GIS to derive at the total area of distributions and the summed scores for all species. The results suggest that the total extent of distribution covers approximately 11,460 km^2 or 46% of the Emerald Triangle landscape. Of this figure, approximately 5,160 km^2 or 45% of the potential distributions were situated in protected area networks, especially in the PVPF and Dong Kanthung NBCA (Figure 22). In addition, approximately 90% of protected areas were predicted as habitat for at least one of 12 selected species.

The summed scores for all species ranging from 1 to 12 were reclassified into 4 richness classes: none; low; moderate and high. Figure 22 also shows that approximately 45% of the Emerald Triangle landscape (study area) was classified as not suitable habitat for the selected species at the current and all future land-use scenarios. If future climate change conditions were combined, the predicted none habitat would range from 50-55%, meaning the selected species will mainly live in protected areas. High species richness class was predicted along the borders between the PVPF (except the western part) and Dong Kanthung NBCA, which will be classified as moderate richness. In addition, the remaining areas in PVPF, Yot Dom, Bun Thrarik-Yot Mon and part of Phou Xiang Thong were predicted as of low richness for the selected species. The entire areas of Pha Taem and Kaeng Tana National Parks were categorized as none habitat for any of the 12 species.

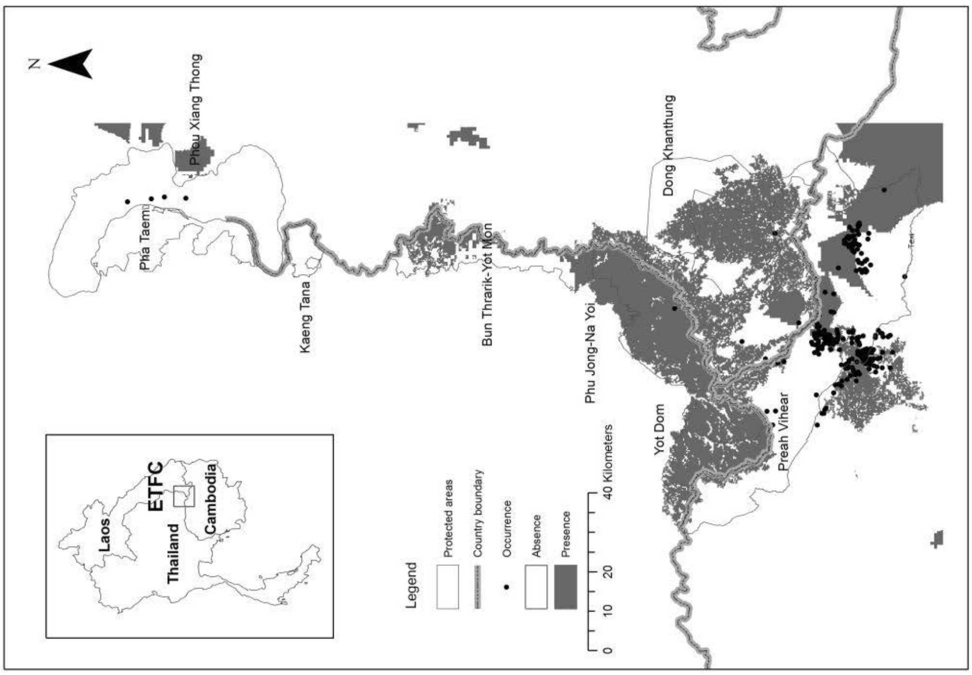


Figure 10 Predicted distribution for gaur

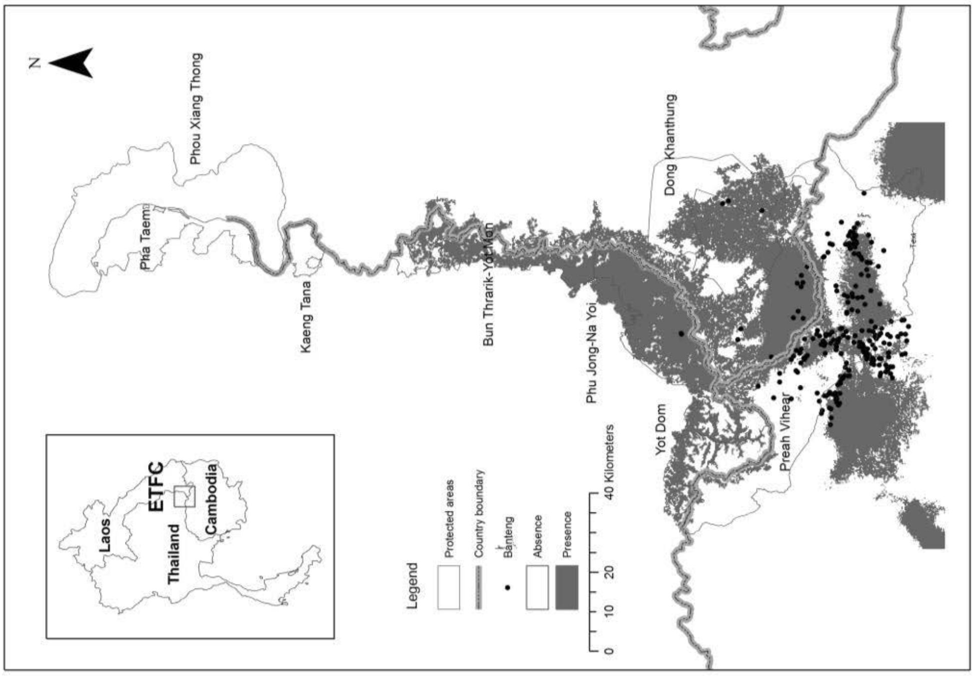


Figure 11 Predicted distribution for banteng

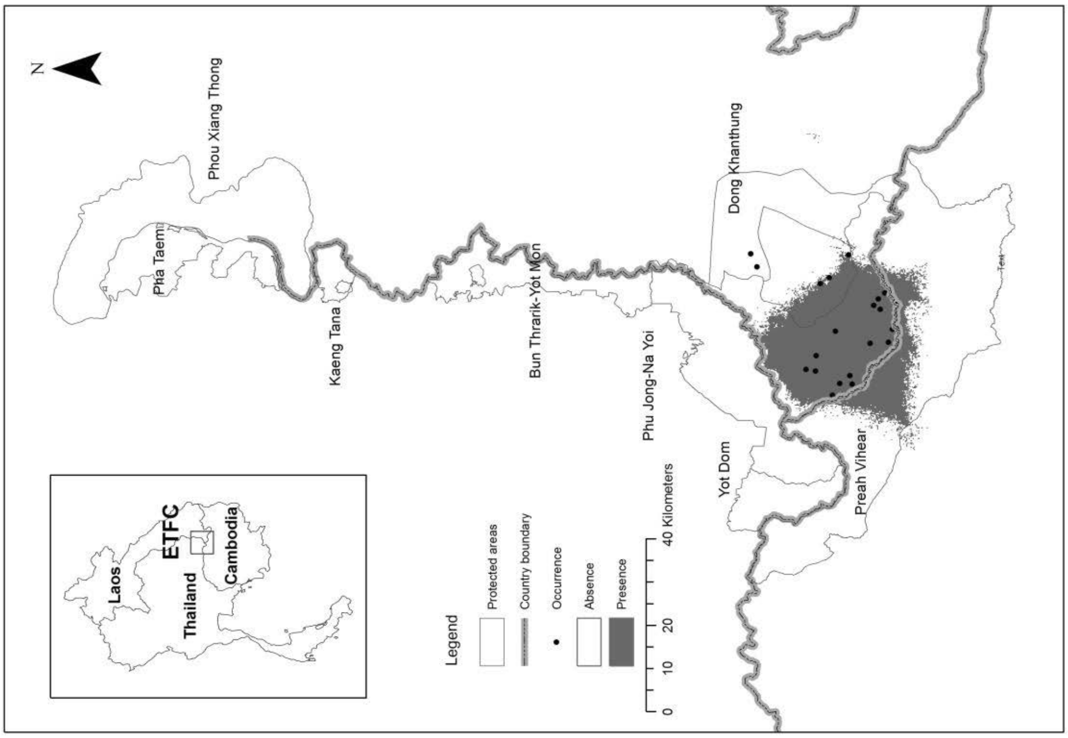


Figure 12 Predicted distribution for Sambar deer

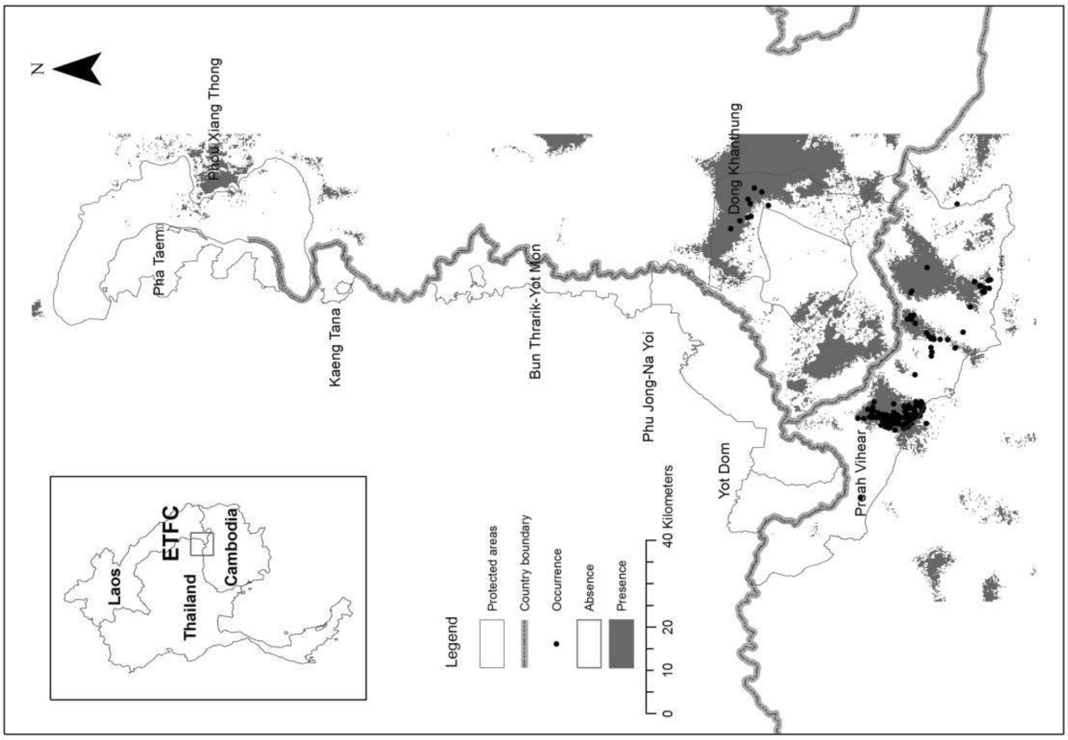


Figure 13 Predicted distribution for *Eld's* deer

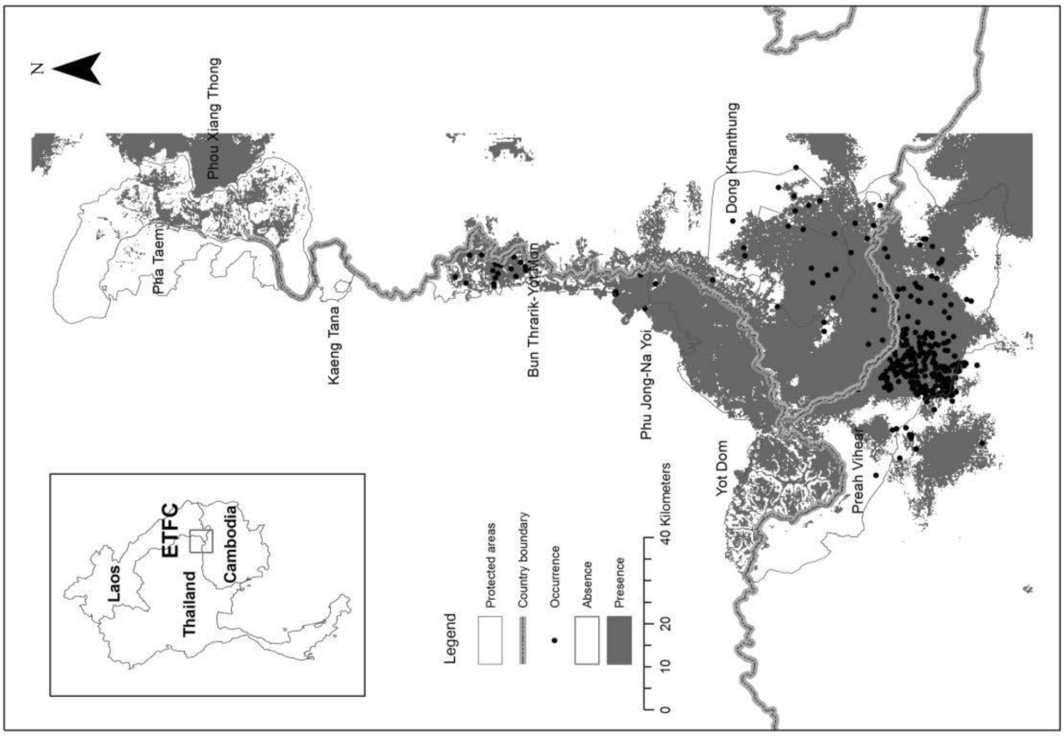


Figure 14 Predicted distribution for elephant

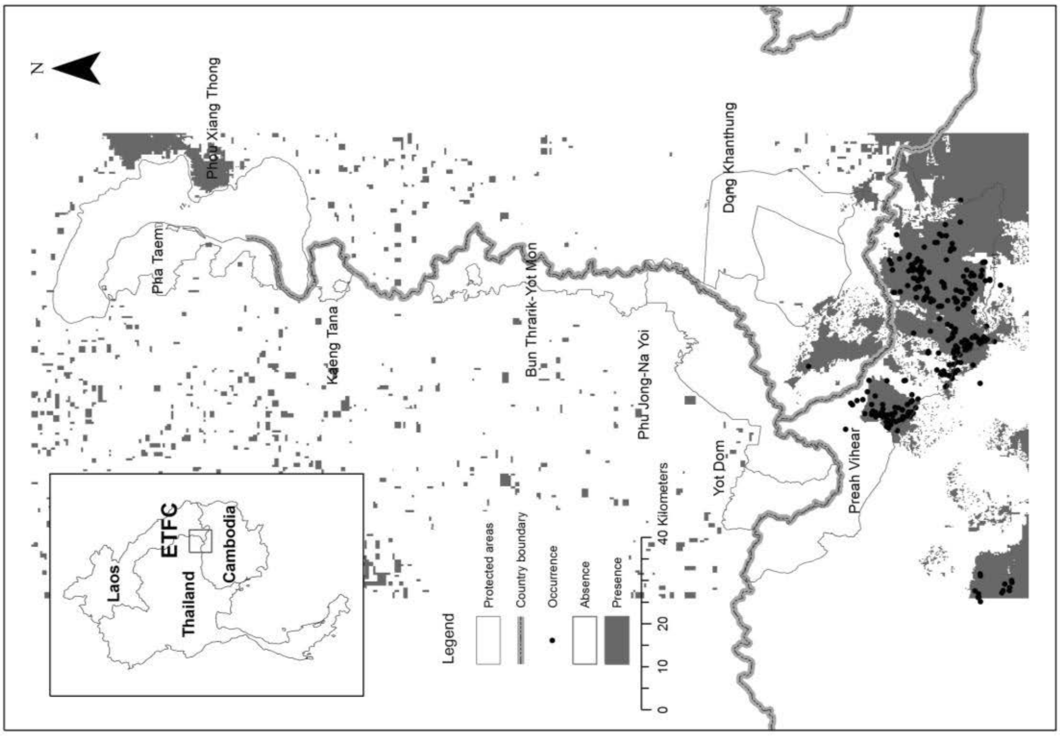


Figure 15 Predicted distribution for Sarus crane

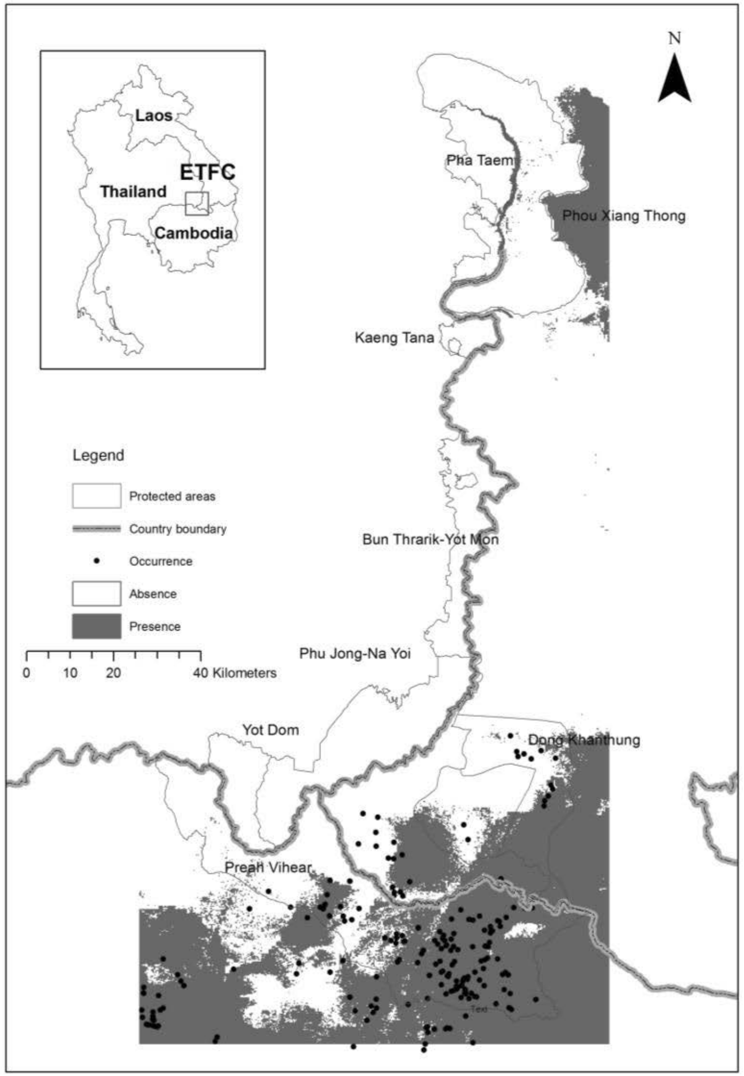


Figure 16 Predicted distribution for Lesser adjutant stork

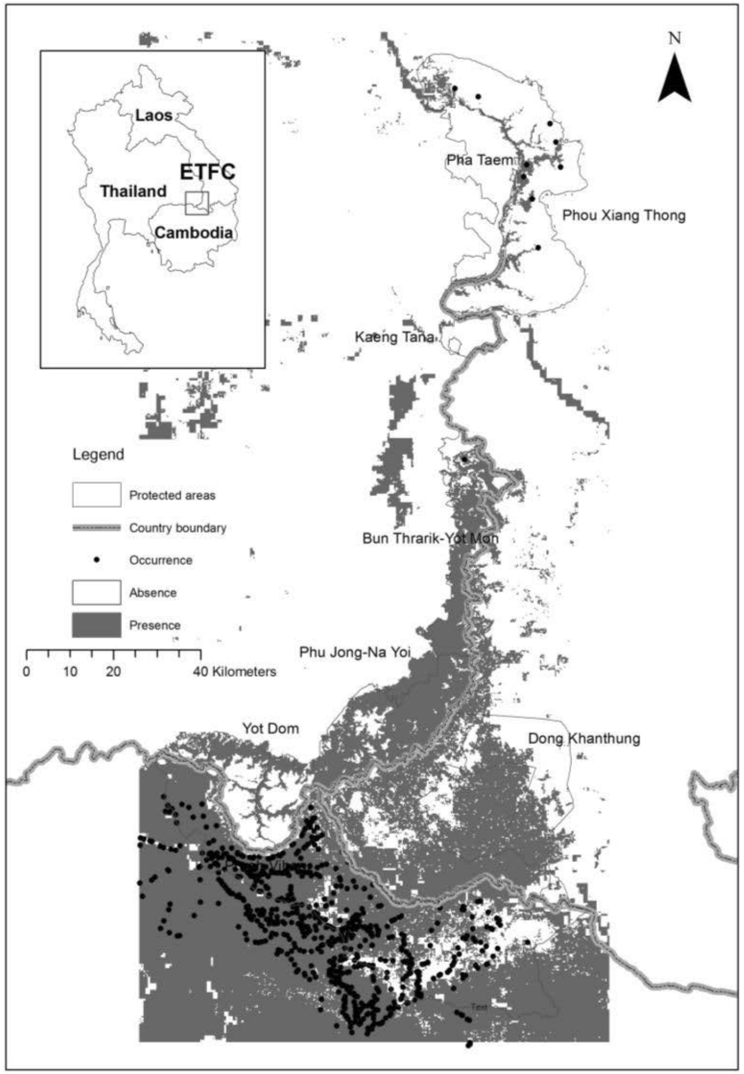


Figure 17 Predicted distribution for barking deer

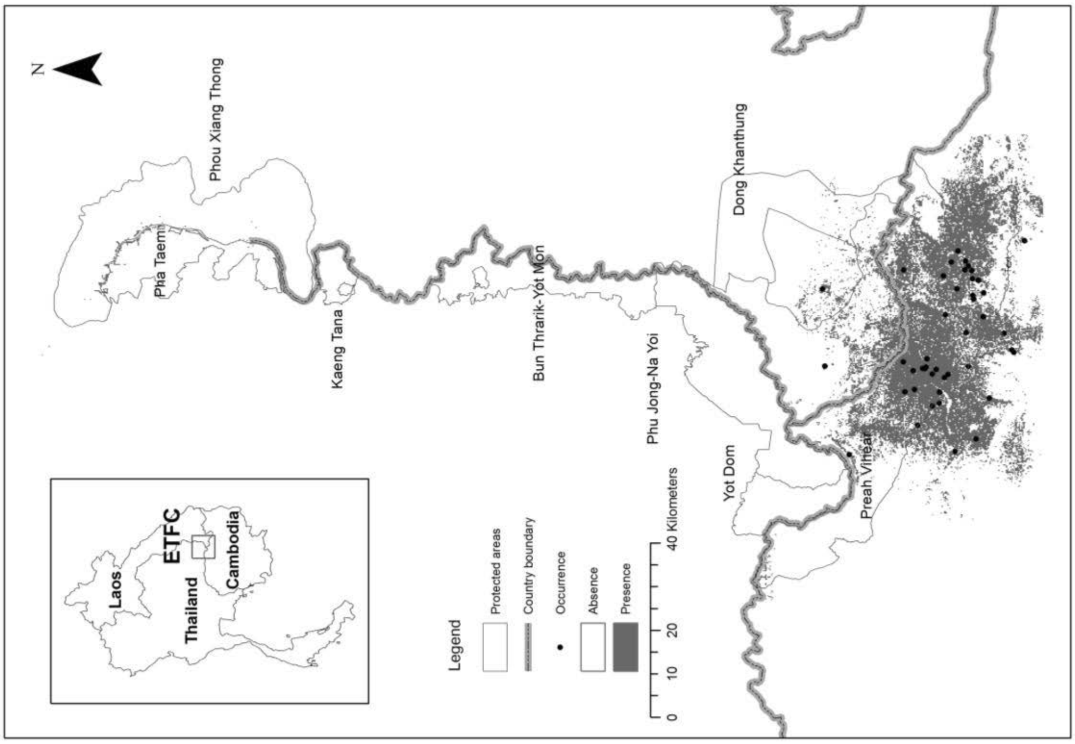


Figure 18 Predicted distribution for leopard

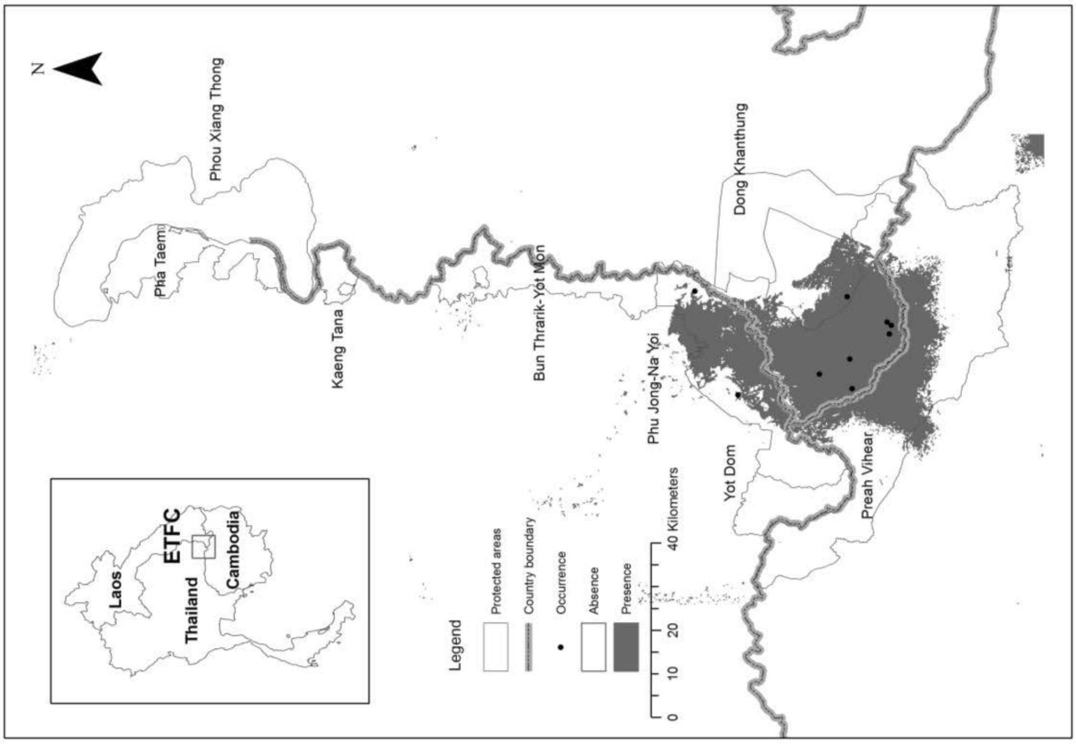


Figure 19 Predicted distribution for tiger

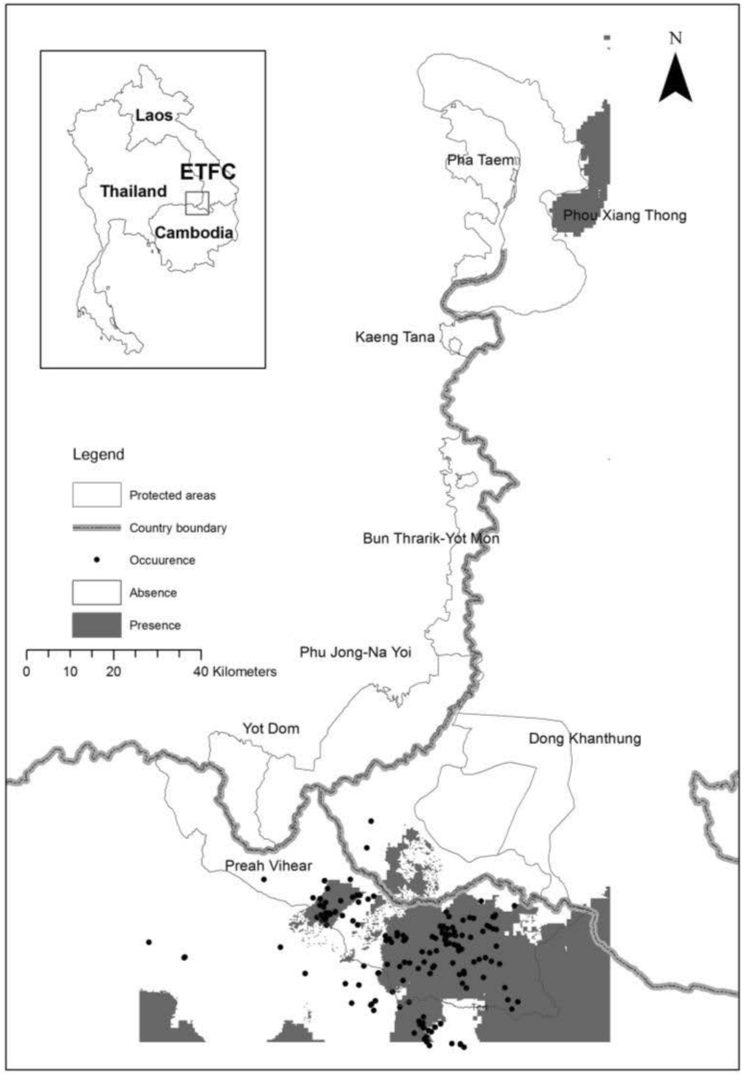


Figure 20 Predicted distribution for Giant ibis

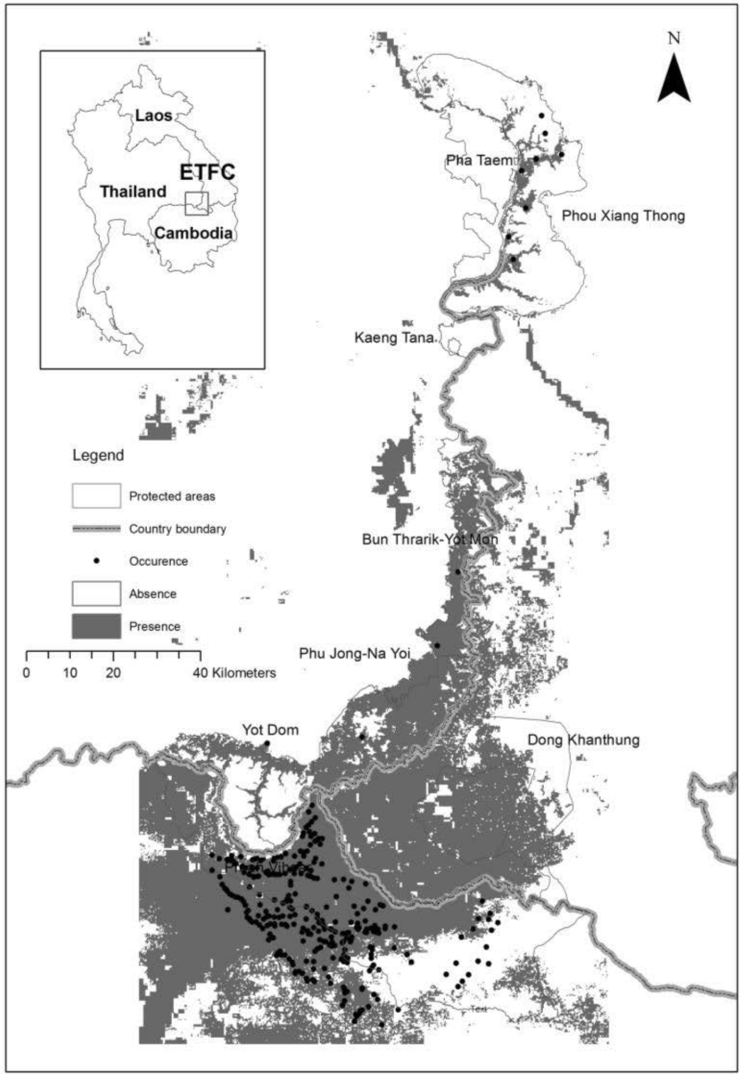


Figure 21 Predicted distribution for wild boar

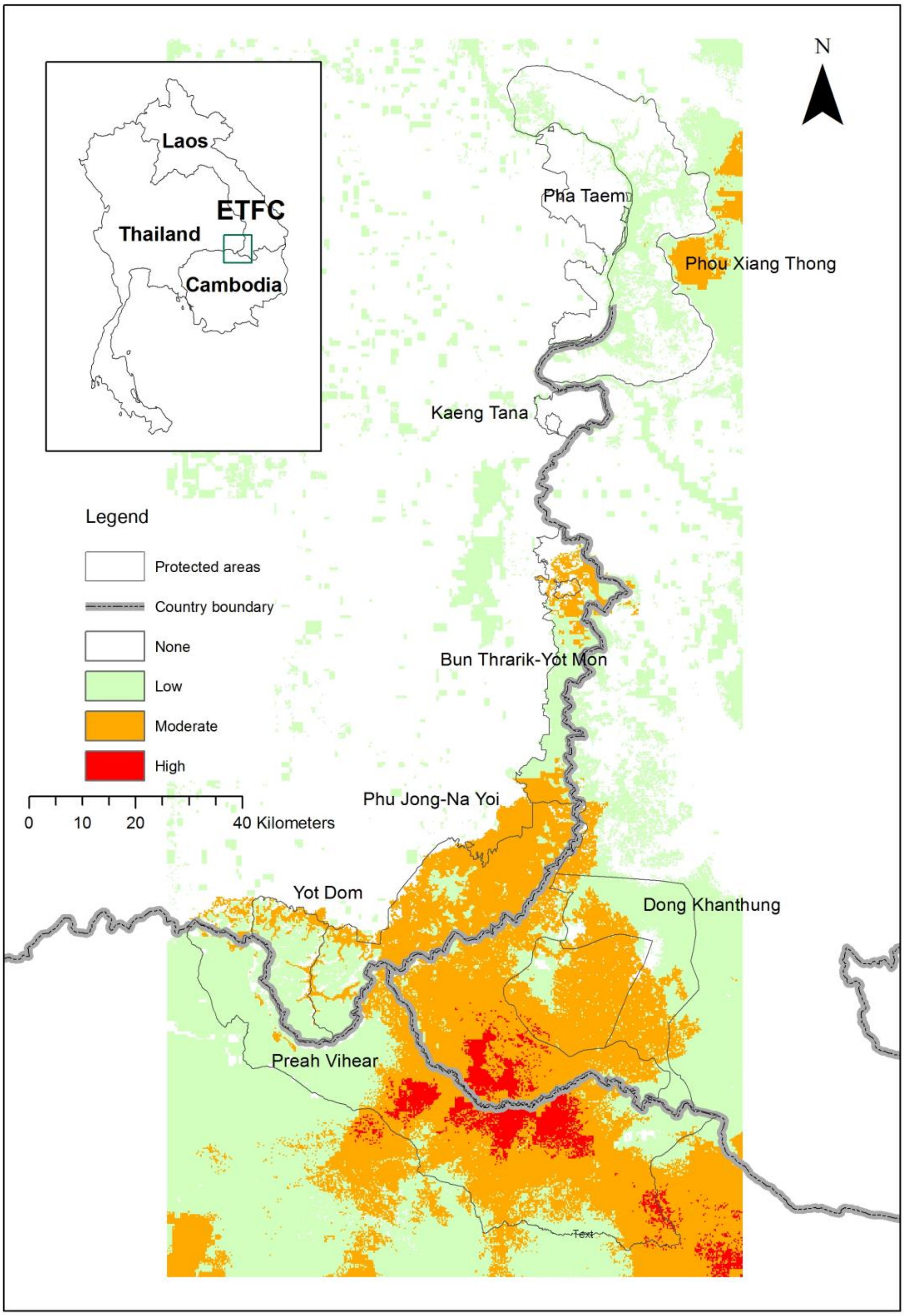


Figure 22 Species richness classes of selected species for modeling in the Emerald Triangle protected forests complex

5.3 GIS Training Courses

Three GIS training courses were conducted during the project phase III. They aimed at developing human resources skills and technical knowledge necessary for effectively developing and sharing core dataset and participating in land use and species distribution modeling. The names of the three training courses and their objectives were as follows:

1) *Introduction of GIS, Map Reading and GPS Mapping.* This training course was conducted for park rangers and interested people involved in the project (e.g. border patrol police staff, RFD officials). The objectives of this course were to refresh GIS skills and to guide in how to collect and develop a standardized core GIS database among the three countries.
2) *GIS Modeling for Forest Land Use Assessment and Prediction.* This training course was jointly organized for GIS staff and park rangers of the three countries involved in the project. The objectives of this course were to train participants in the CLUE model, using default database and to jointly develop land use scenarios for the Emerald Triangle.
3) *GIS - Wildlife Distribution Modeling*. This training course was conducted for GIS staff, park rangers and wildlife scientists of the three countries who were involved in the project. The training aimed at introducing various spatially explicit species distribution models (e.g. logistic regression, maximum entropy [MAXENT]), including their advantages and disadvantages, finalizing wildlife species for modeling and jointly generating distributions of selected species in the Emerald Triangle.

The GIS Consultant worked closely with Project Managers from Thailand and Cambodia, as well as Cambodian staff and Wildlife Consultants to define qualifications of potential candidates, and to identify suitable participants to attend the training courses. Descriptions and results of each training course are presented in the next section.

5.3.1 GIS Training I: GIS Training on Introduction of GIS, Remote Sensing and Map Reading

The 1st GIS training session (A 1.4- 1x2 days *GIS Training on Introduction of GIS, Remote Sensing and Map Reading*) was conducted on November 28th -29th, 2013 at the Pha Taem National Park. A detailed training schedule is shown in Table 15. The Director of National

Park Division, and the Director of Wildlife Conservation Division and Information Center affiliated with Protected Area Administration Region 9 were invited to open the training and to present a lecture on application of remote sensing and GIS for forest monitoring at protected areas in region 9. In addition, Dr. Naris Bhumphanpan (Wildlife Consultant) presented the overview of wildlife diversity and guideline for wildlife survey at the Emerald Triangle. These two presentations stimulated and integrated related activities either implemented by the ITTO project or the Department of National Parks, Wildlife and Plant Conservation. Therefore, participants and concerned individuals & agencies understood overall project goals and objectives.

Table 15 Training schedule of GIS Training on Introduction of GIS, Remote Sensing and Map Reading

Day 1, December 28, 2013

Time	Topic	Responsibility/Instructor
08.00-09.00	Registration	ITTO Project (Thailand Component)
09.00-09.15	Opening and welcome remark	Director of National Park Division, Protected Area Administration Region 9
09.15-09.30	Summary of ITTO Project (Phase I-III) and introduction of participants	Mr. Kamol Wisupakarn (Project Manager)
09.30-10.30	Introduction to Remote Sensing	Prof. Yongyut Trisurat
10.30-10.45	Coffee break	-
10.45-11.30	Application of remote sensing and GIS for forest monitoring at protected areas region	Director of Wildlife Conservation Division and Information Center, Protected Area Administration Region 9
11.30-12.00	Overview of wildlife diversity and guideline for wildlife survey at the Emerald Triangle	Dr. Naris Bhumpakphan
12.00-13.00	Lunch	-
13.00-14.30	Visual interpretation technique and practice	Prof. Yongyut Trisurat
14.30-14.45	Coffee break	-
14.45-16.15	Accuracy assessment and field check	Prof. Yongyut Trisurat and ITTO Project
16.15-16.45	Contingency matrix and presentation of accuracy assessment	Prof. Yongyut Trisurat and participants
16.45-17.00	Summary for day 1	Prof. Yongyut Trisurat
Day 2, December 29th, 2013		
08.00-08.30	Registration	ITTO Project (Thailand Component)
08.30-10.30	Introduction to coordinate system and map reading	Prof. Yongyut Trisurat

Time	Topic	Responsibility/Instructor
10.30-10.45	Coffee break	
10.45-12.00	Introduction to GIS	Prof. Yongyut Trisurat
12.00-13.00	Lunch	
13.00-14.30	GIS exercise (I)	Prof. Yongyut Trisurat and participants
14.30-14.45	Lunch	
14.45-16.00	GIS exercise (II)	Prof. Yongyut Trisurat and participants
16.00-16.15	Training assessment	ITTO Project
16.15-16.30	Awarding training certificate	Project Manager and Prof. Yongyut Trisurat

Training materials provided to participants included:

