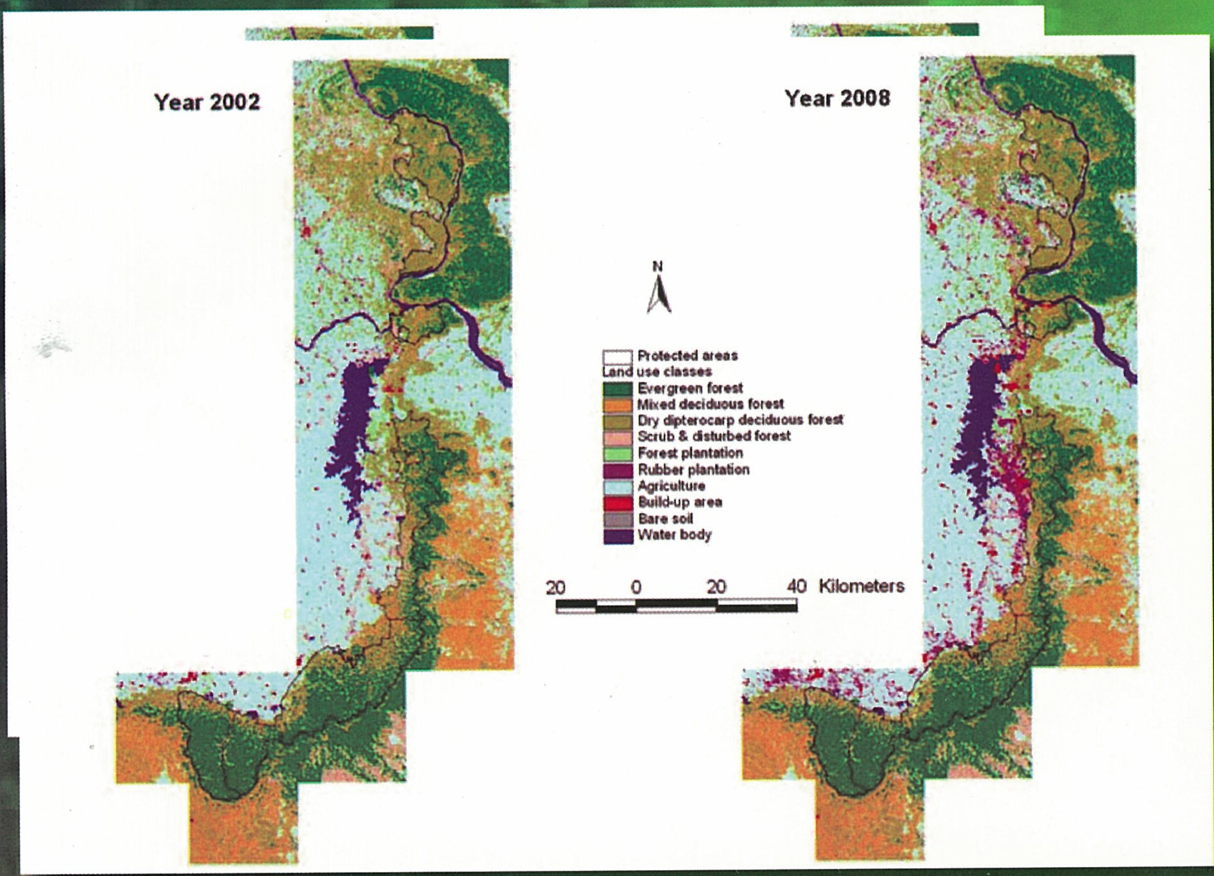
Royal Forest Department

International Tropical Timber Organization

Management of the Emerald Triangle Protected Forest Complex to Promote Cooperation for Transboundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II)

Project PD 289/04 Rev. 1 (F)



GIS Consultant Technical Report

Yongyut Trisurat

Forestry Research Center

Faculty of Forestry

Kasetsart University

May 2010

Royal Forest Department

&

International Tropical Timber Organization

"Management of the Emerald Triangle Protected Forest Complex to Promote Cooperation for Transboundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II)"

PROJECT: PD 289/04 Rev. 1 (F)

Host Government:	**Thailand**
Executing Agency:	**Royal Forest Department**
Project Coordinator:	**Mr. Sunan Arunnopparat**
Starting Date:	**1 March 2008**
Project Duration:	**24 Months**

PROJECT TECHNICAL AND SCIENTIFIC STAFF

(ITTO Project PD 289/04 Rev.1(F)

Mr. Sunan Arunnopparat	Project Director/Coordinator
Mr. Janesak Wichwutipong	Project Deputy Director
Mr. Surasak Louajitseang	Project Deputy Director
Mr. Pichai Eaksiripong	Project Accountant
Mr. Preecha Ongrasert	Project Staff
Miss Vachiraporn Panpinij	Project Staff
Miss Unthira Inthorarak	Project Staff
Miss Wipawee Kaewtan	Project Staff
Mr. Uthai Promnari	Field Project Superintendent
Mr. Direck Sirijongprasert	Field Administration Section
Ms. Wanpen Chanthachot	Field Technical Section
Mr. Veera Amornsakchai	Field Information Section
Mr. Pairat Sukusirajit	Field Conservation Section
Mr. Kamol Wisupakan	Project Manger
Miss Authong Sangnet	Project Secretary

Abbreviations

DDF	:	Deciduous Dipterocarp Forest
DEF	:	Dry Evergreen Forest
DEM	:	Digital Elevation Model
DOLA	:	Department of Local Administration
DNP	:	National Park, Wildlife and Plant Conservation Department
EGAT	:	Electric Generating Authority of Thailand
FIO	:	Forest Industrial Organization
GIS	:	Geographic Information System
GISTDA	:	Geo-informatics and Space Technology Development Agency
GPS	:	Global Positioning System
ITTO	:	International Tropical Timber Organization
IUCN	:	The World Conservation Union
LDD	:	Land Development Department
MDF	:	Mixed Deciduous Forest
NBCA	:	National Biodiversity Conservation Area
NP	:	National Park
PM	:	Project Manager
PPFC	:	Management of the Pha Taem Protected Forest Complex to Promote Cooperation for Transboundary Biodiversity Conservation between Thailand, Cambodia and Laos
RFD	:	Royal Forest Department
ROC	:	Relative Operating Characteristic Method
RPAO	:	Regional Protected Area Management and Administration Office
RTSD	:	Royal Thai Survey Department
SD	:	Standard deviation
TA	:	Technical Advisor
TBCA	:	Transboundary Conservation Area
TOR	:	Terms of Reference
UNESCO	:	The United Nations Educational, Scientific and Cultural Organization
UTM	:	Universal Transverse Mercator
WS	:	Wildlife Sanctuary

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Acknowledgements

The GIS consultant is grateful to the ITTO for funding the Emerald Triangle Protected Forests Complex Project (PD 289/04 Rev.1 (F)) and to the Royal Forest Department for allowing the Faculty of Forestry, Kasetsart University to join the challenge in initiating transboundary biodiversity conservation in this region.

The GIS consultant thanks the Project Director (Mr. Sunnan Arunnopparat), Project Deputy Directors (Mr. Janesak Wichawutipong and Mr. Surasak Louajitseang), and Project Manager (Mr. Kamol Wisupakan) for their encouragement and support in the development of GIS database and training. The GIS consultant also would like to thank the Superintendents and staffs of the Pha Taem National Park, Kaeng Tana National Park, Phu Jong-Na Yoi National Park, Dom Wildlife Sanctuary and Bun Thrik-Yot Mon Proposed Wildlife Sanctuary for providing secondary data to be input in GIS database. Contributions were also made by the Royal Thai Survey Department, Land Development Department, Regional Protected Area Management and Administration Office (Ubon Ratchathani), and Wildlife Ecology Consultant.

The GIS consultant extends sincere thanks to the project staff of the project as follows: Mr. Pichai Eaksiripong, Mr. Preecha Ongrasert, Miss Vachiraporn Panpinij, Miss Unthira Inthorarak and Ms. Wipawee Kaewtan for their reviews and constructive comments on a series of reports submitted to the Royal Forest Department. Special thanks go to Mr. Uthai Promnari, Superintendent of Pha Taem National Park and Project Field Office, and Miss. Authong Sangnet, Project Secretary, for their arrangement in a series of field works and training sessions.

The GIS consultant thank Dr. Damrong Sripraram, Dean of the Faculty of Forestry, Dr. Nikhom Laemsak, Director of the Forestry Research Center, and Assoc. Prof. Dr. Naris Bhumpakphan, Head of Forest Biology Department of the Faculty of Forestry, Kasetsart University for permitting the GIS consultant to conduct this challenging and important assignment. Special recognition is given to Mr. Palle Havmoller for editing the final report.