1) Remote sensing technique for ecosystem monitoring at Khao Yai National Park (Dr. Satit Wacharakitti)
2) Introduction to remote sensing and visual interpretation (Prof. Yongyut Trisurat)
3) Training manual on Introduction to GIS and remote sensing (Prof. Yongyut Trisurat)
4) GIS database and decision support system for field staff of the Protected Area Administration Region 9 (Ubon Ratchathani) (Mr. Vichit Jiramongkolkarn, Director of National Park Division, Protected Area Administration Region 9)
5) Threats and patrolling data (Mr. Wichit Jiramongkolgran)

There were approximately 30 participants from Pha Taem National Park, Kaeng Tana National Park, Phu Jong Nayoi National Park Buntrarik-Yot Mon Wildlife Sanctuary and Yot Dom Wildlife Sanctuary attending the training. Besides, RFD staff, ITTO Project staff and graduate students from Kasetsart University also participated in this training. Names of participants and trainers are attached in Annex 2. In addition, selected photos showing training activities are attached in Box 1.

At the end of the training, the ITTO Project asked participants to evaluate the training performance according to two main criteria namely training content and logistic arrangement. The results are summarized in Table 16.

Table 16 Training evaluation summary of the 1st GIS training

Item	Percent (%)					
	Very high	High	Moderate	Low	Very low	Not satisfy
I. Content and training approach						
1. Training contents meet expectation	43.4	53.3	3.3			
2. Benefits to participant's responsibility	56.7	43.3				
3. Capacity of trainer to disseminate knowledge	70.0	26.7	3.3			
4. Duration of training	16.7	33.3	13.3	36.7		
5. Training materials	23.3	70.0	6.7			
6. Equipment and supply for training	36.7	43.3	16.7	3.3		
Average	41.1	45.0	7.2	6.7		
II. Logistic arrangement						
1. Invitation and contact prior training	40.0	53.3	6.7			
2. Arrangement during training	40.0	60.0				
3. Training venue	40.0	43.3	16.7			
4. Food and drink	33.4	43.3	23.3			
5. Overall satisfaction	60.0	30.0	10.0			
Average	42.7	46.0	11.3			
Overall average	41.8	45.4	9.1	3.6		

In summary, 86% of all participants expressed very high or high satisfaction of the performance of the training session. Nevertheless, about 37% of all participants showed low satisfaction on the duration of training. They preferred to have a longer duration of the training period due to a lot of interesting topics were provided and they could not capture all contents in a short period. The GIS consultant and the Project Manager had discussed this issue before the training. However, we had experiences and observations that if the duration was longer (3-4 days) some participants would leave the training before the end. In addition, fewer participants would attend the training. Therefore, the duration of training was decided to be 2 days.

5.3.2 GIS Training II: GIS Modeling for Forest Land Use Assessment and Prediction

Originally, the 2nd GIS training session was also planned for 2 days (A 1.5 - 1 x 2 days on Joint Training Workshop on GIS Modeling for Forest Land Use Assessment and Prediction). After discussion with the two project managers on the detailed program, the duration of the training workshop was extended to 5 days (March 10-15, 2014). The second training was conducted in Tbeng Mean Chey Preah Vihear province, Cambodia. A detailed training schedule is shown in Table 17.

Table 17. Provisional program of Joint Training Workshop on GIS Modeling for Land Use Planning Scenario (2nd GIS Training)

Day	Description	Resource Person/Faculty
Day 1	Arrival of Participants and Resources Persons	
	Check in at Guess House	
	Dinner	Lim Sopheap
Day 2		
	Session 1: Opening Session	Dany and Kamol Wisupakan
	Welcome (Mr. Ith Phumara,_Cheif Of Preah Vihear Forestry Administration Cantonment	Ith Phumara
	Remark (Dr. Dennis Cengle, Technical Advisor, ITTO PD 577/10 Rev.1 (F))	
	Remarks (Mr. Sapol, ITTO Project Coordinator, Thailand Component)	
	Remarks (Dr.Phonesavanh Thepphasoulithone, Vice Rector of Champasak University	
	Opening Address (H.E. Ung Sam Ath, Deputy Director General of Forestry Administration, Cambodia	
	Introduction of Participants	Participants
	Group Photo and Coffee Break	
	Session 2: Target Key Species of Wildlife in the Emerald Triangle Protected Forests Complex	
	ITTO Transboundary Biodiversity Conservation at the Emerald Triangle Protected Forest Complex, Project Phase III	Dr. Dennis Cengel
	The Target Key Species of Wildlife in Preah Vihear Protected Forest	Prom Sovanna
	Target Key Species of Wildlife in Pha Taem Protected Forest Complex	Dr. Naris Bhumpakphan
	Progress and Target Key Species of Wildlife in Dongkanthung Protected Forest	Dr.Phonesavanh or representative
	Lunch Break	
	Session 3: Land Use Dynamic and Land cover classification	
	Land cover classification in GMS Region	Mrs. Sar Sophyra
	Satellite Imagery Interpretation and Land Cover Assessment	Leng Chivin
	Coffee Break	Lim Sopheap
	Session 4: Land Use Dynamic and Land cover classification	

	Detection of Forest Cover Change in the Pha Taem Protected Forests Complex, Thailand	Mr. Wichit Jiramongkhonkan
	Land Use Classification and Land Use Planning in Cambodia	Kim Sobon
	Dinner	Lim Sopheap
Day 3		
	Session 5: CLUES-s model (Exercise 1: Learning to Know the User-Interface and Exercise 2: Simulating Different Scenarios of Land Use Change)	
	Introduction of Markov Chain (Lecture)	Dr. Yongyut Trisurat
	Open Source Land Use Modeling: and CLUE-s models (Lecture)	Dr. Yongyut Trisurat
	Practice on GIS Land Use Modeling	Resource Person/Faculty
	Coffee Break	
	Session 6: CLUES-s model (Exercise 3: Defining Spatial Policies and Exercise 4: How to Do Statistical Analysis?)	
	Practice on GIS Land Use Modeling	Dr. Yongyut Trisurat
	Lunch Break	Lim Sopheap
	Session 7: Past and Current Land Use in the Emerald Triangle and Future Scenarios (Lecture and Brain Storming)	
	Group Works and Brain Storming on Scenario Development	Dr. Yongyut Trisurat
	Coffee Break	
	Session 8: Creating CLUE-s Application for the Emerald Triangle	
	Group Works on preparation of land use data, location factors and conceptual models)	Dr. Yongyut Trisurat
	Dinner	
Day 4		
	Session 9: Creating CLUE-s Application for the Emerald Triangle	
	Group Works on preparation of parameter files and conditions	Dr. Yongyut Trisurat
	Practice on GIS Land Use Modeling	
	Coffee Break	
	Session 10: Creating CLUE-s Application for the Emerald Triangle	
	Evaluating preliminary results and discussion	Dr. Yongyut Trisurat
	Practice on GIS Land Use Modeling	
	Lunch Break	Lim Sopheap
	Session 11: Creating CLUE-s Application for the Emerald Triangle	
	Defining appropriate scenarios and most likely conditions, and simulating the models	Dr. Yongyut Trisurat
	Practice on GIS Land Use Modeling	
	Coffee Break	Lim Sopheap

	Session 12: Creating CLUE-s Application for the Emerald Triangle	
	Evaluating the designated future land use and implications for biodiversity conservation	Dr. Yongyut Trisurat
	Practice on GIS Land Use Modeling	
	Dinner	Lim Sopheap
Day 5		
	Field Visit to Emerald Triangle Area Between Cambodia-Lao PDR-Thailand (Optional)	Ith Phumara
	Lunch Break: At the Border Cambodia and Lao PDR	Lim Sopheap
	Closing and Certificate Handout	Dany Chheang & Kamol Wisupakan
	Course Evaluation	
	Remarks by the Trainers	
	Remarks by the Dr. Dennis Cengle	
	Distribute Certificates	
Day 6	Departure of participants and resource persons	

The Governor of Preah Vihear Province, Mr. Ung Sam Ath (Deputy Director General of Cambodia Forest Administration), Mr. Hiroshi Nakata (JICA/Technical Advisor of Cambodia Forest Administration) and Mr. Ith Phoumar (Preah Vihear Cantonment, FA) were invited to give speeches and opening remarks at the training workshop.