EXECUTIVE SUMMARY

After completion of the Pha Taem Protected Forests Complex Project Phase I, the Royal Forest Department (RFD) of Thailand and Forestry Administration (FA) of Cambodian jointly developed the Project Phase II Proposal and modified project name to "*Management of the Emerald Triangle protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II)*" because the project scope has extended the implementation to cover protected forests in Cambodia and possibly Laos. The project phase II (PD 289/04 Rev.1 (F) was approved by ITTO co-financed through that organization by Japan, Switzerland and USA for two years (2008-2009). It built on the achievements of project phase I and resolved some pending issues.

The overall objective was to conserve trans-boundary biodiversity in the Emerald Triangle and its specific objectives were 1) to strengthen existing cooperation among the three countries, 2) to enhance protection of biological resources along the tri-national borders, and 3) to strengthen the involvement of local communities and stakeholders in sustainable use and management of natural resources in buffer zone.

The RFD had invited the Forestry Research Center of the Faculty of Forestry, Kasetsart University to render professional services assigned to 1) GIS Consultant, 2) Botany Consultant and 3) Forest Ecology Consultant. Based on the contract agreed upon between the RFD and the Research Center, the GIS consultant had an overall responsibility to plan and establish the information management system using GIS technology combining with other database system for management planning, implementation and monitoring of the biodiversity conservation activities at the Project to be the model for transboundary biodiversity conservation. Eight specific duties were assigned to the GIS Consultant.

The approaches and outputs of eight activities were documented into 6 Chapters, namely Chapter 1: Introduction to the Emerald Triangle Protected Forests Complex Project; Chapter 2) Project Area; Chapter 3: Applied Methodology; Chapter 4: Projecting Land Use and Landscape Change; Chapter 5: Consequences of Land Use Change on Wildlife Distribution; and Chapter 6: Conclusions and Recommendations.

Chapter 1: Introduction to the Emerald Triangle Protected Forests Complex Project

Chapter 1 describes the background of trans-boundary conservation in Thailand, key achievements and pending issues of the Management of the Pha Taem Protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase I). 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 II) were also included. At the end roles and responsible of GIS consultant were shown.

Chapter 2: Project Area

Chapter 2 presents physical feature, biological feature and proposed ecological management zones of the project area derived from the project phase I. It is noted that only a few information were presented for Cambodia and Laos because most activities were implemented in Thailand.

The Emerald Triangle Protected Forest Complex landscape comprises of protected areas and adjoining forested landscape across Thailand, Cambodia and Laos. In Thailand, there are three national parks (Pha Taem, Kaeng Tana and Phu Jong-Na Yoi) and two wildlife sanctuaries (Yot Dom and Bun Thrik-Yot Mon), covering 1,736 km^2. Wildlife Sanctuary, These protected areas are clustered and named the Pha Taem Protected Forest Complex. Nearby protected areas in neighboring countries are Phouxeingthong National Biodiversity Conservation Area (NBCA) (1,200 km^2) in Laos situated to the left of Pha Taem, and to the south is the Protected Forest for conservation of Genetic Resources of Plants and Wildlife in Preah Vihear Province (1,900 km^2).

Three main vegetation types, viz. Dry Evergreen Forest, Mixed Deciduous Forest and Deciduous Dipterocarp Forest, and more than 288 tree species have been identified. At least 49 mammal species, 145 bird species, 30 reptile species and 13 amphibian species are found, but large wildlife such as elephant and bear are observed only along the borders. Based on physical and biological features, four ecological management zones were classified for the Pha Taem Complex, namely core zone, buffer zone, corridor and landscape matrix.

Chapter 3: Applied Methodology

The GIS consultant had reviewed the achievements of Project Phase I, Project Phase II document and discussed with the Technical Advisor (TA), Project Manager (PM) and other consultants, as well as protected staff at the beginning of the project in order to identify important threats to trans-boundary biodiversity conservation in the project areas. It was found that forest encroachment was highlighted by stakeholders as the most important threat to trans-boundary biodiversity at present and in the future. Then, the GIS Consultant drew the problem-tree, and also transformed the problem-oriented to encroachment into the "objectives-tree". The eight activities assigned for GIS consultants were grouped into four outputs to resolve encroachment issue, including 1) updated GIS database, 2) trained protected area staff and stakeholders in GIS/GPS, 3) participatory demarcation implemented, and 4) optimized land demand scenario and quantified its consequence on trans-boundary biodiversity.