Mr. Chheang Dany presented the Key Species of Wildlife in Preah Vihear Protected Forest and Dr. Naris Bhumphanpan provided the overview of wildlife diversity and guideline for wildlife survey at the Emerald Triangle. These two presentations stimulated and integrated activities implemented by the ITTO project and the Cambodia Forestry Administration. Therefore, participants and concerned individuals & agencies had a good overll picture of project goals and objectives.

Training materials provided to participants included:

1) CLUE Model manual (Prof. Peter Verburg)
2) Introduction to Markov Chain Model (Prof. Yongyut Trisurat)
3) Scenario development (Prof. Yongyut Trisurat)
4) Target wildlife species and survey techniques (Dr. Naris Bhumpakphan)
5) Land use change detection and decision support system (Mr. Vichit Jiramongkolkarn, Director of National Park Division, Protected Area Administration Region 9)
6) GIS dataset for land use modeling in the Emerald Triangle (Mr. Utai Dechyosdee, GIS Program Assistant)

There were all together 50 participants/resource persons. Thirty two participants were from Cambodia, 6 from Laos and 12 from Thailand. It is noted that three Superintendents (Phu Jong-Na Yoi National Park, Bunthrarik Yot Mon Wiildlife Sanctuary and Yot Dom Wildlife Sanctuary), Director of Wildlife Division and Director, National Park Division, DNP Regional Office 9, Ubon Ratchathanee also participated in the workshop. Participants from Cambodia included government officials, NGO representatives and lecturers from Preak Leap National College of Agriculture. Participants from Laos consisted of three lecturers from Champasack University and Forestry officials. Names of participants and trainers are attached in Annex 3.

At the end of the training, the Local Organizing Committee (Cambodia Component) asked participants to evaluate the training performance according to three main criteria namely training content, logistic arrangement and overall training. Thirty-six participants returned the questionnaires. The training evaluation results showed that the contents of training were average (ranks 13-38%) to good (41-77%) (Table 18). The main constraints of the training contents included limited time and subject matter. Most participants did not have knowledge background on GIS and spatial modeling. Therefore, they could not truly understand the concepts and practices within 3 days.

The GIS consultants and local organizers had foreseen the issues on level of GIS understanding, languages and participant knowledge background. However, we could not select suitable candidates because of poor human resource capacities, especially from Laos and Cambodian. To minimize these issues, we used four languages (English, Thai, Laotian and Cambodian) and more exercises. Nevertheless, the percentage of overall satisfaction was over 80%. Most participants realized the usefulness and the power of GIS and the participatory approach for land use modeling and wildlife distribution prediction in the Emerald Triangle area. In addition, more than 70% of participants appreciated logistic arrangement and facilities offered during the training, although it was the first meeting held in this new building.

Table 18 Training evaluation summary of the 2nd GIS training

Details	Percent (%)					
	Very high	High	Moderate	Low	Very low	Not satisfy
I. Content of training						
The content was appropriate and met my expectations	5.56	77.78	13.89	2.78	0.00	0.00
The content was useful and I will be able to be use it on the job	16.67	61.11	22.22	0.00	0.00	0.00
The transfer of knowledge of the resource persons during the training was appropriate and suitable	2.78	61.11	33.33	2.78	0.00	0.00
The period of time allowed for the training was appropriate	0.00	41.67	38.89	16.67	0.00	2.78
The documents and supporting materials provided were suitable	2.78	75.00	11.11	11.11	0.00	0.00
II. Organization of training						
Cooperation between the participants	13.89	72.22	11.11	0.00	2.78	0.00
Facilitation of the training organizers	8.33	72.22	16.67	2.78	0.00	0.00
Suitability of the training room	11.11	75.00	11.11	2.78	0.00	0.00
Satisfaction with meals and breaks	11.11	75.00	11.11	2.78	0.00	0.00
III. Overall satisfaction with the training	2.78	86.11	11.11	0.00	0.00	0.00

5.3.3 GIS Training 3: GIS - Wildlife Distribution Modeling

The 3rd GIS training session on GIS-Wildlife Distribution Modeling was planned to the last for 5 days (A 1.5 - 1 x 5 (2) days) on October 20-25, 2014). The venue of the training was Toh Saeng Kong Chiam Hotel, Ubon Ratchathani Province, Thailand. A detailed training schedule is shown in Table 19. The training aimed at introducing various spatially explicit species distribution model (e.g. logistic regression, maximum entropy [MAXENT]), advantages and disadvantages, finalizing wildlife species for modeling and jointly generating distributions of selected species in the Emerald Triangle

Table 19 Provisional program of Training Workshop on GIS-Wildlife Distribution Modeling (3rd GIS Training)

Time	Topic	Responsible Person
	Day 1 – October 20, 2014	
13.00-16.00	Arrival of participants	Project-Thailand Component
16.00-17.00	Brief of Workshop Introduction	Project-Thailand Component
18.00	Welcome Dinner	
	Day 2 – October 21, 2014	
08.00-09.00	Registration	Project-Thailand Component
09.00-09.10	Opening Address	Mr. Suchat Kalawongsa, RFD representative
09.10-09.20	Welcome Addresses	Mr. Dany Chhaeng and Dr. Dennis Cengel, ITTO-Project (Cambodia component)
09.20-09.30	Workshop Objective and Introduction	Dr. Yongyut and participants
09.30-10.30	Final Wildlife Technical Report(Thailand and Laos) Cambodia	Dr. Naris Bhumpakphan and Representative of Champasack University FA Representative
10.30-10.45	Coffee Break	Project-Thailand Component
10.45-12.00	Finalize Key Wildlife Targets for Modeling	Dr. Naris and Team
12.00-13.00	Lunch	Project-Thailand Component
13.00-14.30	Map Coordinates and Introduction to GIS	Dr. Yongyut
14.30-14.45	Coffee Break	Project-Thailand Component
14.45-17.30	Field Excursion to Pha Taem national Park	Project-Thailand Component
	Day 3 - October 22, 2014	
08.00-08.30	Registration	Project-Thailand Component
08.30-10.00	Wildlife habitat welfare	Dr. Naris
10.00-10.15	Coffee Break	Project-Thailand Component
10.15-12.00	Wildlife Mapping (Cartography Overlay)	Dr. Yongyut and Participants
12.00-13.00	Lunch	Project-Thailand Component
13.00-14.30	Wildlife Mapping (Logistic Regression)	Dr. Yongyut and Participants
14.30-14.45	Coffee Break	Project-Thailand Component
14.45-16.30	Wildlife Mapping (Logistic Regression-Cont.)	Dr. Yongyut and Participants
	Day 4 - October 23, 2014	
08.00-08.30	Registration	Project-Thailand Component
08.30-10.30	Wildlife Modeling With MAXENT (I)	Dr. Yongyut
10.30-10.45	Coffee Break	Project-Thailand Component
10.45-12.00	Wildlife Modeling With MAXENT (II)	Dr. Yongyut and Participants
12.00-13.00	Lunch	Project-Thailand Component
13.00-15.00	Case Studies on Wildlife Modeling	Dr. Yongyut and Participants
15.00-15.15	Coffee Break	Project-Thailand Component
15.15-15.30	Training Evaluation	Project-Thailand Component
15.30-16.00	Awarding Certificate and Closing	RFD representative
	Day 5 - October 24, 2014	
08.30-10.30	Preparation of conclusion and reports	Project-Thailand and Cambodia Component
11.00	Departure of participants	

Training materials provided to participants included

1) A MAXENT Model v3.3.3e Tutorial (Nick Young, Lane Carter and Paul Evangelista)
2) Modeling species distribution (Prof. Yongyut Trisurat)
3) A statistical explanation of MAXENT for ecologists (Elith et al., 2011)
4) Lecture notes: coordinate; introduction to GIS; GIS analysis and overlay; and logistic regression (Prof. Yongyut Trisurat)
5) Progress report on GIS database (Prof. Yongyut Trisurat)
6) Final Tecxhnical Report on Wildlife Ecology (Dr. Naris Bhumpakphan)

Mr. Suchat Kalawongsa, Director of Forestry International Coordination Office of the Royal Forest Department welcomed participants and gave the opening remark. Then, Dr. Phonesavanh Thepphasoulithone (Deputy-Rector of Champasak University), Mr. Dany Chheang (Manager of Cambodia Component) and Dr. Dennis Cengel (Project Technical Advisor of the Cambodia Component) were invited to give speeches and expectations of the training workshop.

After the opening, Dr. Naris Bhumphanpan (Wildlife Consultant) presented the Final Technical Report on wildlife diversity and potential species for monitoring at the Emerald Triangle. The results of wildlife surveys in Preah Vihear Protected Forest and Dong Kanthung proposed National Biodiversity Conservation Area were also presented by scientists from Champasak University and FA of Cambodia, respectively. The main contents of this training course were conducted by Prof. Yongyut Trisurat (GIS consultant) through normal lecture, exercise, discussion and presentation of group works.

There were all together 41 participants/resource persons. Eighteen participants were from Cambodia, 5 from Laos and 18 from Thailand. It is noted that this training course was a continuation from the second training course on land-use modeling held in Cambodia. Therefore, more than 80% of participants were the same as the second course. All Superintendents of the protected areas situated in the Pha Taem complex, Director of Wildlife Division and Director, National Park Division, DNP Regional Office 9, Ubon Ratchathanee attended the training workshop. Participants from Cambodia included government official and ITTO project/Cambodia component. Participants from Laos consisted of five staff from Champasack University. Names of participants and trainers are attached in Annex 4.

At the end of the training, the Local Organizing Committee asked participants to evaluate the training performance according to three main criteria namely training content, logistic arrangement and overall training. Thirty-six participants returned the questionnaires. The training evaluation results showed that the contents of training were ranked between highest and good (>80%) (Table 20). The main constraint of the training contents was the period of time allowed for the training. It should be noted that the objectives of this training course were to introduce species distribution modeling techniques and to finalize key wildlife species for modeling. It was not aimed to train participants to become experts in GIS modeling. In addition, most participants had basic knowledge of GIS and spatial modeling obtained from previous training courses. Therefore, the identified constraint was unavoidable.

In addition, more than 80% of participants appreciated logistic arrangement and facilities offered during the training. The percentage of overall satisfaction was over 80%. Most participants realized the usefulness and the power of GIS for wildlife distribution prediction in the Emerald Triangle area. In addition, they agreed to select 12 wide-ranging species having trans-boundary territory. These species include nine mammals: gaur; banteng; sambar; *Eld's* deer; Asian elephant; barking deer; leopard; tiger and wild boar; and three birds: Sarus crane; Lesser adjutant stork; and Giant ibis.

Table 20 Training evaluation summary of the 3rd GIS Training

Content of training	Level of satisfaction (%)					
	Very high	High	Moderate	Low	Very low	Not satisfy
I. The content was appropriate and met my expectations						
The content was useful and I will be able to be used it on the job.	17	71	13	0	0	0
The transfer of knowledge of the resource persons during the training was appropriate and suitable.	21	63	17	0	0	0
The period of time allowed for the training was appropriate.	8	58	33	0	0	0
The documents and supporting materials provided were suitable	17	75	8	0	0	0
II. Organization of training						
Cooperation between the participants	17	75	8	0	0	0
Facilitation of the training organizers	17	71	13	0	0	0
Suitability of the training room	17	71	13	0	0	0
Satisfaction with meals and breaks	17	63	21	0	0	0
III. Overall satisfaction with the training	8	79	13	0	0	0

6. CONCLUSIONS AND RECOMMENDATIONS

The GIS consultant had overall responsibility to update the GIS database for trans-boundary biodiversity conservation planning and to assist joint researches on land-use modeling and wide-ranging species distribution in the ETFC through the involvement of multi-stakeholders from the three participating countries. Six specific duties were assigned to the GIS Consultant as outlined in Chapter 1.

The GIS database is intended to be used to support biodiversity conservation and protected areas management and decision-making at both the PPFC and the ETFC levels. Therefore, two GIS databases were updated and or developed during the project phase III. The first database at the scale of 1:50,000 is for the PPFC. It consists of 11 themes and more than 30 layers, including their attributes. Basically, they were updated from the project phase II using up-to-date data and satellite images. The second database covers the entire Emerald Triangle landscape and surrounding areas. This dataset includes 9 themes and 18 layers. The coverage of protected areas in Lao PDR (Phou Xeing Thong and Dong Khanthung) and in Cambodia (Preah Vihear Protected Forest) and wildlife occurrences were included. Generally, they were gathered from existing databases that are available in other organizations (e.g., FA, Mekong River Commission, FAO, WorldClim database, previous phase). The main purposes of the database development were for land use modeling and prediction of species distributions.

The current land-use map across the Emerald Triangle landscape was visually interpreted from satellite images and the rate of reduction was calculated accordingly. Future land-use patterns were predicted using the Dyna-CLUE model based on four different land-use scenarios in 2030 defined by multi-stakeholders from the three countries. The model results indicated that dry dipterocarp forest in the north of Dong Khanthung provincial protected forest in Lao PDR and to the west of Pha Taem National Park in Thailand would be threatened by encroachment for agriculture and rubber plantation. If on restriction policy, parts of the Preah Vihear protected forest in Cambodia and Phou Xiang Thong National Biodiversity Conservation Area in Lao PDR would be converted to arable land in 2030. Evergreen forests were predicted as relatively intact at the current stage because they are found either inside protected areas or in steep terrains, thus become natural barriers for human-intervention.

The predicted deforestation in combination with future climate change would cause negative impacts on wildlife distribution and wildlife hotspots in the Emerald Triangle protected forest complex. The multi-stakeholders from the three countries selected 12 species for modeling their distributions. The criteria used for selection of target species include: 1) wide distribution in the Emerald Triangle (having trans-boundary territory), 2) regionally and nationally threatened status, 3) adequate observation records and 4) iconic or flagship for conservation.

The results revealed that the likely suitable habitats for 12 wildlife species in 2013 derived from the logistic regression and the MAXENT model cover approximately 19% of the Emerald Triangle landscape and 61% of this figure were as predicted to be in protected area networks, especially in the PVPF and Dong Kanthung NBCA. Protected areas in Thailand were predicted as having relatively low suitable for the modeled species. This phenomena resulted from the dissimilarity of survey efforts in the study areas. Intensive wildlife surveys were conducted in the Preah Vihear during 1998-2006, but they were rarely or conducted only once in Lao PDR and Thailand.

In addition, three GIS training courses were conducted during the project phase III, which aimed at developing human resources in the skills and technical knowledge necessary for understanding and using GIS database in land use and species distribution modeling. These training courses consisted of *a) Introduction of GIS, Map Reading and GPS Mapping, b) GIS Modeling for Forest Land Use Assessment and Prediction and 3) GIS - Wildlife Distribution Modeling*. The participants of the first training were GIS staff, park rangers and wildlife scientists from Thailand but the remaining courses were conducted for participants from the three countries who were involved in the project. It should be noted that the results of the second and the third courses were used for land-use modeling and wildlife distribution modeling in the Emerald Triangle landscape as discussed in the sections 5.1 and 5.2, respectively.

7. IMPLICATIONS FOR PRACTICES

7.1 Integration of Scenarios and Models

The results of this research clearly demonstrate that the scenarios and modeling of land use would contribute to a better understanding of management decisions to protect the remaining forest cover and to maintain trans-boundary biodiversity across the Emerald Triangle landscape. The scenario framework provided opportunities for multi-stake holders to effectively participate and raised their concerns and ambition of future land use options based on two main drivers, namely 1) population growth and 2) uncertainty of economic trends that are stimulated by the AEC scheme. In addition, the spatially explicit land use modeling method (CLUE-s) make it possible to visually present land use patterns, locations and magnitude of change in the landscape. So that, multi-stakeholders involved in the project have the same picture and understanding of what, when, where and how the future phenomena happen for effective collaboration. The integration of scenarios and models used in this project is applicable for other projects implemented at local, national and regional scales.

7.2 Important Habitats of Selected Species

The distributions of the 12 species and the centers of species richness were predicted in the Preah Vihear protected forest adjoining the Dong Khanthung NBCA and along the tri-national borders, which suffer less from fragmentation and other human disturbances. These results confirm the important role of core area located in large protected areas in conserving medium- to large-bodied mammal species. In addition, threatened species were restricted in a few patches due to specific ecological factor requirements and less human disturbance. In contrast, substantial suitable habitats for common taxa (e.g., barking deer and wild boar) and landscape bird species (Giant ibis, Sarus crane and Lesser adjutant stork) were predicted outside protected areas because these taxa occupy various habitats ranging from pristine to human-altered natural landscapes. Their preferable habitats include paddy fields and open woodland close to water bodies that mainly exist outside protected areas.

The results of this research also revealed that these species will require significant movement across the tri-national borders to respond heterogeneously to topographic features and seasonal climatic conditions. Based on field surveys, literature reviews and discussion with local residents these species seasonally move from places to places. Recently, a herd of elephants and a few guars move to Bun Thrarik-Yot Mon Wildlife Sanctuary and Pha Taem National Park in Thailand, respectively to avoid human disturbance in Lao PDR. Although, protected areas in Thailand are either relatively small or isolated or lack core area and have less suitable habitats for many selected mammal species, the protection measures are more effective than Lao PDR and Cambodia (Trisurat 2007; Bhumpakphan, in press).

7.3 Translating research results into concrete actions

Although border tension and armed conflicts between Thailand and Cambodia erupted twice during the project phases, technical contacts and cooperation between teams of participating countries have survived and quickly rebooted political and diplomatic relationship. The ETFC project is able to translate trans-boundary conservation concepts into concrete actions to enhance continuing collaboration between all relevant agencies, as well as sustainable livelihoods of local communities.

The tangible achievements of this technical report include a) developing and updating GIS databases for the PPFC and the Emerald Triangle, b) improving knowledge and understanding of multi-stakeholders on GIS and its potential uses for trans-boundary biodiversity conservation through a series of training sessions and joint wildlife research projects and c) identifying risk areas of future deforestation and the consequences on wide-ranging species distribution in the Emerald Triangle.

In terms of the international collaboration to support trans-boundary biodiversity conservation initiatives, this report provided research outputs on land-use modeling and predicted distributions of 12 wide-ranging species having trans-boundary territory, and used to formulate compatible management framework reflected in the *common vision* of the project.

It is noted that the projected species distribution models should not be used as accurate predictors of where species will be in the future because of the various limitations of the factors used in the models as mentioned above. Despite these limitations, the modeled results provide an understanding of the potential effects of land-use scenarios, so that policy makers can proactively strengthen collaborative trans-boundary biodiversity conservation to response to projected range shifts. The priority areas for protection include moderate and high richness classes and the predicted deforestation between 2013 and 2030. In addition, the lessons from this project can be applied to conservation planning of individual or protected areas complexes.

The lessons learned and the research results have been disseminated to national and international communities. Two articles, 1) *Predicting Land-use and Land-cover Patterns Driven by Different Scenarios in the Emerald Triangle Protected Forests Complex and 2) Promoting Trans-boundary Biodiversity Conservation between Thailand, Lao PDR* and Cambodia have been accepted to be published in Thai Forestry Journal and ITTO Tropical Forestry Update Bulletin in early 2015, respectively. In addition, parts of the results were presented at the CBD COP 12 meeting in Korea and Joint Meeting on Promotion of *Trans-boundary Biodiversity Conservation in the Taninthayi Range between Myanmar and Thailand* held in Bangkok on 29 July 2014.