A copy of GIS database and data dictionary was sent to the Forestry Administration of Cambodia in order to extend lessons learned from the Project Phase I for improvement and standardization of GIS database design and ecological survey methods. In Thailand, more GIS layers (approximately 20 layers) were developed to support expected outputs of the Project Phase II. In addition, all existing map layers (point, line polygon and grid) developed during the Project Phase I using the projected coordinate system of Indian 1975 UTM Zone 48N to the projected coordinate system of WGS 1984 UTM Zone 48N, which is commonly used by all government agencies nowadays. Three training courses on 1) Introduction of GIS and Map Reading, 2) Using GIS/MIST for Effective Patrolling, and 3) Land Use Allocation and Land Use Change for protected area staff and local multi-stakeholder. All together 109 participants from five protected areas in Thailand and local multi-stakeholders were trained. After training, PPFC staff conducted post activities such as participatory demarcation at Ban Pak La, Khong Jium district, and mapping *Diptercarp alatus* using by school teachers and students.

Chapter 4: Projecting Land Use and Landscape Change

This chapter presented the extent of land use classes in 2008 that was visually interpreted from satellite image and land use change during 2002-2008 was detected using GIS. In addition, the GIS consultant used the dyna-CLUE-s model to simulate land use change based on three land demand scenarios in 2030: trend scenario, integrated land use scenario and conservation-oriented land use scenario. The expected forest covers in 2030 for these three scenarios are 37, 40 and 40%, respectively. The remaining forest cover will be found mainly in Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary where accessibility to these areas is difficult. However, forest cover in Kaeng Tana National Park, Bunthrik Yot Mon Wildlife Sanctuary and buffer zone will decline significantly from year 2002.

Chapter 5: Consequences of Land Use Change on Wildlife Distribution

The predicted deforestation would cause negative impacts on wildlife distribution and wildlife hotspots in the Emerald Triangle protected forest complex. Therefore, predicted wildlife distributions and their concentrations in the landscape were simulated using wildlife habitat models developed in the Project Phase I. The results revealed that the likely suitable habitats for eight focal wildlife species in 2030 are predicted relatively less than year 2002. However, they have no significantly different (P=0.05). Suitable habitats and wildlife hotspots are mainly located in western Thailand's protected areas and extend to Laos and Cambodia in both periods. In Thailand, Phu Jong-Na Yoi and Yot Dom are determined as important high to high suitability for all wildlife species because they contain intact forest and limited human disturbances.

Chapter 6: Conclusions and recommendations

Chapter 6 summarized main findings and recommended key points for the effective trans-boundary biodiversity conservation. It is strongly recommended that the GIS center of the regional office in Ubon Ratchathani province should host and maintain GIS database of the PPFC and works as GIS mentors for protected area staff. This is to ensure that the GIS database will be kept in good shape for future uses. List of GIS layers and schedule for updating was also proposed. Finally, the results of predicted wildlife distribution and wildlife hotspots in 2030 clearly show that long-term survival of biodiversity in this region depend on cooperation among three countries to protect intact forest and remaining suitable habitats, especially in Laos and Cambodia. Even though, Thailand's protected areas are more effective than Laos and Cambodia, but they are not large enough to accommodate viable population and ecological processes of target species in the Emerald Triangle.

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สรุปสำหรับผู้บริหาร

หลังจากสิ้นสุดการดำเนินโครงการจัดการผืนป่าอนุรักษ์ผาแต้ม ระยะที่ 1 กรมป่าไม้ ประเทศไทย และกรมบริหารป่าไม้ ประเทศกัมพูชา ได้ร่วมกันจัดทำข้อเสนอโครงการ โดยเปลี่ยนชื่อเป็นโครงการจัดการผืนป่าอนุรักษ์สามเหลี่ยมมรกต เพื่อส่งเสริมการอนุรักษ์ความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศไทย ประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชนลาว (ระยะที่ 2) เนื่องจากมีพื้นที่โครงการครอบคลุมพื้นที่ในประเทศกัมพูชาและลาวด้วย โครงการระยะที่ 2 (PD 289/04 Rev.1 (F) ได้รับการอนุมัติจากองค์การป่าไม้เขตร้อน (ITTO) โดยการสนับสนุงบประมาณร่วมกันระหว่างประเทศญี่ปุ่น ประเทศสวิทเซอร์แลนด์ และประเทศสหรัฐอเมริกา มีระยะดำเนินงาน 2 ปี (2551-2552) โดยมีกิจกรรมต่อเนื่องจากโครงการระยะที่ 1 และแก้ไขปัญหาที่ยังเหลืออยู่