ANNEXES

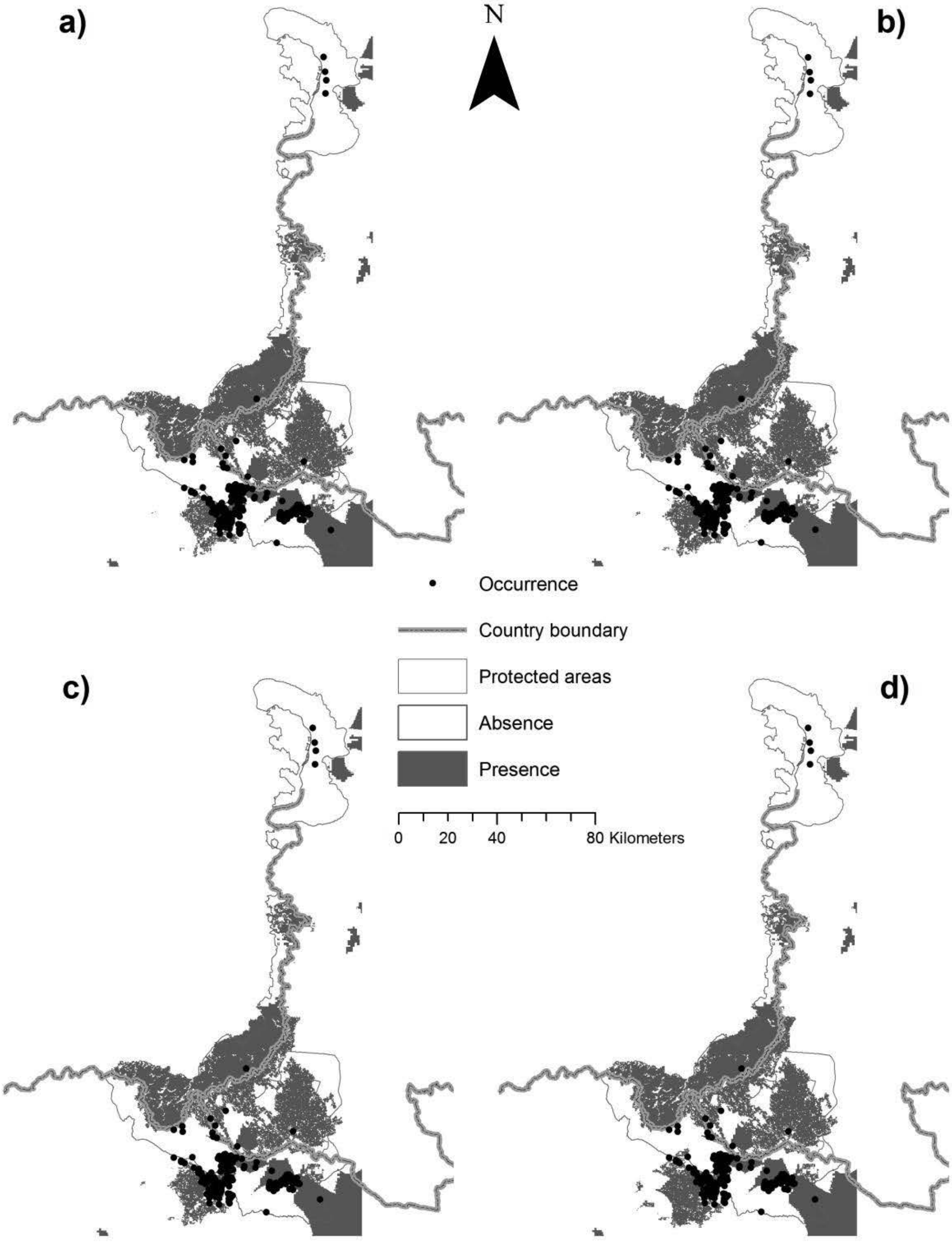
Annex 1 Correlation matrix of environmental variables determining species distribution in the Emerald Triangle landscape

Variables	ANN._RAIN	DRY_Q_RAIN	WET_Q_RAIN	DEM	SLOPE	ASPECT	ROAD_DIST	STREAM_DIST	CITY_DIST	POPULATION	TIGER_PREY	LEOP_PREY
ANN._RAIN	**1**	-.022	**.964**	.272	.253	.001	.126	.335	.185	-.057	-.019	-.011
DRY_Q_RAIN	-.022	**1**	-.136	.207	.240	-.002	.426	.201	.033	-.099	.297	.287
WET_Q_RAIN	**.964**	-.136	**1**	.263	.240	.005	.010	.276	.100	-.040	-.137	-.131
DEM	.272	.207	.263	**1**	.622	.019	.209	-.080	.112	-.050	-.212	-.249
SLOPE	.253	.240	.240	.622	**1**	-.011	.197	.021	.063	-.055	-.100	-.116
ASPECT	.001	-.002	.005	.019	-.011	**1**	-.016	.012	-.001	.019	.020	.022
ROAD_DIST	.126	.426	.010	.209	.197	-.016	**1**	.197	.292	-.109	.263	.252
STREAM_DIST	.335	.201	.276	-.080	.021	.012	.197	**1**	.154	-.051	.235	.241
CITY_DIST	.185	.033	.100	.112	.063	-.001	.292	.154	**1**	-.065	.448	.454
POPULATION	-.057	-.099	-.040	-.050	-.055	.019	-.109	-.051	-.065	**1**	-.071	-.078
TIGER_PREY	-.019	.297	-.137	-.212	-.100	.020	.263	.235	.448	-.071	**1**	.971
LEOP_PREY	-.011	.287	-.131	-.249	-.116	.022	.252	.241	.454	-.078	.971	**1**

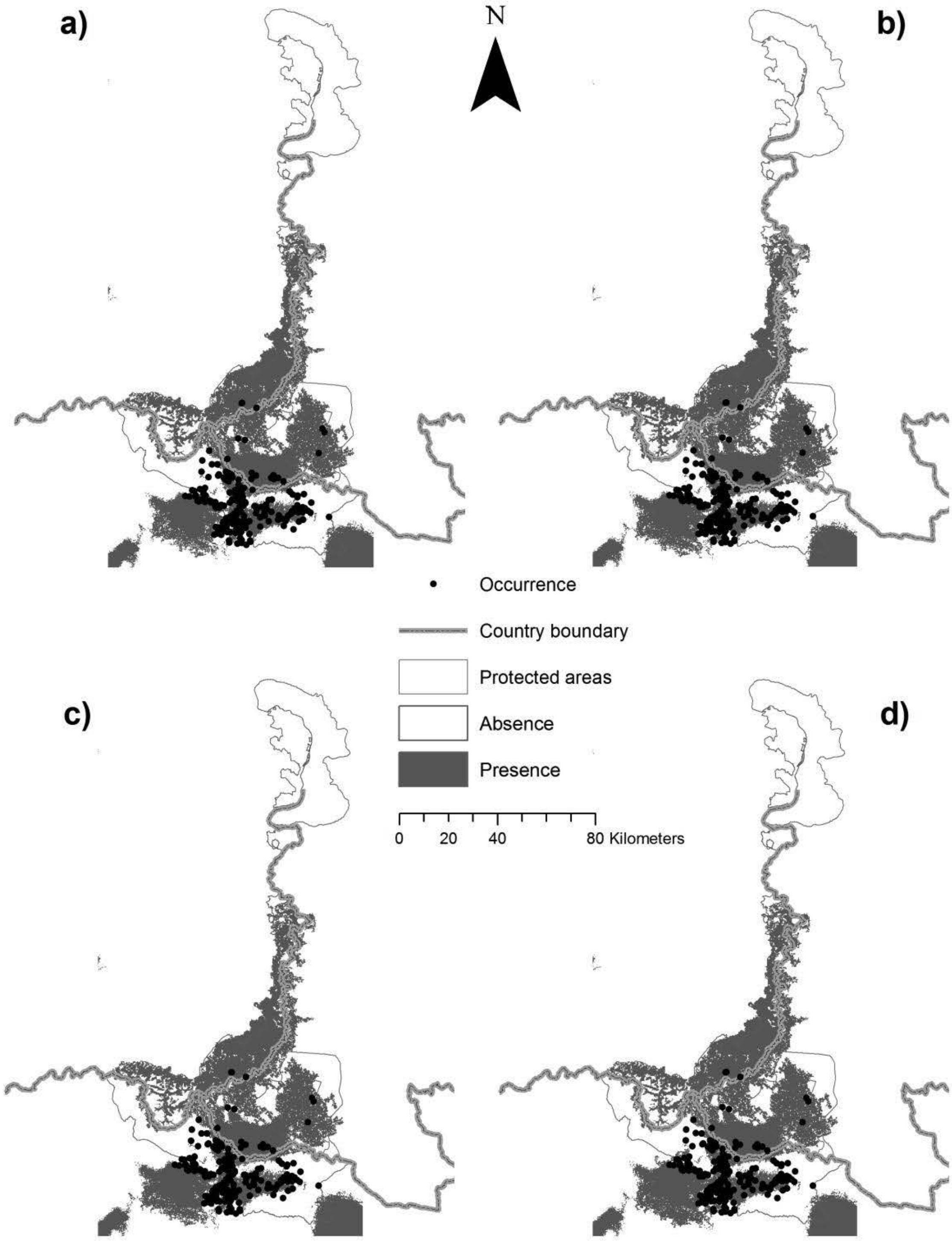
Remarks: ANN._RAIN, annual rainfall; DRY_Q_RAIN, rainfall in the driest quarter; WET_QRAIN, rainfall in the wettest quarter; DEM, digital elevation model; SLOPE, percent slope; ASPECT, aspect direction (degree from north direction); ROAD_DIST, proximity to road; SSTREAM_DIST, proximity to stream network; CITY_DIST, proximity to district center; POULATION, population density per km;, TIGER_PREY, tiger prey species; and LEOP_PREY, leopard prey species

ANNEX 2

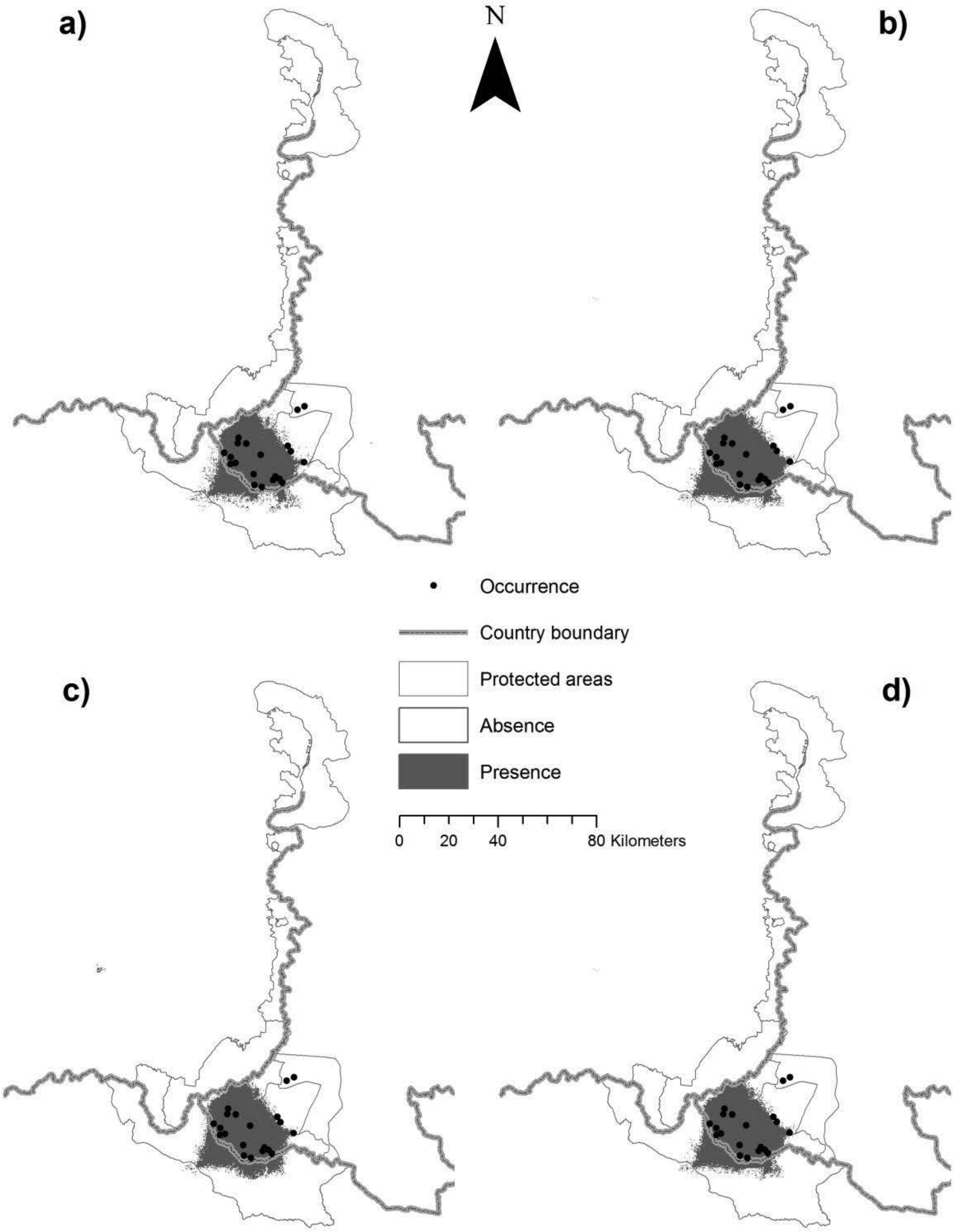
PREDICTED DISTRIBUTIONS OF SELECTED WILDLIFE UNDER LAND-USE CHANGE SCENARIOS



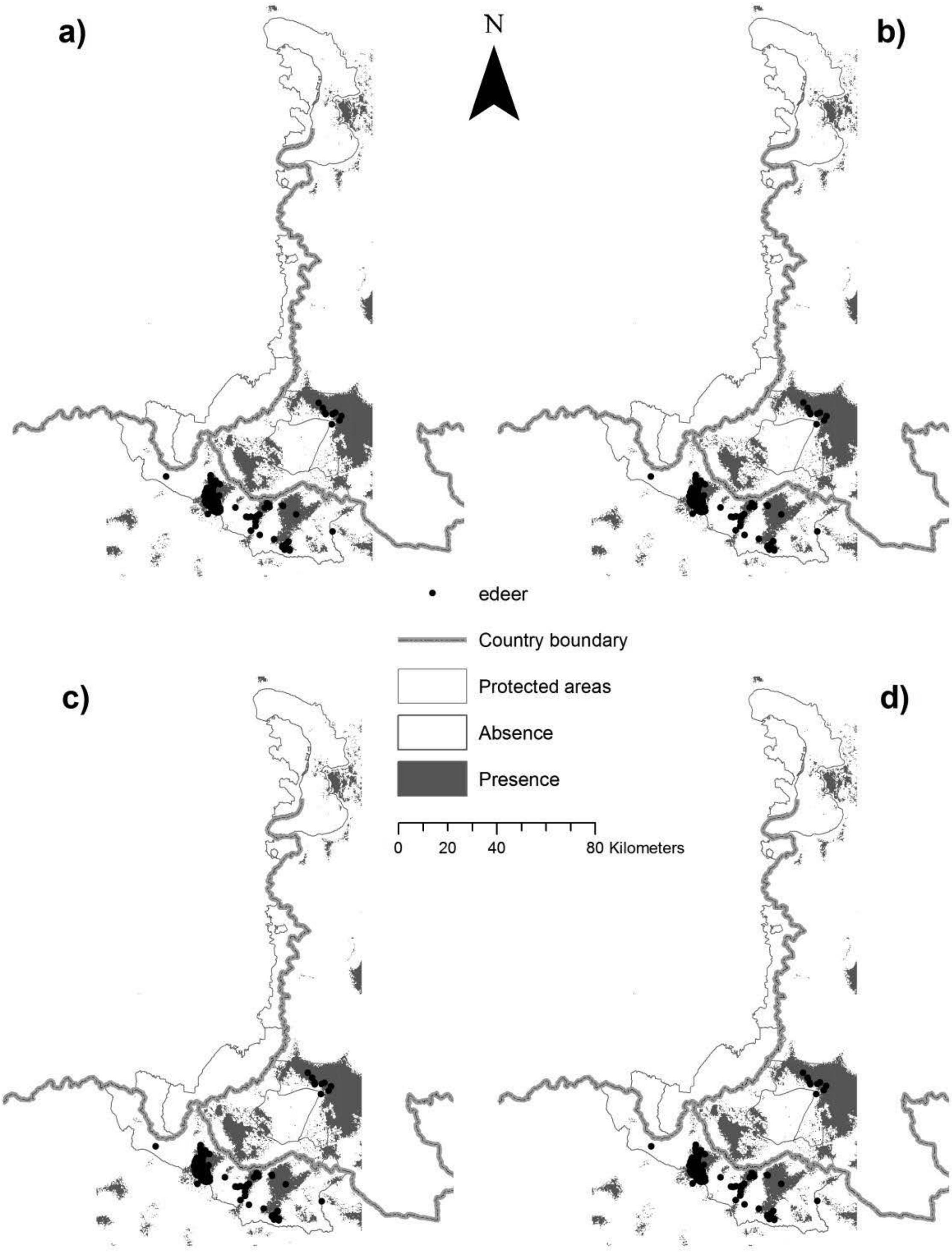
Annex 2.1 Predicted distribution for gaur in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



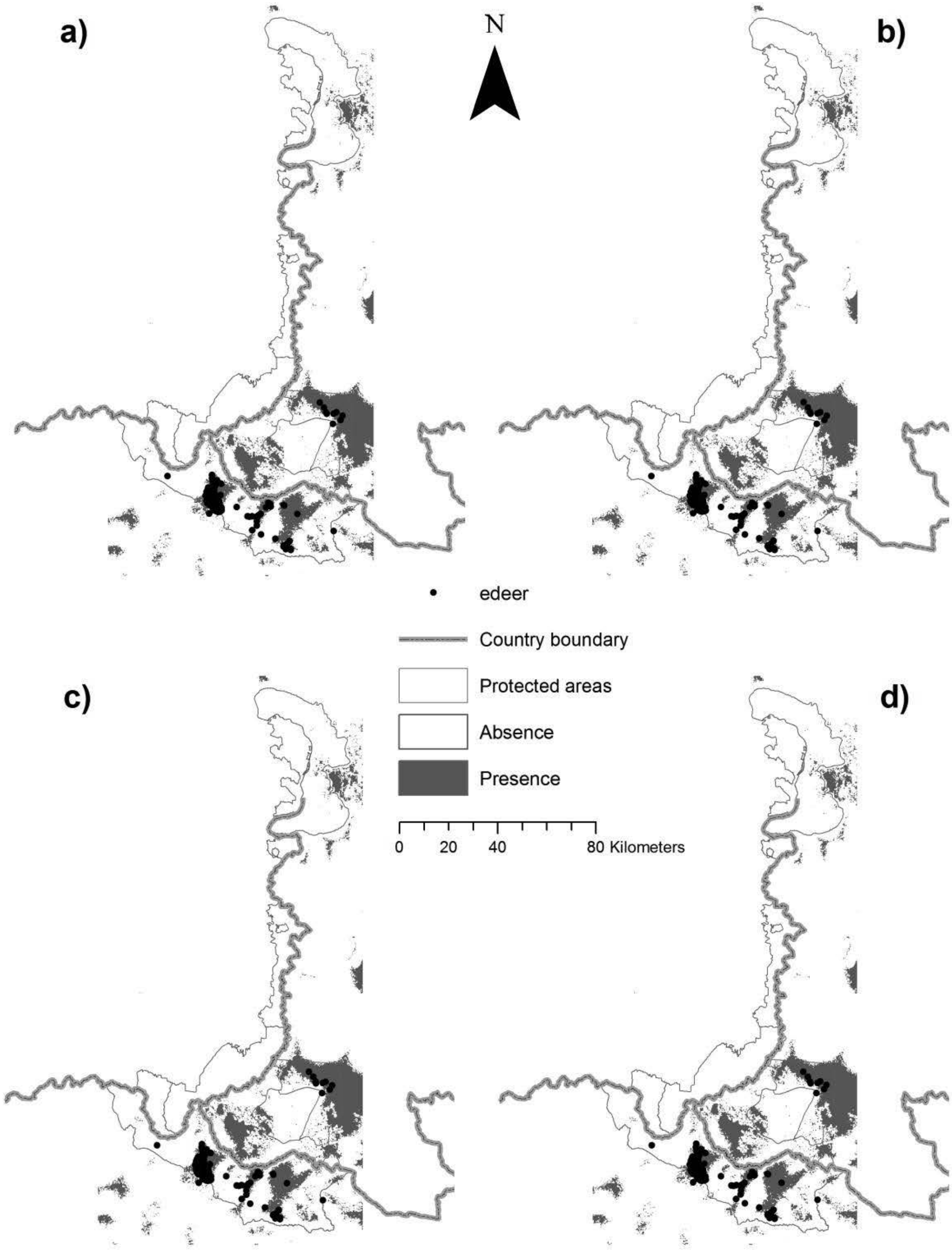
Annex 2.2 Predicted distribution for banteng in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



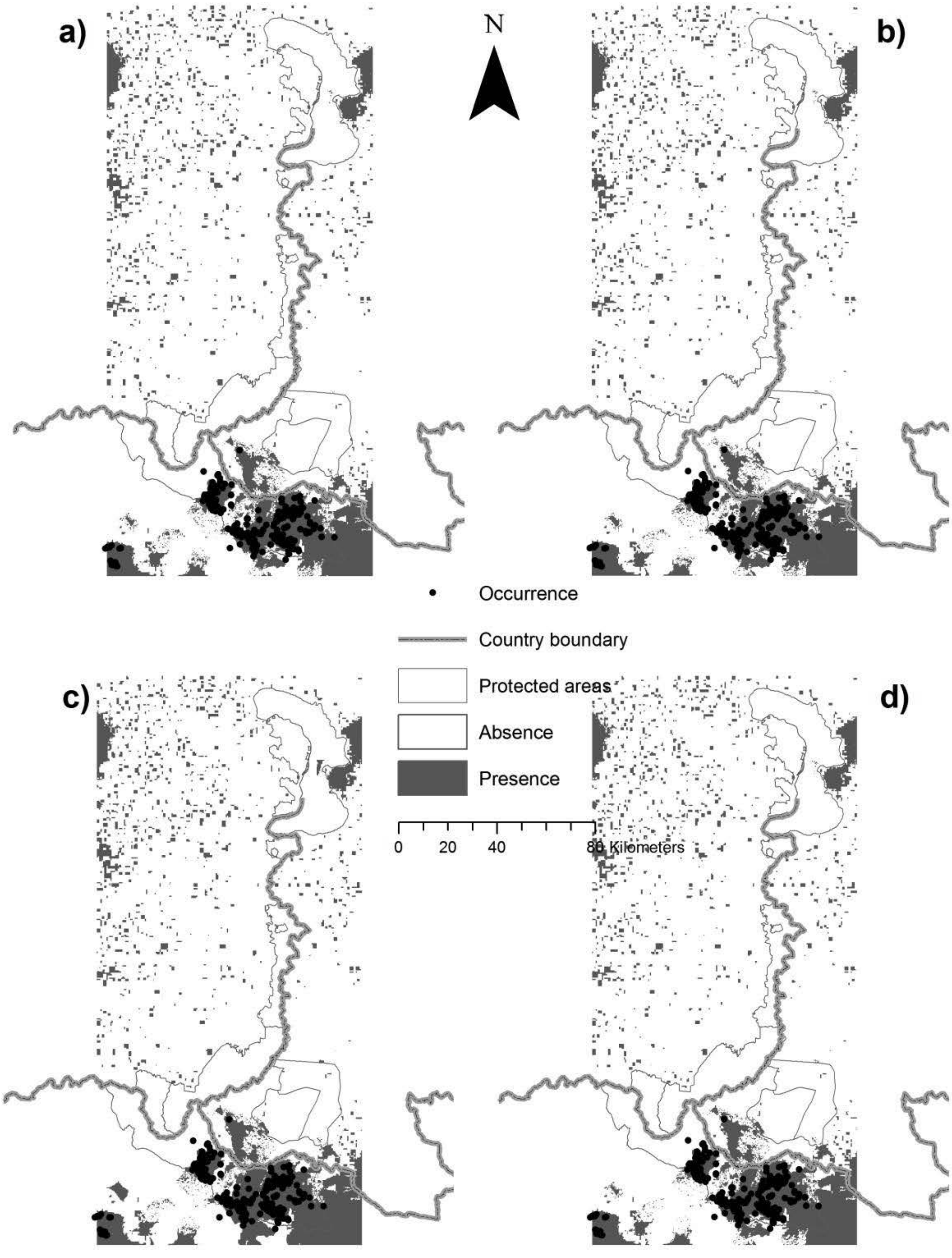
Annex 2.3 Predicted distribution for Sambar deer in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