โครงการระยะที่ 2 มีเป้าหมายรวมเพื่อการอนุรักษ์ความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศบริเวณผืนป่าอนุรักษ์สามเหลี่ยมมรกต และมีวัตถุประสงค์เฉพาะ ดังนี้ 1) เพื่อเสริมสร้างความร่วมมือระหว่าง 3 ประเทศในการอนุรักษ์ความหลากหลายทางชีวภาพ 2) เพื่อเพิ่มขีดความสามารถด้านการป้องกันรักษาทรัพยากรชีวภาพ บริเวณพรมแดนของ 3 ประเทศ และ 3) เพื่อเสริมสร้างความร่วมมือของประชาชนในท้องถิ่นและผู้มีส่วนได้-ส่วนเสีย ในการใช้ประโยชน์อย่างยั่งยืนและการจัดการทรัพยากรธรรมชาติในเขตกันชน

กรมป่าไม้ ได้เชิญศูนย์วิจัยป่าไม้ คณะวนศาสตร์ มหาวิทยาลัยเกษตรศาสตร์ จัดหาผู้เชี่ยวชาญในการดำเนินงานโครงการ 3 ด้าน ประกอบด้วย 1) ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ (GIS Consultant) 2) ผู้เชี่ยวชาญด้านพฤกษศาสตร์ (Botany Consultant) และ 3) ผู้เชี่ยวชาญด้านนิเวศวิทยาป่าไม้ (Forest Ecology Consultant) ภายใต้สัญญาที่ตกลงร่วมกันระหว่างกรมป่าไม้และศูนย์วิจัยป่าไม้ ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ มีหน้าที่รับผิดชอบเกี่ยวกับการวางแผนและการจัดทำระบบสารสนเทศภูมิศาสตร์ เพื่อสนับสนุนการวางแผนการจัดการ การดำเนินงานและการติดตามความหลากหลายทางชีวภาพของโครงการฯ ซึ่งสามารถใช้เป็นรูปแบบสำหรับพื้นที่อื่นต่อไป โดยมีกิจกรรมที่ชัดเจนจำนวน 8 กิจกรรม

ผู้เชี่ยวชาญด้านระบบสารสนเทศทางภูมิศาสตร์ ได้กำหนดแนวทางการดำเนินงานกิจกรรมทั้ง 8 กิจกรรมและผลผลิต พร้อมทั้งนำเสนอในรายงานทางวิชาการฉบับนี้ จำนวน 6 บท ประกอบด้วย บทที่ 1 แนะนำโครงการจัดการผืนป่าอนุรักษ์สามเหลี่ยมมรกต บทที่ 2 พื้นที่โครงการ บทที่ 3 วิธีการดำเนินงาน บทที่ 4 การคาดคะเนการเปลี่ยนแปลงการใช้ที่ดินและสภาพภูมิทัศน์ บทที่ 5 ผลกระทบของการเปลี่ยนแปลงการใช้ที่ดินต่อการกระจายของสัตว์ป่า และ บทที่ 6 สรุปและข้อเสนอแนะ

บทที่ 1: แนะนำโครงการจัดการผืนป่าอนุรักษ์สามเหลี่ยมมรกต

บทที่ 1 อธิบายความเป็นมาของการอนุรักษ์ความหลากหลายทางชีวภาพ ข้ามเขตแดนระหว่างประเทศในประเทศไทย ผลที่ได้ที่สำคัญและประเด็นปัญหาที่ยังคงเหลือ จากการดำเนินโครงการจัดการผืนป่าอนุรักษ์ผาแต้ม เพื่อส่งเสริมการอนุรักษ์ความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศไทย ประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชนลาว (ระยะที่ 1) พร้อมทั้งได้กล่าวถึงเป้าหมายรวมและวัตถุประสงค์เฉพาะของโครงการจัดการผืนป่าอนุรักษ์สามเหลี่ยมมรกต เพื่อส่งเสริมการอนุรักษ์ความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศไทย ประเทศกัมพูชาและประเทศสาธารณรัฐประชาธิปไตยประชาชนลาว (ระยะที่ 2) และบทบาท หน้าที่ของผู้เชี่ยวชาญด้านระบบสารสนะทศภูมิศาสตร์ ที่ระบบไว้ในสัญญา.