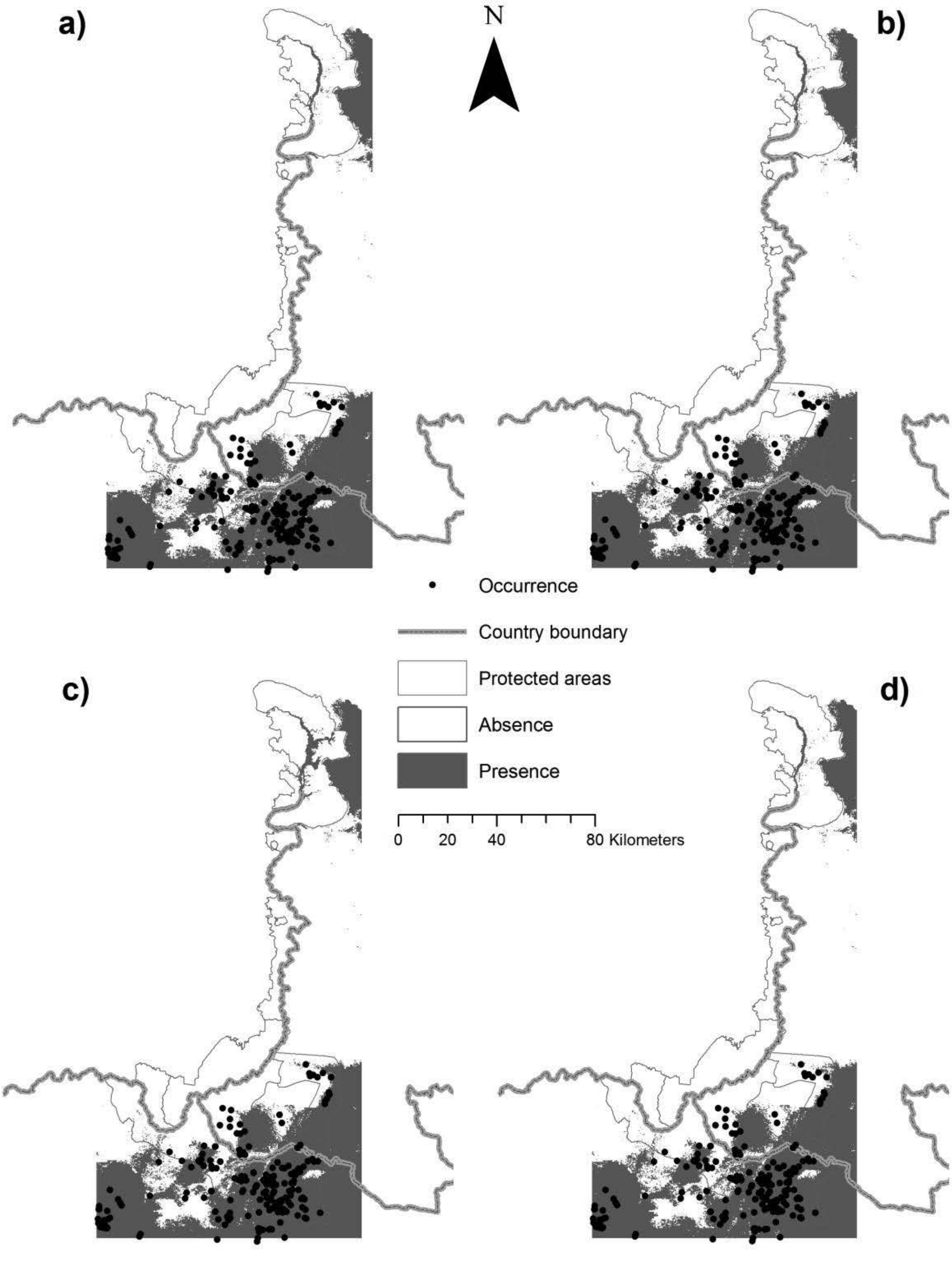
Annex 2.4 Predicted distribution for *Eld's* deer in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



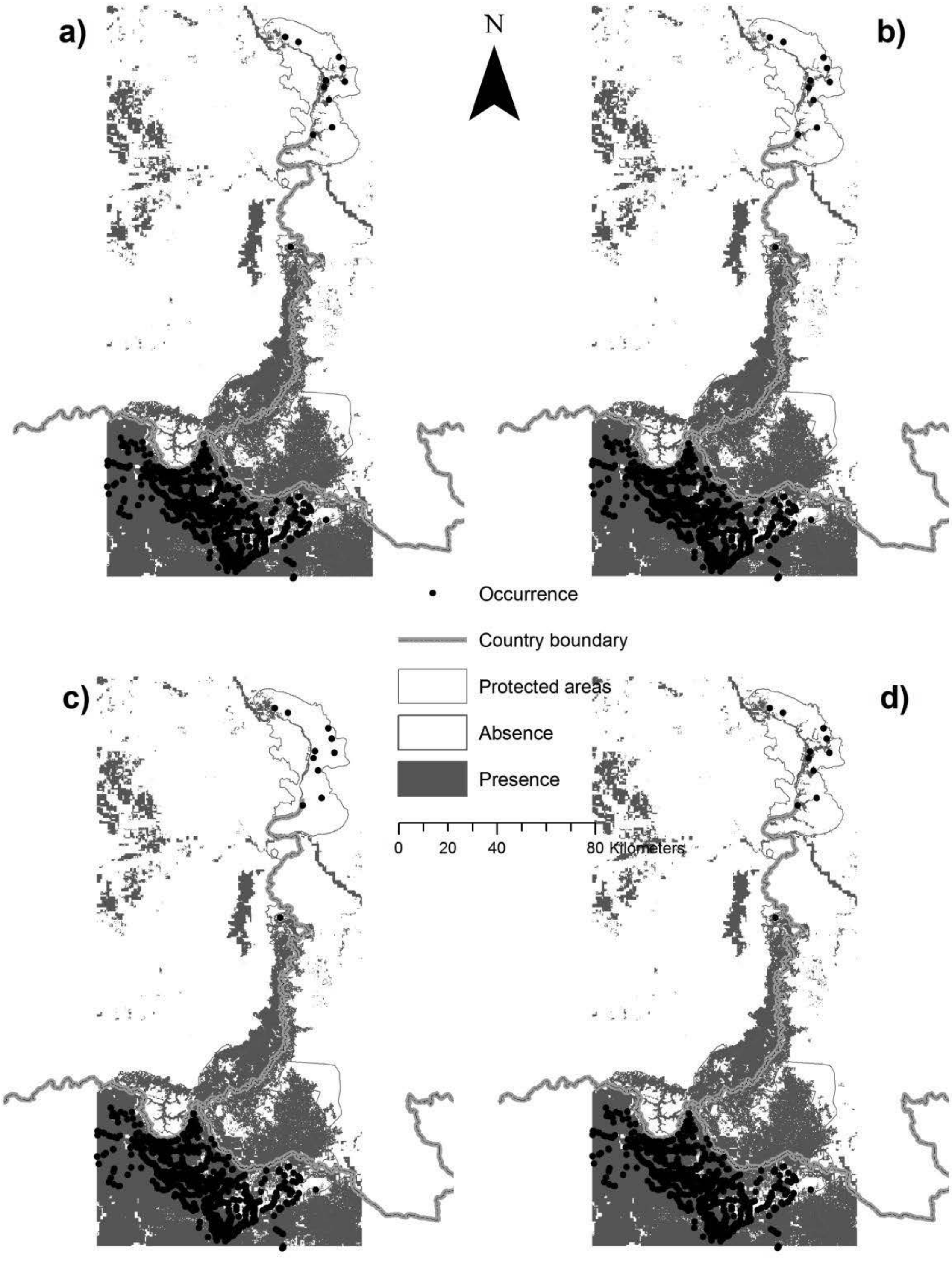
Annex 2.5 Predicted distribution for elephant in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



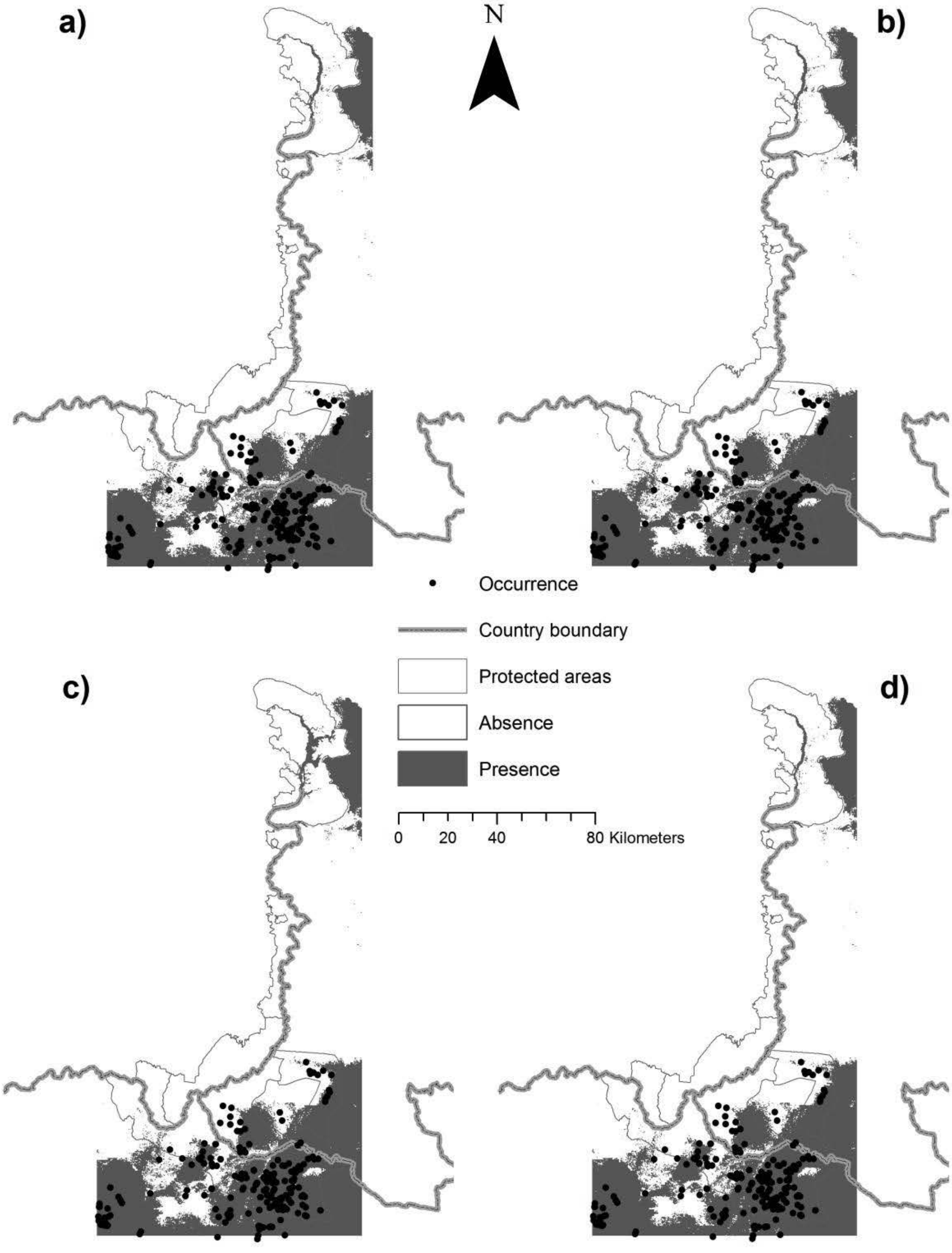
Annex 2.6 Predicted distribution for Sarus crane in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



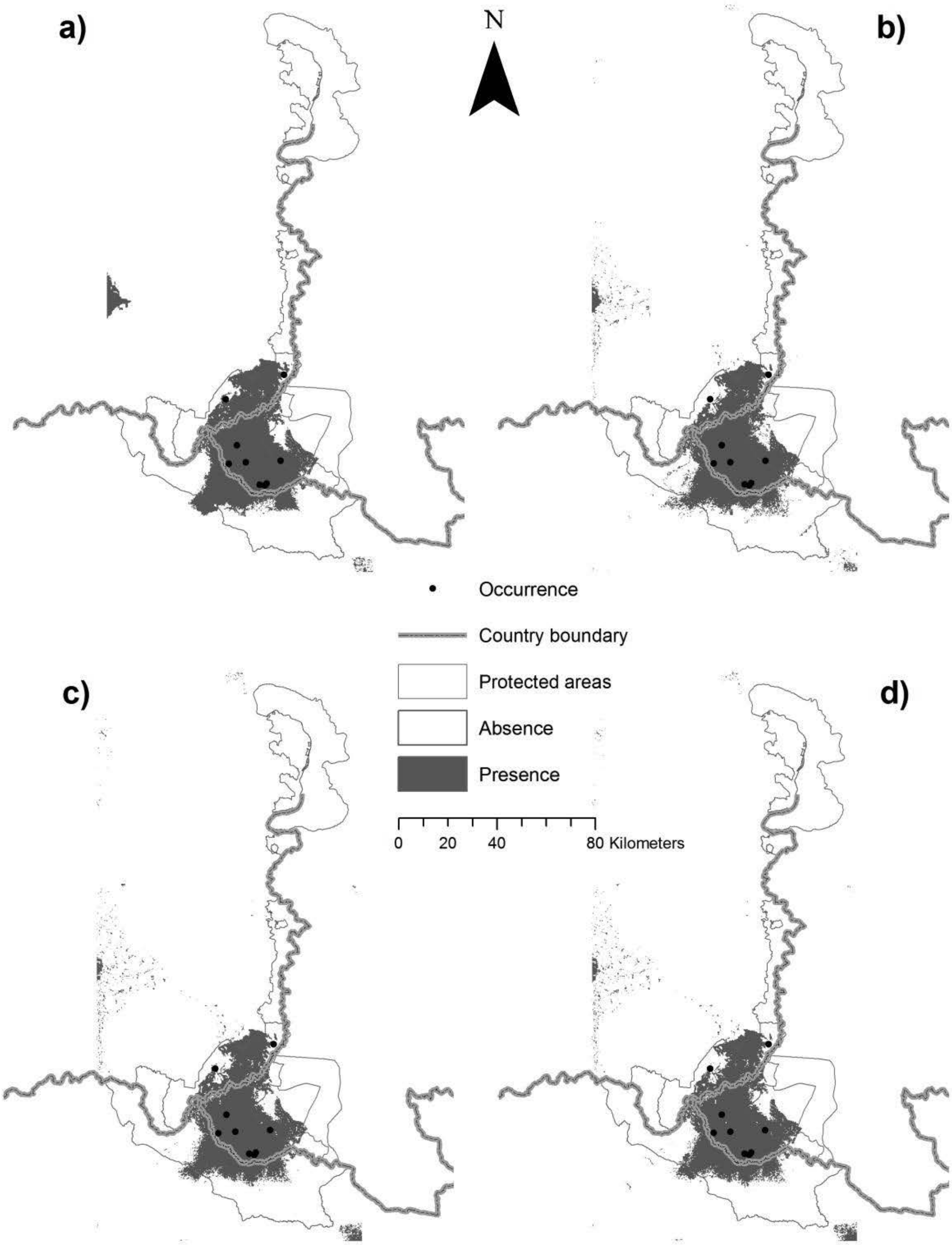
Annex 2.7 Predicted distribution for Lesser adjutant stork in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



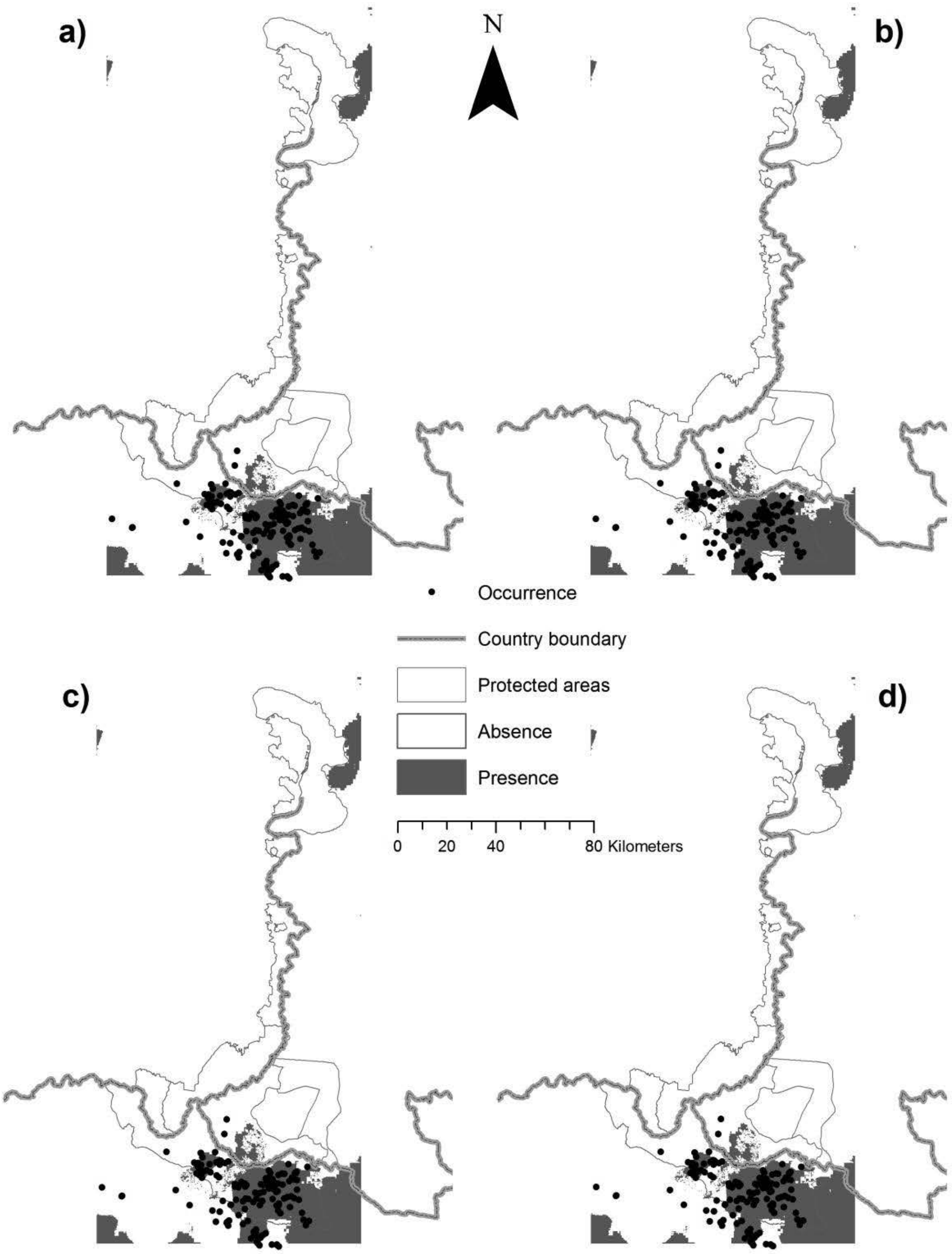
Annex 2.8 Predicted distribution for barking deer in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



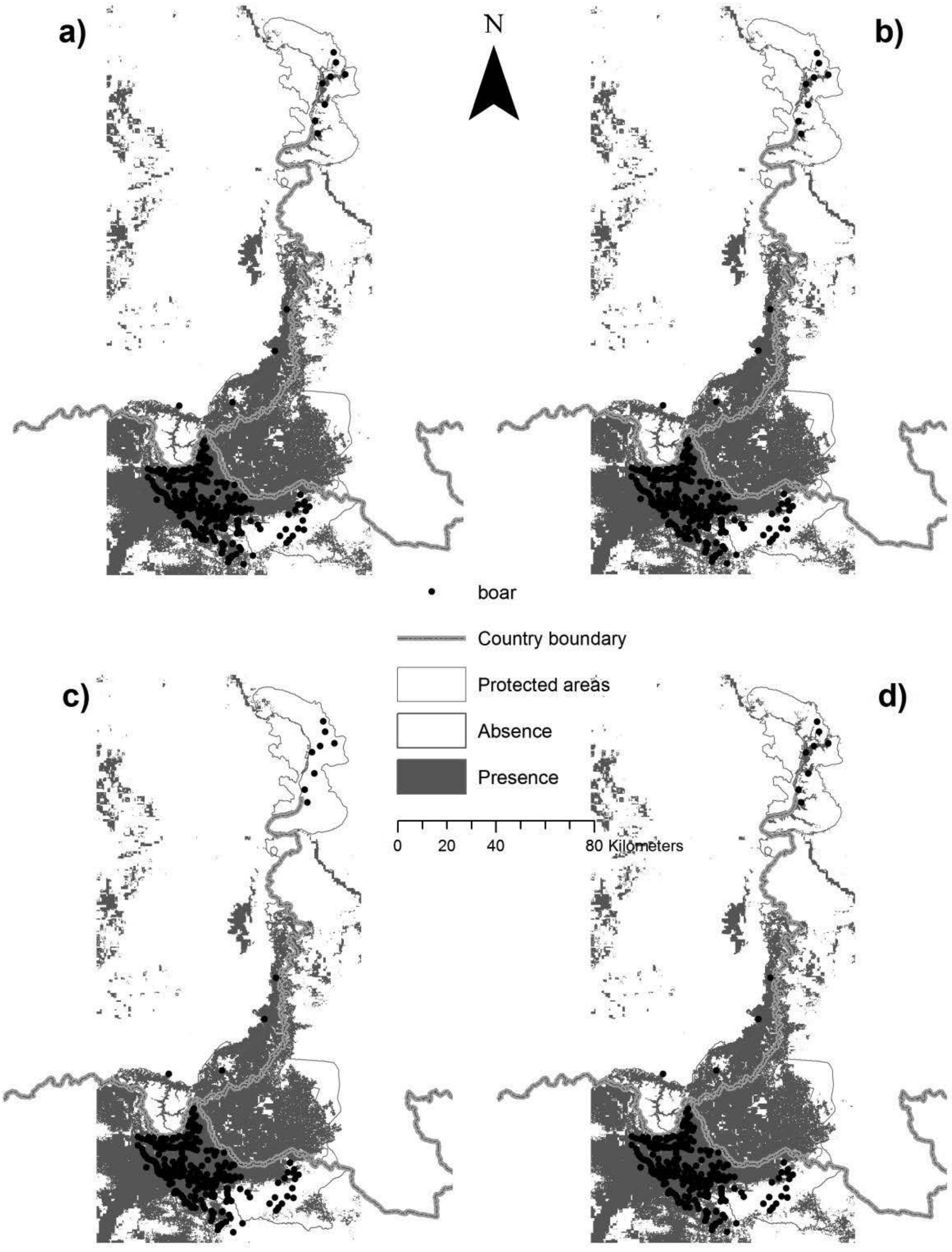
Annex 2.9 Predicted distribution for leopard in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



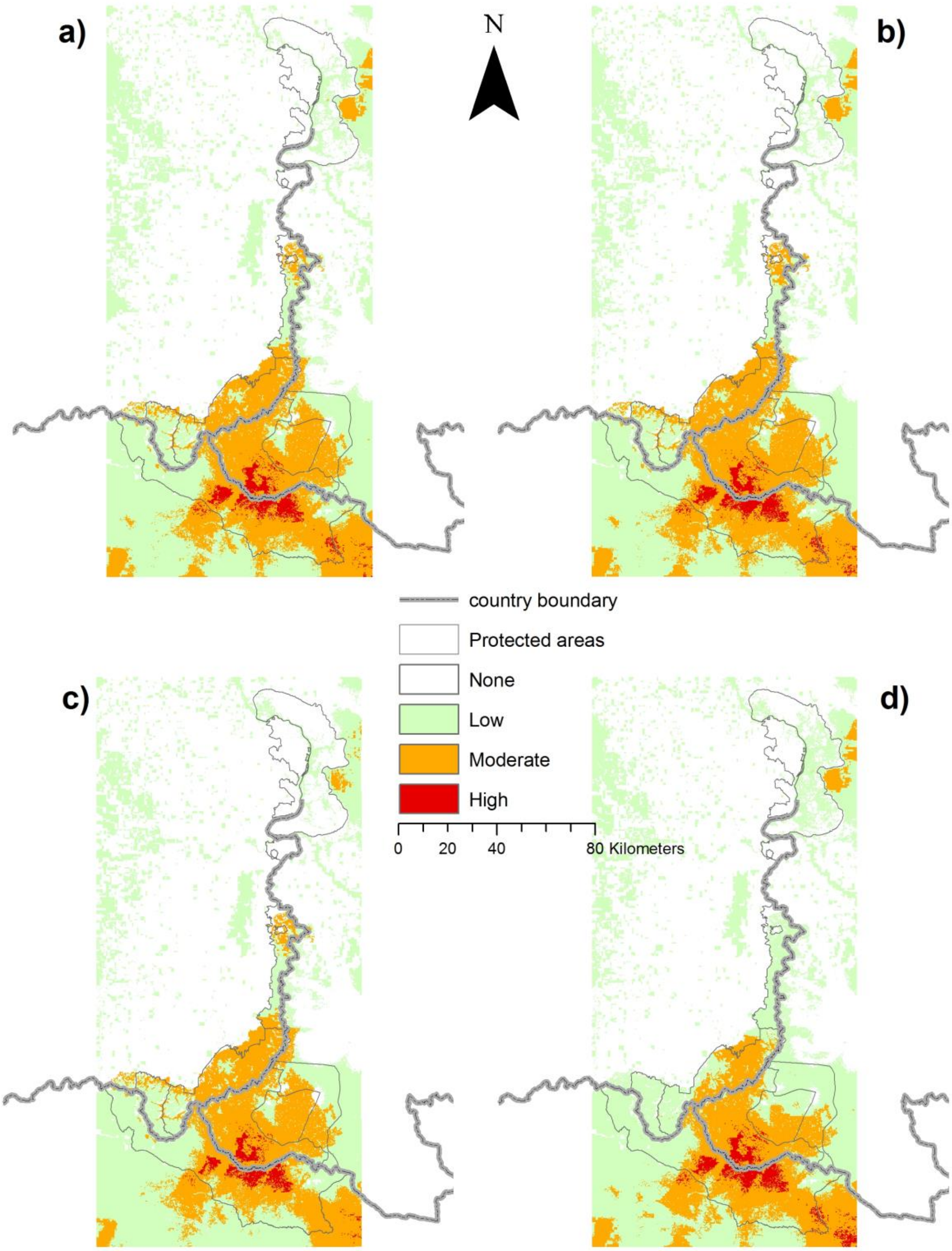
Annex 2.10 Predicted distribution for tiger in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



Annex 2.11 Predicted distribution for giant ibis in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



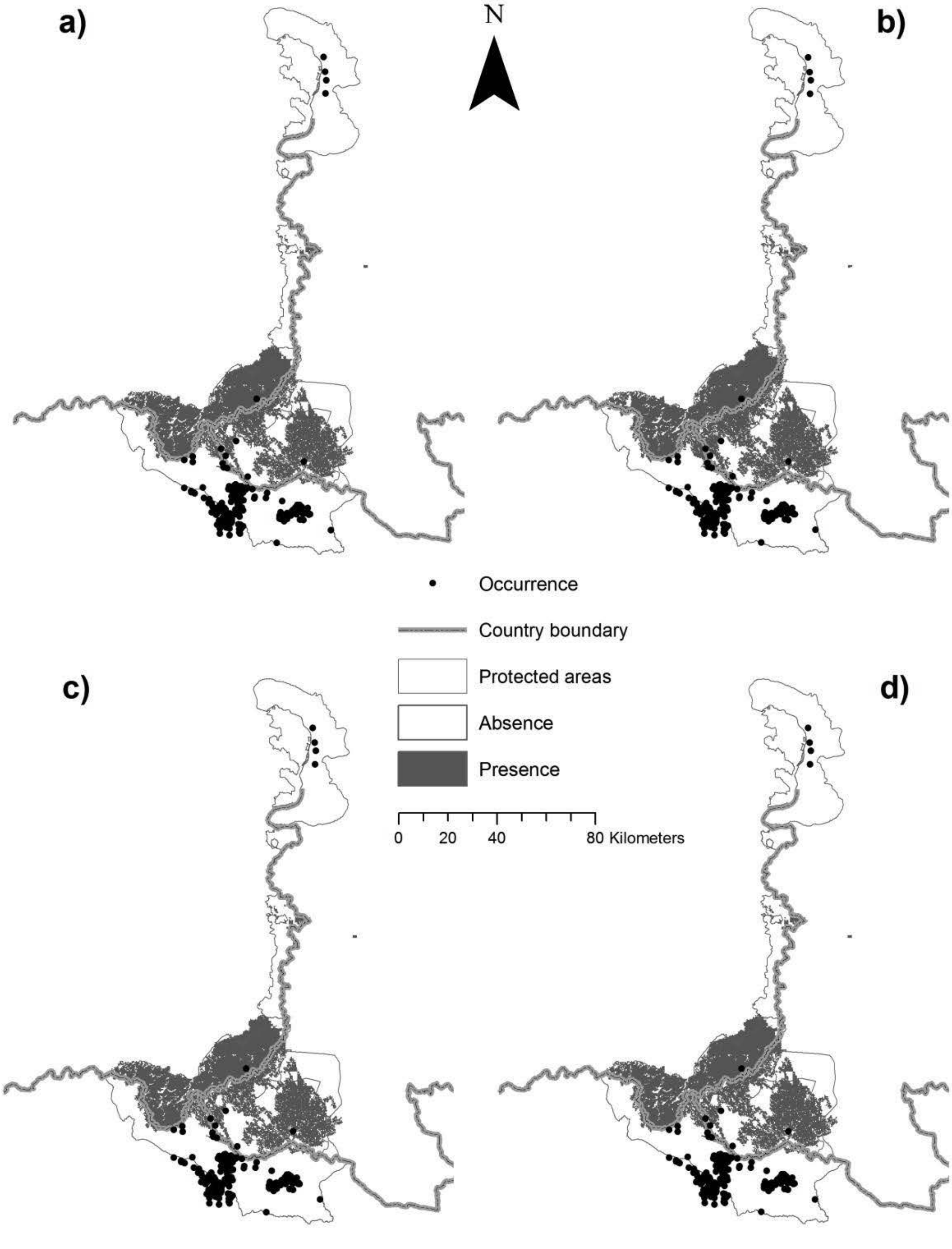
Annex 2.12 Predicted distribution for wild boar in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



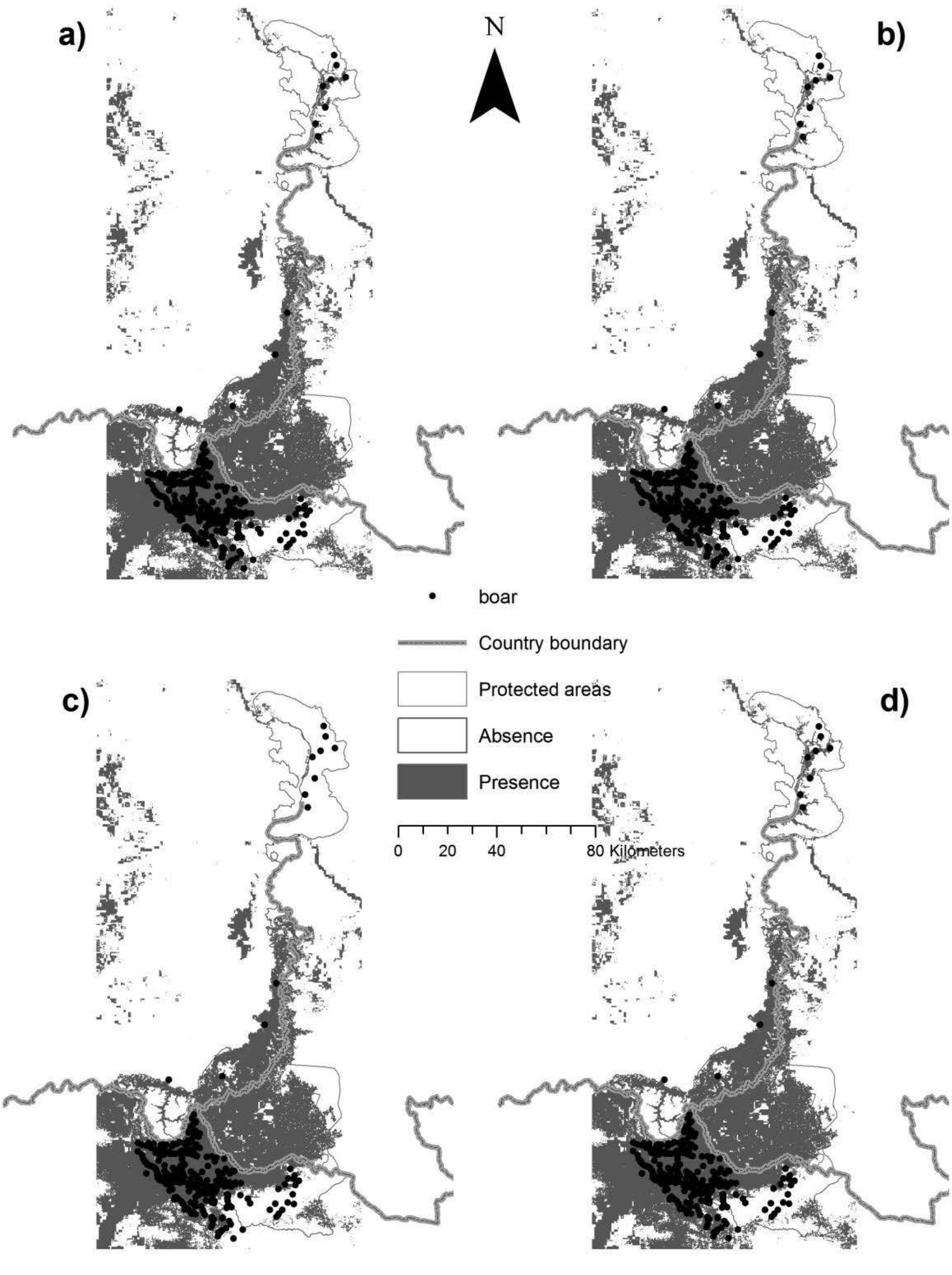
Annex 2.13 Predicted species richness in 2030 under different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation

ANNEX 3

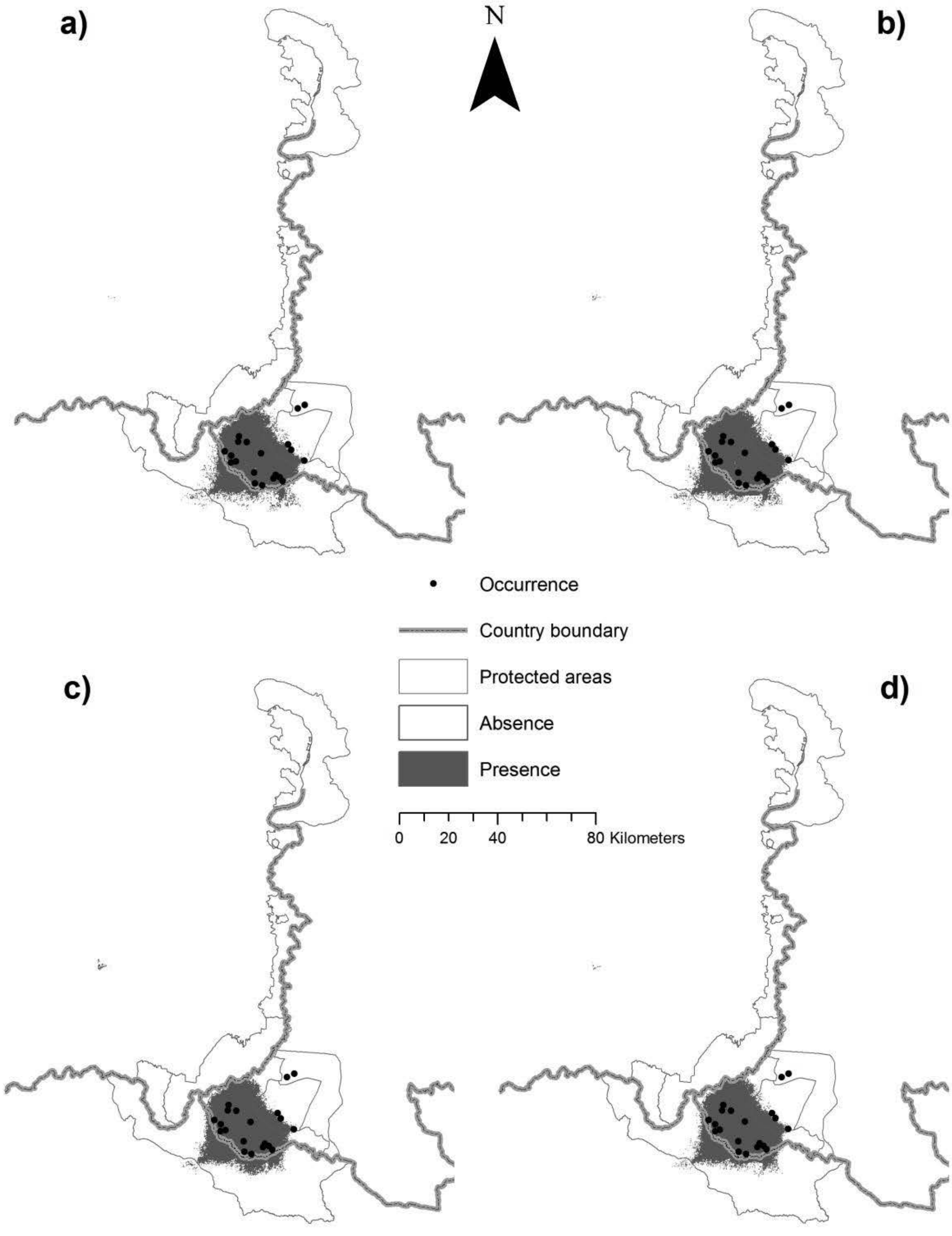
PREDICTED DISTRIBUTIONS OF SELECTED WILDLIFE UNDER THE COMBINATION OF CLIMATE AND LAND-USE CHANGE SCENARIOS



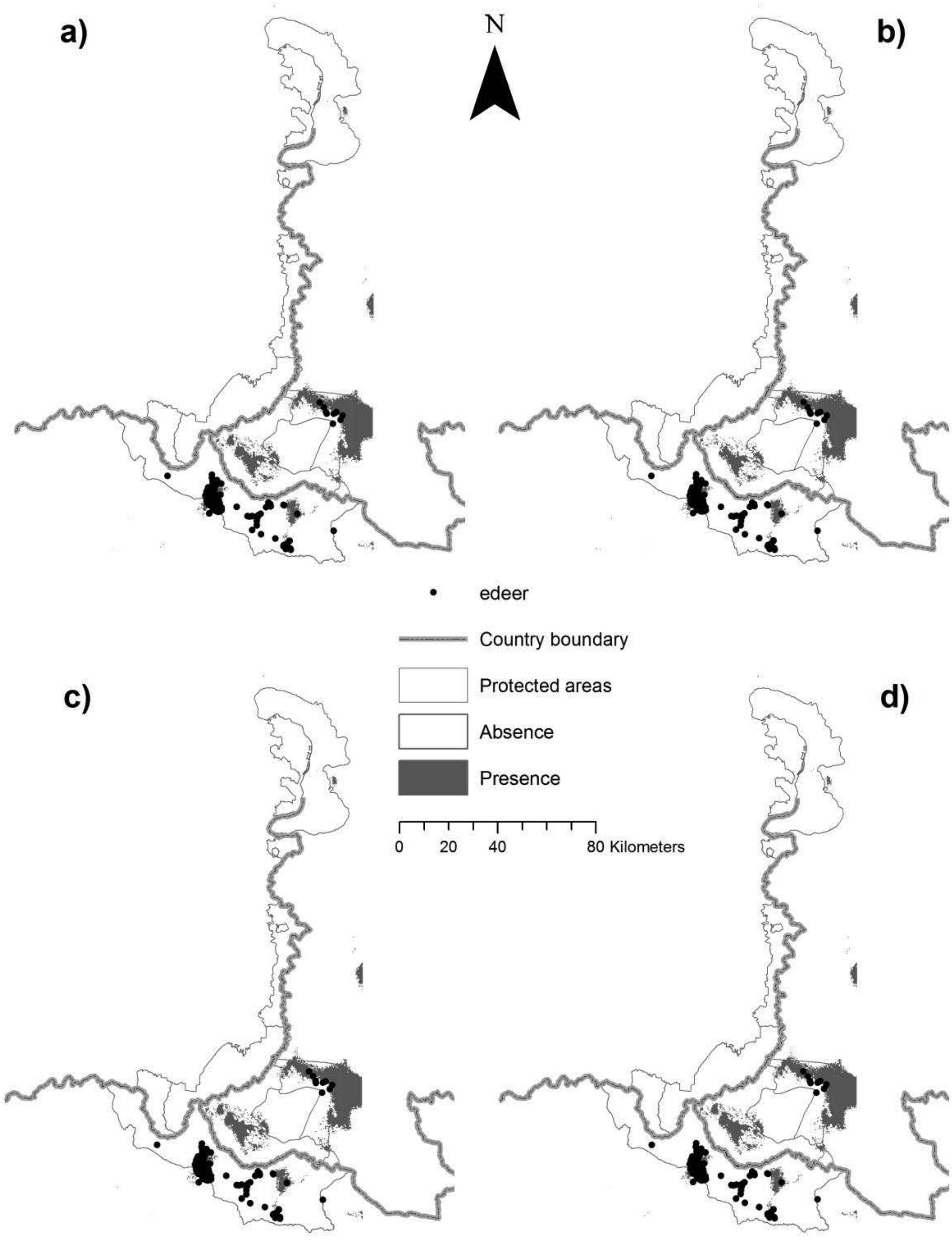
Annex 3.1 Predicted distribution for gaur in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



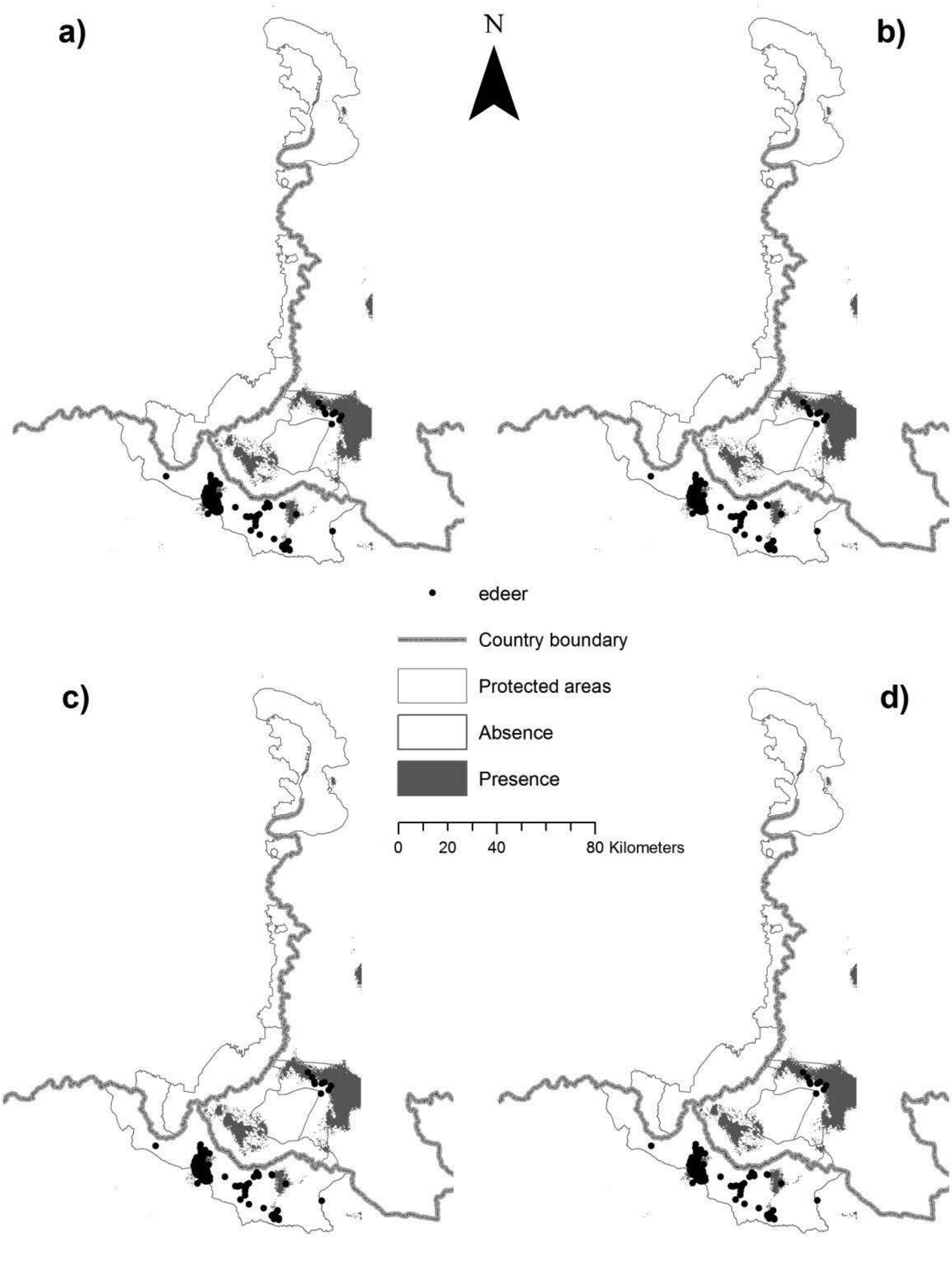
Annex 3.2 Predicted distribution for banteng in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



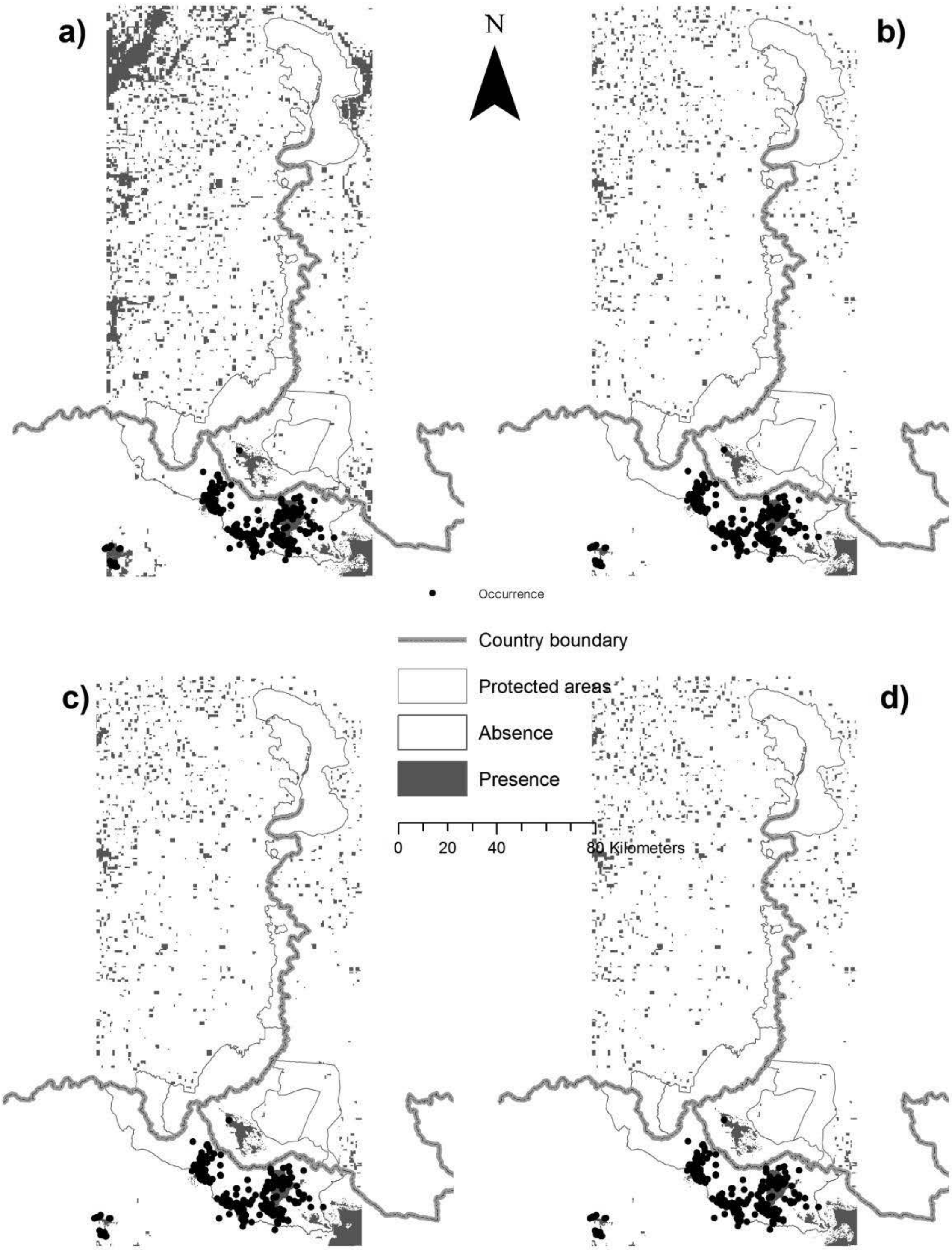
Annex 3.3 Predicted distribution for Sambar deer in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