บทที่ 2 พื้นที่โครงการ

บทที่ 2 นำเสนอข้อมูลด้านกายภาพ ข้อมูลชีวภาพ และเขตการจัดการระบบนิเวศผืนป่าอนุรักษ์ผาแต้ม ที่ได้รับจากการดำเนินโครงการฯระยะที่ 1 ข้อมูลในประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชานลาวมีเล็กน้อย เนื่องจากกิจกรรมส่วมากดำเนินในประเทศไทย

ผืนป่าอนุรักษ์สามเหลี่ยมมรกต ครอบคลุมพื้นที่อนุรักษ์และพื้นที่ป่าใกล้เคียงในประเทศไทย ประเทศกัมพูชา และสาธารณรัฐประชาธิปไตยประชาชนลาว ในประเทศไทย มีพื้นที่อุทยานแห่งชาติ 3 แห่ง (ผาแต้ม แก่งตะนะ และภูจองนายอย) และ เขตรักษาพันธุ์สัตว์ป่า 2 แห่ง (ยอดโดมและบุณฑริก-ยอดมน) มีพื้นที่รวมประมาณ 1,736 กม^2 พื้นที่ทั้งหมดรียกว่าผืนป่าอนุรักษ์ผาแต้ม ทางทิศตะวันออกติดต่อกับ Phouxeingthong National Biodiversity Conservation Area (NBCA) (1,200 กม^2) ซึ่งตั้งอยู่ปสาธารณรัฐประชาธิปไตยประชาชนลาว และทางทิศใต้ติดต่อกับ Protected Forest for conservation of Genetic Resources of Plants and Wildlife in Preah Vihear Province (1,900 กม^2) ของประเทศกัมพูชา

ชนิดป่าเด่นในพื้นที่ 3 ชนิด ได้แก่ ป่าดิบแล้ง ป่าเบญจพรรณ และป่าเต็งรัง และพบพรรณไม้มากกว่า 288 ชนิด จากการสำรวจพบสัตว์เลี้ยงลูกด้วยน้ำนม 49 ชนิด นก 145 ชนิด สัตว์เลื้อยคลาน 30 ชนิด และสัตว์สะเทินน้ำสะเทินบก 13 ชนิด แต่สัตว์ป่าขนาดใหญ่เช่น ช้าง หมี พบเฉพาะบริณแนวพรมแดนประเทศเท่านั้น จากข้อมูลด้านกายภาพและข้อมูลด้านชีวภาพ พื้นที่โครงการฯ แบ่งออกเป็น 4 เขตการจัดการนิเวศ ประกอบด้วย เขตแกนกลาง เขตกันชน เขตเชื่อมต่อ และพื้นที่รอบนอก

บทที่ 3 วิธีการดำเนินงาน

ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ ได้ทบทวนผลงานของโครงการฯ ระยะที่ 1 รายละเอียดโครงการฯ ระยะที่ 2 และปรึกษากับที่ปรึกษาด้านวิชาการของโครงการ ผู้จัดการโครงการ

และเจ้าที่อุทยานแห่งชาติและเขตรักษาพันธุ์สัตว์ป่าในพื้นที่โครงการ เพื่อระบุภัยคุกคามที่สำคัญต่อความหลากหลายทางชีวภาพ ผลการดำเนินงานพบว่า การบุกรุกพื้นที่เพื่อการเกษตรเป็นภัยคุกคามที่สำคัญและส่งผลกระทบต่อการอนุรักษ์ความหลากหลายทางชีวภาพบริเวณพื้นที่โครงการมากที่สุด ทั้งในปัจจับันและอนาคต ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ ได้เขียน "ต้นไม้ของปัญหา (problem-tree)" เพื่อให้เห็นความเชื่อมโยงระหว่างสาเหตุและผลของการบุกรุกพื้นที่ พร้อมทั้งแปลงถ้อยความดังกล่าวเป็น "ต้นไม้ของวัตถุประสงค์ (objectives-tree)" และแบ่งกลุ่มกิจกรรมที่ได้รับมอบหมายและผลผลิต เพื่อตอบสนองต่อปัญหาการบุกรุกพื้นที่ เป็น 4 ด้าน คือ 1) การปรับปรุงฐานข้อมูลระบบสารสนเทศภูมิศาสตร์ (GIS) ให้ทันสมัย 2) การฝึกอบรมเจ้าหน้าที่จากพื้นที่อนุรักษ์และผู้มีส่วนได้-ส่วนเสีย ด้านระบบสารสนเทศภูมิศาสตร์และการกำหนดค่าพิกัดทางภูมิศาสตร์โดยดาวเทียว (GIS/GPS) 3) การรังวัดหมายแนวเขตโดยกระบวนการมีส่วนร่วม และ 4) การกำหนดทางเลือกความต้องการใช้ที่ดินที่เหมาะสมและประเมินผลกระทบต่อความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศ .