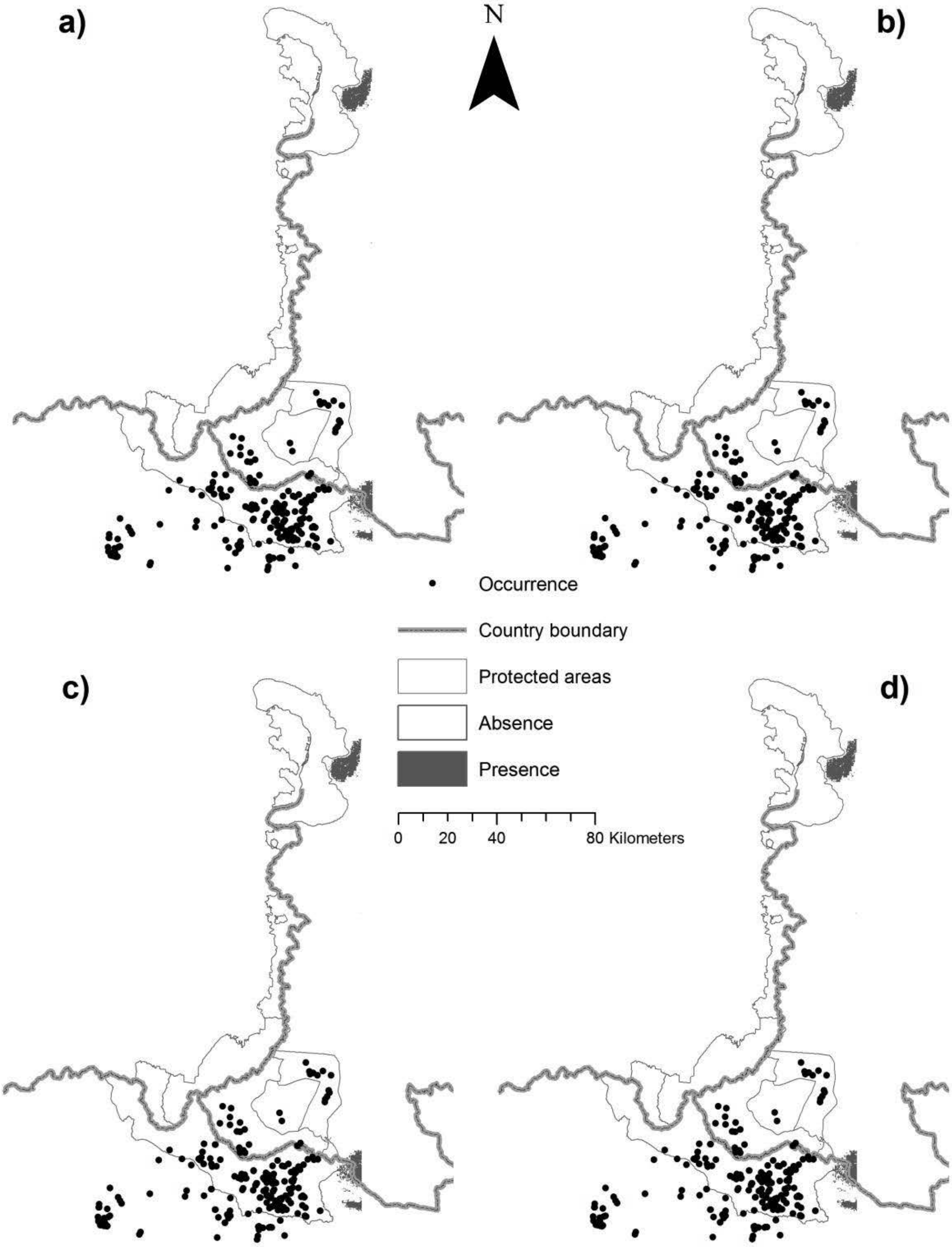
Annex 3.4 Predicted distribution for *Eld's* deer in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



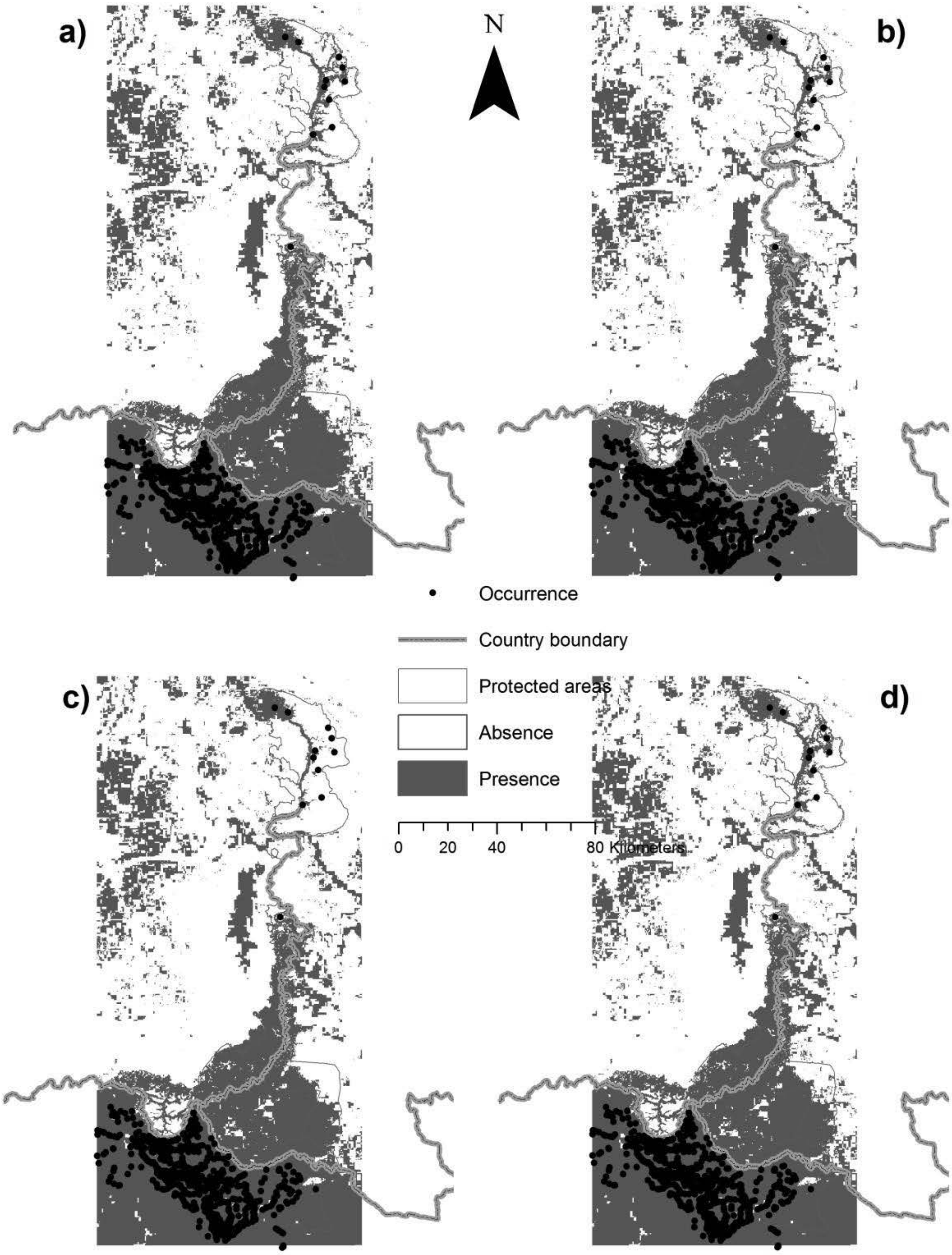
Annex 3.5 Predicted distribution for elephant in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



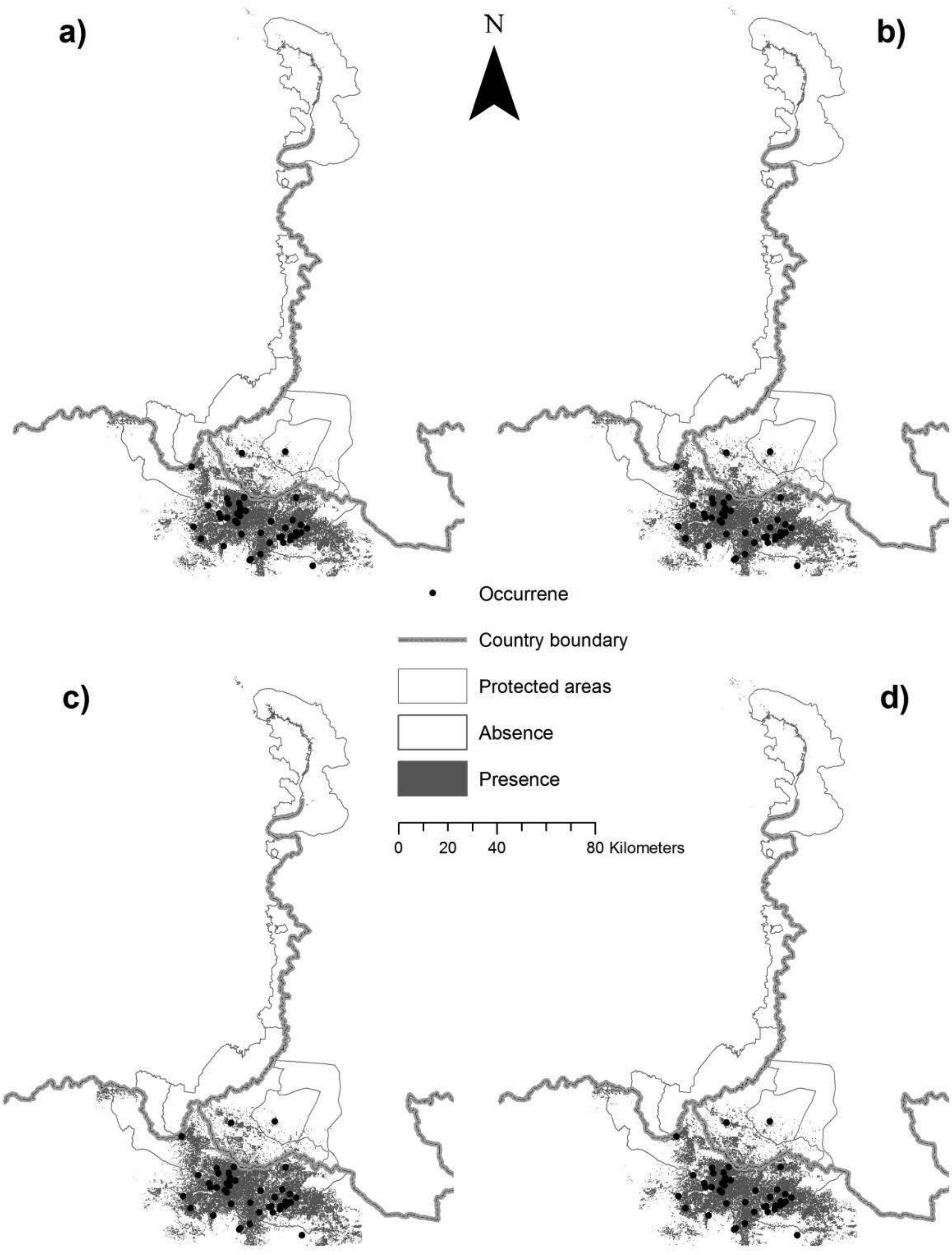
Annex 3.6 Predicted distribution for Sarus crane in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



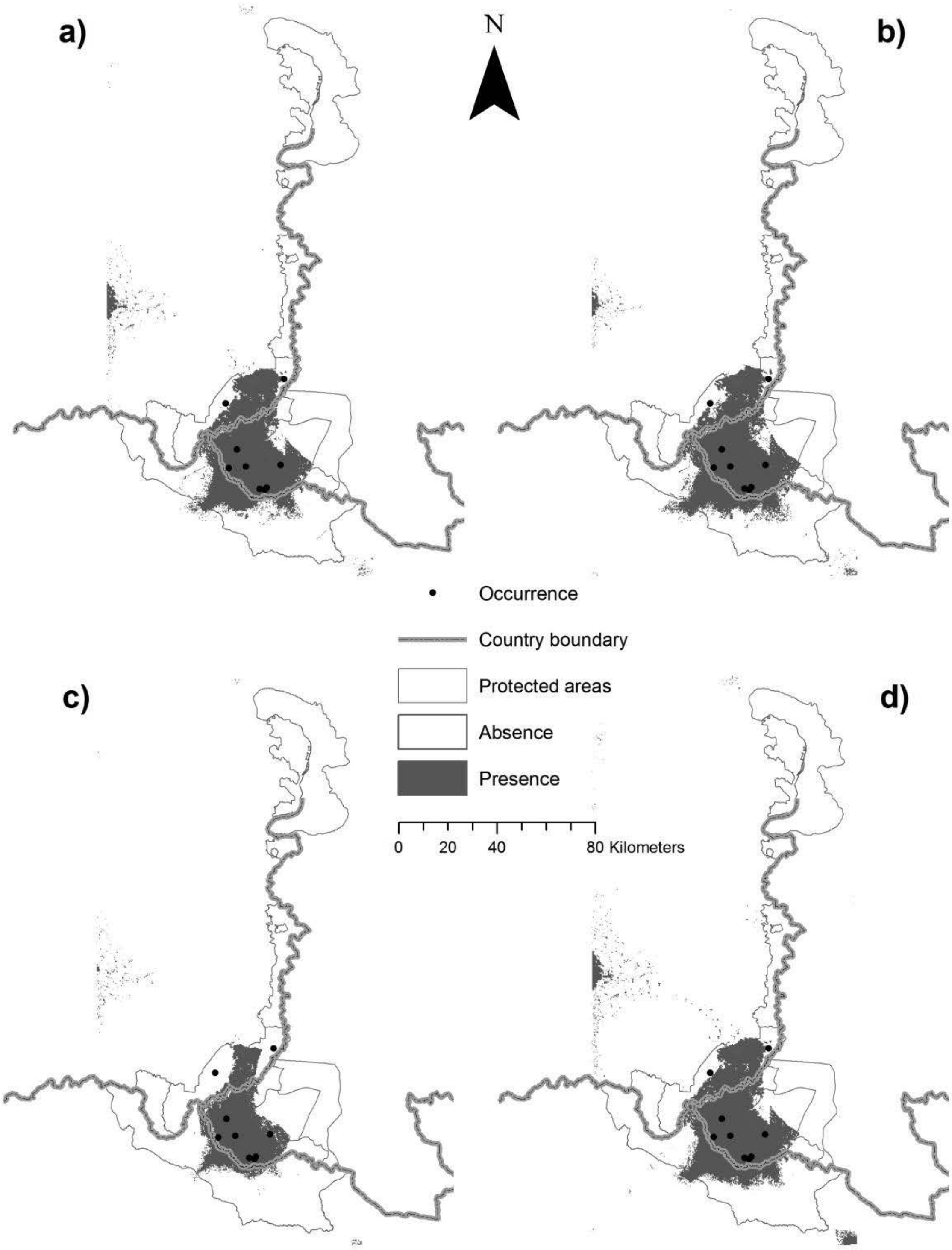
Annex 3.7 Predicted distribution for Lesser adjutant stork in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



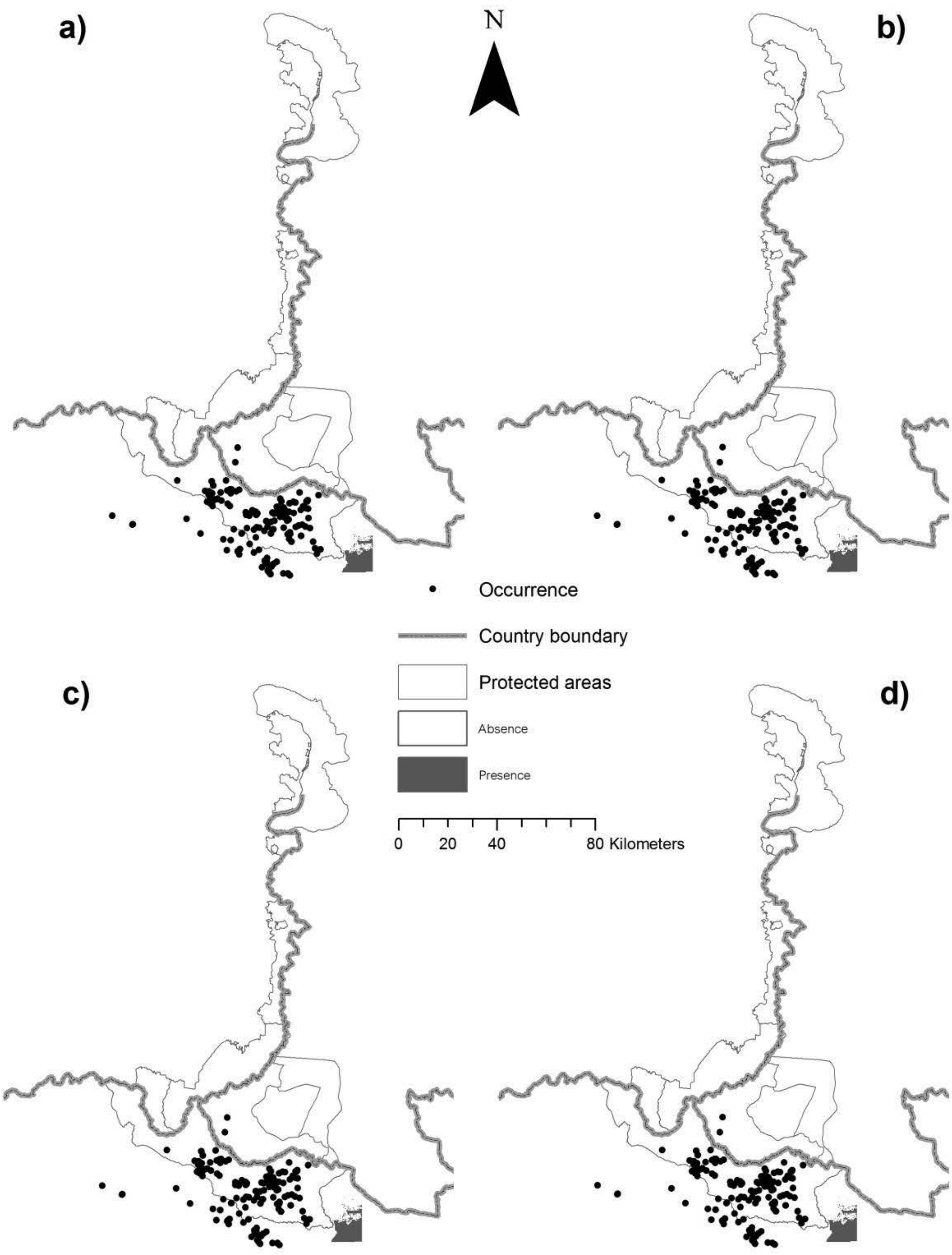
Annex 3.8 Predicted distribution for barking deer in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



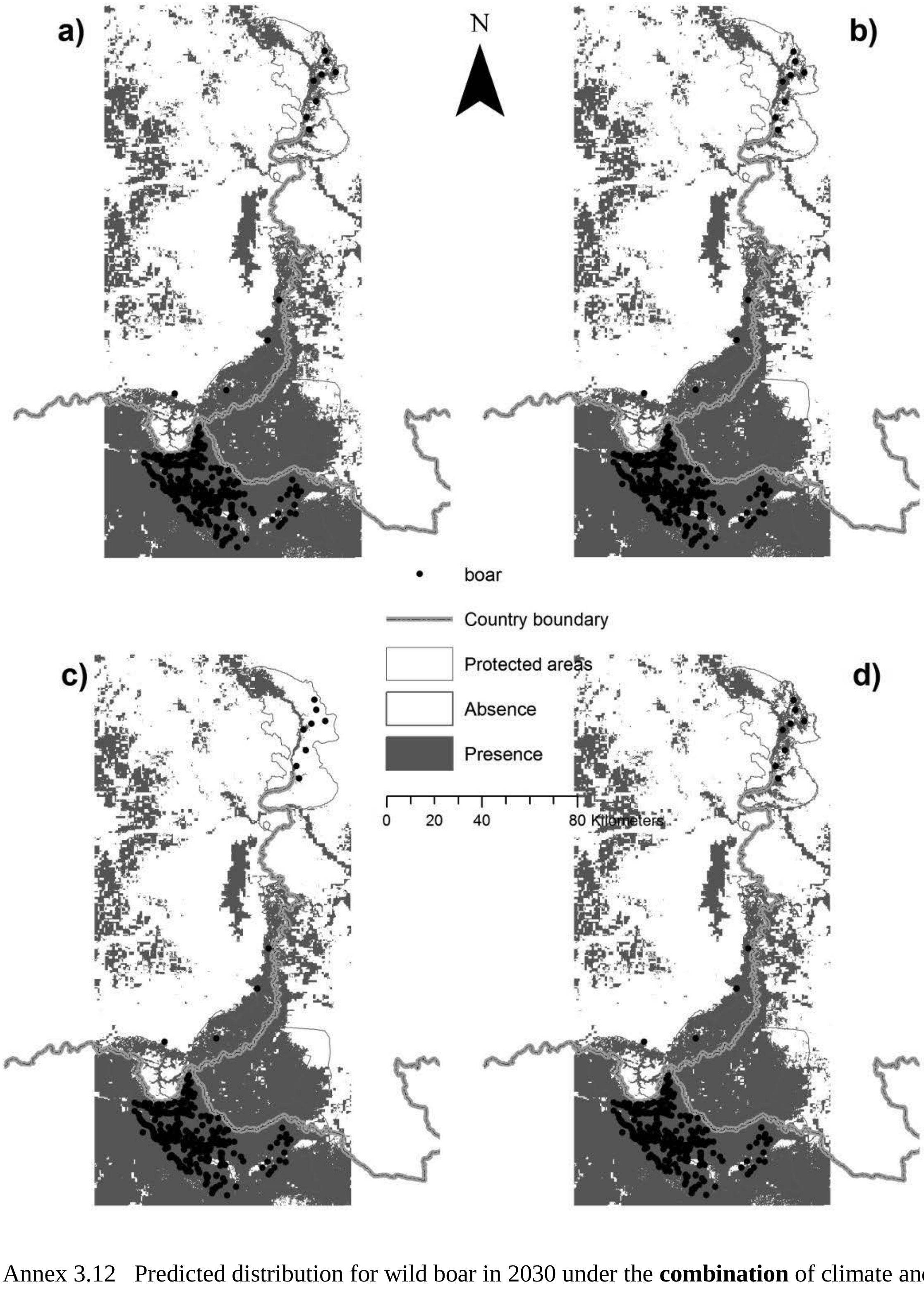
Annex 3.9 Predicted distribution for leopard in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