ในระหวางการดำเนินงานโครงการฯ ระยะที่ 2 และผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ ได้มอบฐานข้อมูลระบบสารสนเทศภูมิศาสตร์และพจนานุกรมฐานข้อมูล ให้กับกรมบริหารป่าไม้ ประเทศกัมพูชา เพื่อใช้เป็นแนวทางในจัดทำฐานข้อมูลระบบสารสนเทศภูมิศาสตร์ให้เป็นมาตรฐานเดียวกัน และใช้ในการสำรวจข้อมูลทางนิเวศวิทยา ในประเทศไทย ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ ได้ดำเนินการจัดทำชั้นข้อมูลระบบสารสนเทศทางภูมิศาสตร์ เพิ่มเติมประมาณ 20 ชั้นข้อมูล เพื่อสนับสนุนการดำเนินโครงการฯ ในระยะที่ 2 และชั้นข้อมูลระบบสารสนเทศทางภูมิศาสตร์ ที่ได้จัดทำไว้ในโครงการฯ ระยะที่ 1 ทั้งหมด (ข้อมูลจุด ข้อมูลเส้น ข้อมูลพื้นที่ และตารางกริด) โดยใช้ระบบค่าพิกัด Indian 1975 UTM Zone 48N ได้เปลี่ยนเป็นระบบค่าพิกัด WGS 1984 UTM Zone 48N ตามระบบแผนที่ใหม่ที่ใช้อยู่ในปัจจุบัน นอกจากนี้ ได้ดำเนินการฝึกอบรมเชิงปฏิบัติเพื่อให้ความรูช้แก่เจ้าหน้าที่พื้นที่อนุรักษ์และผู้มีส่วนได้-ส่วนเสีย รวม 3 หลักสูตร ประกอบด้วย หลักสูตรที่ 1 เรื่องความรู้เบื้องต้นระบบสารสนเทศภูมิศาสตร์และการอ่านแผนที่ หลักสูตรที่ 2 เรื่อง การใช้ระบบ GIS และ MIST เพื่อสนับสนุนการลาดตระเวนที่มีประสิทธิภาพ และหลักสูตรที่ 3 เรื่อง การจำลองการจัดสรรที่ดินและการเปลี่ยนแปลงการใช้ที่ดิน โดยมีผู้ผ่านการฝึกอบรม รวมทั้งสิ้น 109 คน หลังการฝึกอบรม เจ้าหน้าที่โครงการฯ ร่วมกับเจ้าหน้าที่อุทยานแห่งชาติ เขตรักษาพันธุ์สัตว์ป่าในพี้ที่โครงการฯ ได้ดำเนินกิจกรรมที่ต่อเนื่องหลายกิจกรรม เช่น การรังหวัดหมายแนวเขตโดยกระบวนการมีส่วนร่วมที่บ้านปากลา อำเภอโขงเจียม การสำรวจไม้ยาง โดยคณะครูและนักรียน เป็นต้น

บทที่ 4 การคาดคะเนการเปลี่ยนแปลงการใช้ที่ดินและสภาพภูมิทัศน์

เนื้อหาบทนี้ นำเสนอแผนที่การใช้ที่ดิน ปี พ.ศ. 2551 ซึ่งได้จากการแปลภาพถ่ายดาวเทียมโดยสายตา และประเมินการเปลี่ยนแปลงการใช้ที่ดินระหว่างปี พ.ศ. 2545-2551 โดยใช้ระบบสารสนเทศภูมิศาสตร์ นอกจากนี้ ผู้เชี่ยวชาญระบบสารสนเทศภูมิศาสตร์ ได้ใช้แบบจำลอง dyna-CLUEs คาดคะเน