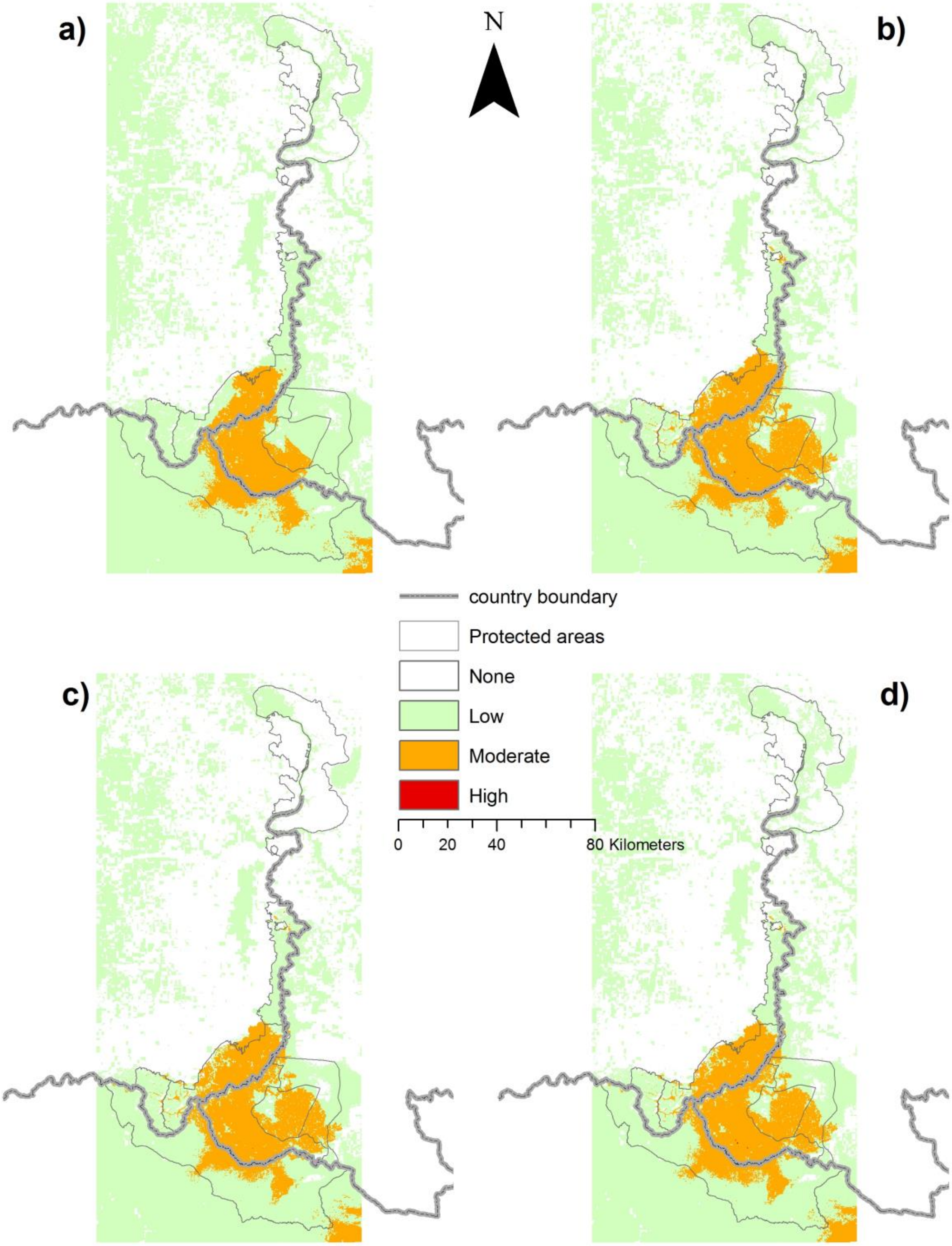
Annex 3.10 Predicted distribution for tiger in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



Annex 3.11 Predicted distribution for giant ibis in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



Annex 3.12 Predicted distribution for wild boar in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation



Annex 3.13 Predicted species richness in 2030 under the **combination** of climate and different land-use change scenarios: a) low economic decline and localized resource degradation; b) unsustainable development and serious resource degradation; c) sustainable poverty and stable resources; and d) sustainable development and limited resources degradation

Annex 4 List of participants and resource persons attending the 1st GIS Training Session 28-29 November 2013

No	Name in Thai	Name in English	Organization
1	นายธงชัย ศรีสะอาด	Mr. Thongchai Srisaart	Buntrik Yod Mon
2	นายวุฒิชัย นุสนธิ์	Mr. Wuttichai Nuson	Buntrik Yod Mon
3	นางสาวจารุวรรณ ศรีอึ่ง	Miss Jaruwan Sriaung	Buntrik Yod Mon
4	นายแสงจันทร์ ชาวตระการ	Mr. Saengchan Chaotakan	Ubon Ratchatani Reg 12, RFD
5	นายสุบรรณ์ แสวงผล	Mr. Suban Sawaengphon	Ubon Ratchatani Reg 12, RFD
6	นายอุทิศ วิริยะรุ่งโรจน์สกุล	Mr. Uthit Viriyarungrojsakul	Ubon Ratchatani Reg 12, RFD
7	นางสาวอรทัย ทันวิมา	Miss Oorathai Tanwima	Phu Jong Na Yoi
8	นางสาวสุพรรณี ฝางคำ	Miss Supannee Fangkam	Phu Jong Na Yoi
9	นางสาวปฏิญญา นิคม	Miss Patinya Nikhom	Phu Jong Na Yoi
10	นายสมชาย กอมณี	Mr. Somchai Kurmanee	Kaeng Ta Na
11	นายวีระพันธ์ เรือนแก้ว	Mr. Weerapan Raunkao	Kaeng Ta Na
12	นายวิรัช พันธุ์จันทร์	Mr. Wirat Panchan	Kaeng Ta Na
13	นายสกุลทัย จันทร์สุข	Mr. Sakulthai Junsook	Pha Taem
14	นายไพโรจน์ ผิวอ่อน	Mr. Phairot Paew-on	Pha Taem
15	นายขอบคุณ คำมั่น	Mr. Khobkhun Khamman	Pha Taem
16	นายอนัน จักษุนิล	Mr. Anan Jaksunin	Yod Dom
17	นายวิชัย ภารุนัย	Mr. Wichai Pharunai	Yod Dom
18	นายสุภาพ ฦาชา	Mr. Suphap Luecha	Yod Dom
19	นางสาวเกษราภรณ์ จันทร์จริง	Miss Ketsarapon Chunchring	Project staff
20	นายเจริญศักดิ์ ป้องพิมพ์	Mr. Charoensak Pongpim	Project staff
21	นายพิทยา คำมั่น	Mr. Phittaya Khamman	Project staff
22	นายธีรวัฒน์ ภูมิลาวัลย์	Mr. Theerawat Phummilawan	Project staff
23	นางสาวนลิน ป้องพิมพ์	Miss Narin Pongpim	Project staff
24	นางสาวอรฤดี มณีทอง	Miss Onruedee Maneethong	Protected Area Administration Region 9
25	นายอัครเดช เดชธิสา	Mr. Akaradet Dettisa	Protected Area Administration Region 9
26	นายรัฐพล บุญมี	Mr. Rattapon Bunmee	Protected Area Administration Region 9
27	นางสาวเบญญา ขุนณรงค์	Miss Benya Khunnarong	Kasetsart University
28	นางสาวศศิธร หาสิน	Ms. Sasitorn Hasin	Kasetsart University
29	นายบารมี สกลรักษ์	Mr. Baramee Sakolrak	Kasetsart University

Names of resource persons

No	Name in Thai	Name in English	Organization
1	ศ.ดร. ยงยุทธ ไตรสุรัตน์	Prof. Dr. Yongyut Trisurat	Kasetsart University
2	ดร. นริศ ภูมิภาคพันธ์	Dr. Naris Bhumpakphan	Kasetsart University
3	นายวิชิต จิรมงคลการ	Mr. Wichit Jiramongkolgran	Protected Area Administration Region 9
4	นายธานนท์ โสภิตชา	Mr. Thanon Sophitcha	Protected Area Administration Region 9
5	นายกมล วิศุภกาญจน์	Mr. Kamol Wisupakarn	ITTO Project Manager

Annex 5 List of Participants and Trainers Attending the Joint Training Workshop on GIS Modeling for Forest Land Use Planning

No.	Name	Institution	Position	Country
1	H.E. Ung Sam Ath	Forestry Administration	Deputy Director General	Cambodia
2	Mr. Hiroshi Nakata	Forestry Administration	Technical Advisor	Japan
3	Mr. Ith Phoumara	Preah Vihear Cantonment, FA	Chief	Cambodia
4	Mr. Chheang Dany	ITTO-Project	Project Manager	Cambodia
5	Dr. Dennis Cengel	ITTO-Project	Project Technical Advisor	USA
6	Mr. Kim Sobon	ITTO-Project	Project Site Manager, Forest land Use Planning Specialist	Cambodia
7	Mr. Nhan Bunthan	ITTO-Project	GIS Mapping Specialist	Cambodia
8	Ms. Lim Sopheap	ITTO-Project	Project Admin and Accountant	Cambodia
9	Mr. Tan Setha	Dept. Wildlife and Biodiversity, FA	Deputy Chief, Wildlife and Biodiversity office	Cambodia
10	Mr. Pang Phanit	ITTO-Project	Forest and Biodiversity Conservation Officer	Cambodia
11	Mr. Say Sinly	ITTO-Project	Field Assistant for Forest Land Use Planning	Cambodia
12	Mr. Noun Sokhom	Preah Vihear Cantonment, FA	Deputy Chief,	Cambodia
13	Mr. Mak Panha	Preah Vihear Cantonment, FA	Chief, Choam Ksan Division	Cambodia
14	Mr. Vong Viseth	Preah Vihear Cantonment, FA	Deputy Chief, Chheb Division	Cambodia
15	Mr. Lonh Ponnarith	Preah Vihear Cantonment, FA	Deputy Chief, Rovieng Division	Cambodia
16	Mr. Sum Sovutha	Preah Vihear Cantonment, FA	Deputy Chief, Rovieng Division	Cambodia
17	Mr. Hang Samrith	Preah Vihear Cantonment, FA	Chief, Kantort Triage	Cambodia

18	Mr. Chey Setha	Preah Vihear Cantonment, FA	Staff	Cambodia
19	Mr. Yim Bunthet	Preah Vihear Cantonment, FA	Staff	Cambodia
20	Mr. Houch Sreann	Preah Vihear Cantonment, FA	Staff	Cambodia
21	Mr. An Visal	Preah Vihear Cantonment, FA	Staff	Cambodia
22	Mr. Chou Chandararith	Pailin Cantonment, FA	Acting Chief	Cambodia
23	Mr. Nop Chhaya	Oddar Meanchey Cantonment, FA	Deputy Chief of Bantey Ampil Divisionl	Cambodia
24	Mr. Prum Vibolratanak	Preak Leap National College of Agriculture	Acting Dean, Forestry Faculty	Cambodia
25	Mr. Im Saovorith	DFA. Samrong	Deputy Chief	Cambodia
26	Mr. Kim Chantha	FA	Vice Chief of Inspectorate	Cambodia
27	Mr. Khlok Siphan	Try Pheap Import Export Co. Ltd.,	Staff	Cambodia
28	Mr. Sroy Rama	Try Pheap Import Export Co. Ltd.,	Staff	Cambodia
29	Mr. Sok Seila	Try Pheap Import Export Co. Ltd.,	Staff	Cambodia
30	Mr. Sok Vutthin	MoE	Kulen Prumtep wildlife Sanctuary	Cambodia
31	Mr. Saroeun Sithika	Preah Vihear Cantonment, FA	Staff	Cambodia
32	Mr. Chay Reth	Preah Vihear Cantonment, FA	Staff	Cambodia
33	Mr. Vilavanh Saphangthong	Champasak University	Vice Dean	Lao PDR
34	Mr. Inpeng Duangvongsa	Champasak University	Lecturer	Lao PDR
35	Mr. Bounthavy Vongkhamchanh	Champasak University	Lecturer	Lao PDR
36	Mr. Angkham Bouthdala	Champasak University	Lecturer	Lao PDR
37	Mr.Vichitta Soumphonphakdy	Champasak Province	Chief of Forest Protection Unit	Lao PDR

38	Mr.Visouk Tanchanthoun	Champasak Province	Deputy Head of Resources Management Section	Lao PDR
39	Mr. Suchat kalyawongsa	Royal Forest Department	ITTO Project Deputy Director	Thailand
40	Mr. Sapol Boonsermsook	Royal Forest Department	ITTO-Project Coordinator	Thailand
41	Mr. Kamol Wisupakan	ITTO-Project	Project Manager	Thailand
42	Prof. Dr. Yongyut Trisurat	Faculty of Forestry, Kasetsart University	ITTO-Project GIS Consultant	Thailand
43	Dr. Naris Bhumpakphan	Faculty of Forestry, Kasetsart University	ITTO-Project Wildlife Consultant	Thailand
44	Mr. Wichit Jiramongkhonkan	DNP, Regional Office 9, Ubon Ratchathanee	Director, Wildlife Division, DNP Regional Office 9, Ubon Ratchathanee	Thailand
45	Mr. Thanon Sopitcha	DNP, Regional Office 9, Ubon Ratchathanee	Director, National Park Division, DNP Regional Office 9, Ubon Ratchathanee	Thailand
46	Mr. Teerayut Wongpaiseart	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, PhuJong-Nayoi National Park, Ubon Ratchathanee	Thailand
47	Mr. Somsak Khonthon	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Bunthrik-Yodmon Wildlife Sanctuary, Ubon Ratchathanee	Thailand
48	Mr.Thaned Buakaeo	RFD	ITTO-Project Staff	Thailand
49	Mr. Pramote Ratree	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Yod Dome Widlife Sanctuary, Ubon Ratchathanee	Thailand
50	Mr. Utai Dachyosdee	Kasetsart University	Staff	Thailand

Annex 6 List if Participants attending GIS - Wildlife Distribution Modeling Joint Training Workshop

No	Name	Institution	Title	Country
1	Mr. Suchat Kalyawongsa	Royal Forest Department	Director, International Cooperation Office	Thailand
2	Ms. Rabieb Seigongpan	Royal Forest Department	ITTO-Project Coordinator Staff	Thailand
3	Mr. Krischana Nissa	Royal Forest Department	ITTO-Project Staff	Thailand
4	Mr. Kampanat Dokmai	Royal Forest Department	ITTO-Project Staff	Thailand
5	Mr. Thanakorn Keeratiphakhawat	Royal Forest Department	Assistance Project Coordinator	Thailand
6	Mr. Thaned Boukaeo	Royal Forest Department	ITTO-Project Staff	Thailand
7	Mr. Kamol Wisupakan	ITTO-Project	Project Manager	Thailand
8	Ms. Niranrat Pom-im	Royal Forest Department		Thailand
9	Ms.Varangkhana Tophila	ITTO-Project	Project Support Staff	Thailand
10	Mr. Wichit Jiramongkhonkan	DNP, Regional Office 9, Ubon Ratchathanee	Director, Wildlife Division,	Thailand
11	Mr. Thanon Sopitcha	DNP, Regional Office 9, Ubon Ratchathanee	Director, National Park Division,	Thailand
12	Mr. Teerayut Wongpaiseart	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, PhuJong-Nayoi National Park,	Thailand
13	Mr. Somsak Khonthon	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Bunthrik-Yodmon Wildlife Sanctuary,	Thailand
14	Mr. Pramote Ratree	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Yod Dome Widlife Sanctuary,	Thailand
15	Mr. Nakarin Suthatto	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Pha Taem National Park,	Thailand
16	Mr. Verachai Kamlung-ngam	DNP, Regional Office 9, Ubon Ratchathanee	Superintendent, Kang Tana National Park,	Thailand
17	Prof. Dr. Yongyut Trisurat	Faculty of Forestry, Kasetsart University	Project GIS Consultant	Thailand
18	Assoc. Prof. Dr. Naris Bhumpakphan	Faculty of Forestry, Kasetsart University	Project Wildlife Consultant	Thailand
19	Dr. Phonesavanh Thepphasoulithone	Champasak University	Vice President, Champasack University	Lao PDR
20	Mr. Inpeng Duangvongsa	Champasack University	Lecturer	Lao PDR
21	Mr. Bounthavy Vongkhamchanh	Champasack University	Lecturer	Lao PDR
22	Mr. Angkham	Champasack	Lecturer	Lao PDR

No	Name	Institution	Title	Country
	Bouthdala	University Champasack University	Lecturer	Lao PDR
23	Mr. Noun Sokhom	Preah Vihear Cantonment, FA	Deputy Chief,	Cambodia
24	Mr. Mak Panha	Preah Vihear Cantonment, FA	Chief, Choam Ksan Division	Cambodia
25	Mr. Hang Samrith	Preah Vihear Cantonment, FA	Chief, Rovieng Division	Cambodia
26	Mr. Sum Sovatha	Preah Vihear Cantonment, FA	Deputy Chief, Rovieng Division	Cambodia
27	Mr. Vong Viseth	Preah Vihear Cantonment, FA	Deputy Chief, Chheb Division	Cambodia
28	Mr. Lonh Ponnarith	Preah Vihear Cantonment, FA	Deputy Chief, Tbeng Meanchay Division	Cambodia
29	Mr. Yim Bunthet	Preah Vihear Cantonment, FA	Deputy Chief, Rovieng Triage	Cambodia
30	Mr. Houch Sreann	Preah Vihear Cantonment, FA	Staff	Cambodia
31	Mr. Chheang Dany	ITTO-Project	Project Manager	Cambodia
32	Dr. Dennis J. Cengel	ITTO-Project	Project Technical Advisor	USA
33	Ms. Lim Sopheap	ITTO-Project	Project Admin and Accountant	Cambodia
34	Mr. Kim Sobon	ITTO-Project	Project Site Manager, Forest land Use Planning Specialist	Cambodia
35	Mr. Pang Phanit	ITTO-Project	Forest and Biodiversity Conservation Officer	Cambodia
36	Mr. Say Sinly	ITTO-Project	Field Assistant for Forest Land Use Planning	Cambodia
37	Mr. Pheng Sophak	ITTO-Project	Community Livelihood Development Officer	Cambodia
38	Mr. Chou Chandararith	Pailin Cantonment, FA	Acting Deputy Chief	Cambodia
39	Mr. Nop Chhaya	Oddar Meanchey Cantonment, FA	Deputy Chief of Bantey Ampil Divisionl	Cambodia
40	Mr. Im Saovorith	Oddar Meanchey Cantonment, FA	Deputy Chief, Samrong Division	Cambodia
41	Mr. You Viy	Svay Reang Cantonment, FA	Chief, Svay Reang Division	Cambodia

Box 1 Some photos showing the 1st GIS training activities

Registration

Lecture by Mr. Wichit Jiramongkolgran

Lectured by Prof. Dr. Yongyut Trisurat

Group exercise

Field check

Field check

Awarding training certificate

Group photo

Box 2 Some photos showing the 2nd GIS training activities

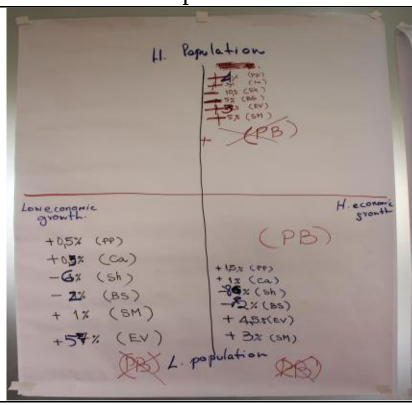
Opening session

Group photo in front of training venue

Lectured by Prof. Dr. Yongyut Trisurat

Group exercise

Presentation of group work



Group work

Box 3 Some photos showing training activities (GIS training III)

Opening session

Group photo

Lectured by Prof. Dr. Yongyut Trisurat

Group exercise

Awarding certificate of participation

Field excursion at Pha Taem National Park

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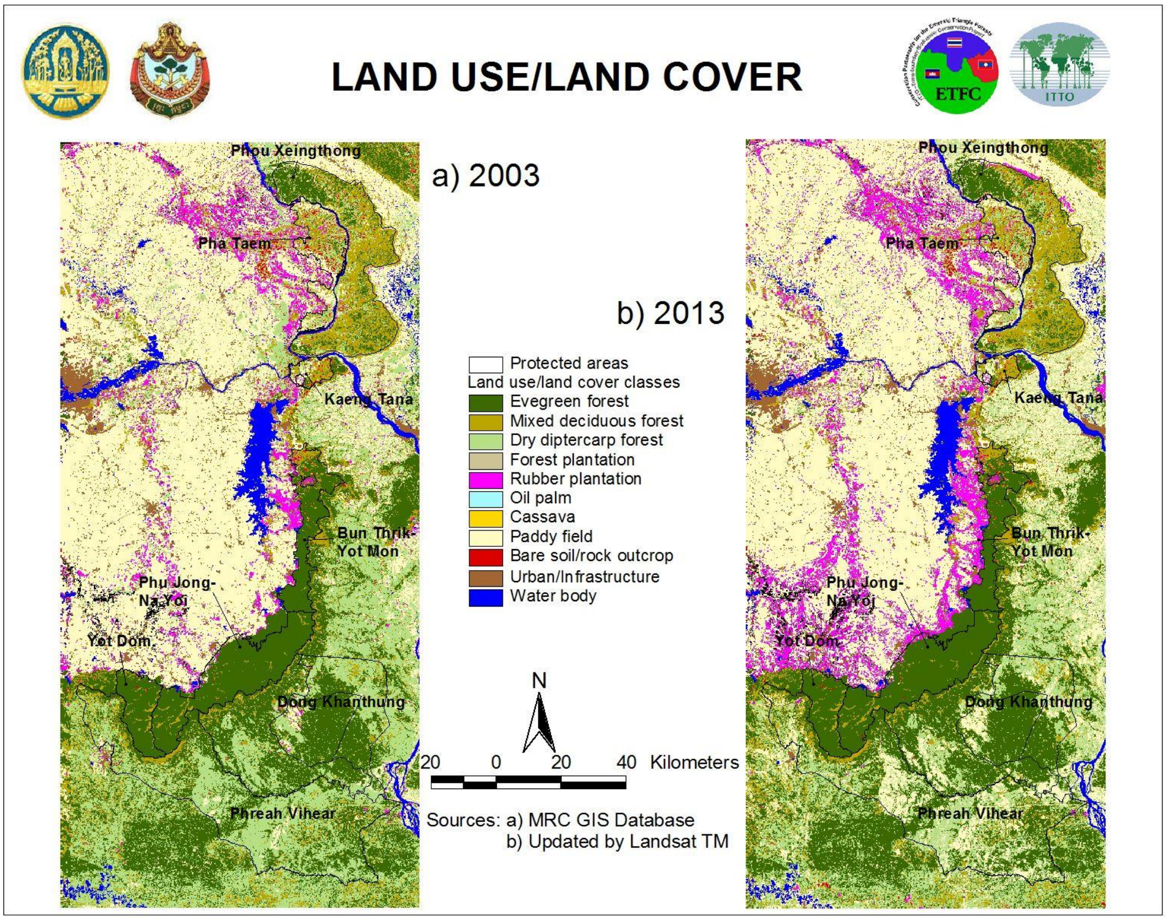

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