การเปลี่ยนแปลงการใช้ที่ดินในปี พ.ศ. 2573 (ค.ศ. 2030) ภายใต้ความต้องการใช้ที่ดิน 3 ทางเลือก ประกอบด้วย 1) แนวโน้มการเปลี่ยนแปลงการใช้ที่ดินในปัจจุบัน 2) การใช้ที่ดินอย่างบูรณาการ และ 3) การใช้ที่ดินแบบอนุรักษ์ ซึ่งจะมีผลให้พื้นที่ป่าธรรมาติในปี พ.ศ. 2573 คงเหลือประมาณ 37, 40 และ 40% ตามลำดับ โดยพื้นที่ป่าคงเหลือจะมีมากในพื้นที่อุทยานแห่งชาติภูจองนายอย เขตรักษาพันธุ์สัตว์ป่ายอดโดม เนื่องจากการเข้าถึงพื้นที่ยาก ส่วนพื้นที่ป่าในอุทยานแหงชาติแก่งตะนะ เขตรักษาพันธุ์สัตว์ป่าบุณฑริก และแนวกันกันลดลงอย่างมาก จากปี พ.ศ. 2545

บทที่ 5 ผลกระทบของการเปลี่ยนแปลงการใช้ที่ดินต่อการกระจายของสัตว์ป่า

การบุกรุกพื้นที่ป่าในอนาคต คาดว่าจะส่งผลกระทบในทางลบต่อการกระจายของสัตว์ป่า และพื้นที่ที่มีสัตว์ป่าชุกชุม ในบริเวณผืนป่าอนุรักษ์สามเหลี่ยมมรกรต ดังนั้น ผู้เชี่ยวชาญด้านระบบสารสนเทศทางภูมิศาสตร์ ได้ใช้แบบจำลองการกระจายของสัตว์ป่า ซึ่งพัฒนาจากโครงการระยะที่ 1 มาประเมินพื้นที่กระจายของสัตว์ป่าและพื้นที่ที่มีสัตว์ป่าชุกชุม ผลการวิเคราะห์ข้อมูลพบว่า ขนาดพื้นที่ถิ่นที่อยู่อาศัยที่เหมาะสมของสัตว์ป่าที่สำคัญ 8 ชนิด ในปี พ.ศ. 2557 มีพื้นที่ลดลงเล็กน้อย แต่ไม่แตกต่างกับปี พ.ศ. 2545 อย่างมีนัยสำคัญทางสถิติ ที่ระดับนัยสำคัญ 0.005 ถิ่นที่อยู่อาศัยที่เหมาะสมของสัตว์ป่าและพื้นที่ที่มีสัตว์ป่าชุกชุม พบมากทางทิศตะวันตกของผืนป่าอนุรักษ์ผาแต้ม ติดต่อกับพื้นที่ป่าในประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชนลาว ทั้งในปี พ.ศ. 2545 และ พ.ศ. 2573 ในประเทศไทยอุทยานแห่งชาติภูจองนายอย และเขตรักษาพันธุ์สัตว์ป่ายอดโดม เป็นพื้นที่ที่มีสัตว์ป่าชุกชุม เนื่องจากยังมีป่าที่สมบูรณ์และถูกรบกวนจากคนน้อย

บทที่ 6 สรุปและข้อเสนอแนะ

บทที่ 6 สรุปผลที่ได้รับและข้อเสนอแนะที่สำคัญที่ได้รับจากการดำเนินโครงการ เพื่อการอนุรักษ์ความหลากหลายทางชีวภาพข้ามเขตแดนระหว่างประเทศอย่างมีประสิทธิภาพ ผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์ แนะนำให้ศูนย์ข้อมูลระบบสารสนแทศภูมิศาสตร์ สำนักงานบริหารพื้นที่อนุรักษ์ (อุบลราชธานี) ทำหน้าที่จัดเก็บและปรับปรุงฐานข้อมูลระบบสารสนเทศทางภูมิศาสตร์ และทำหน้าที่เป็นพี่เลี้ยงให้กับเจ้าหน้าที่อุทยานแห่งชาติและเขตรักษาพันธุ์สัตว์ป่าในพื้นที่ศึกษา ทั้งนี้ เพื่อใหม่นใจว่าข้อมูลทั้งมหดที่ได้จัดทำภายใต้โครงการฯ จะได้รับการดูแลรักษาอย่างดีอละพร้อมใช้งานในอนาคต รายชื่อชั้นข้อมูลและระยะเวลาในการปรับปรุงข้อมูลให้ทันสมัยได้นำเสนอในรายงาน ผลของการวิเคราะห์การกระจายของสัตว์ป่าและพื้นที่ที่มีสัตว์ป่าชุกชุมในอนาคต ชี้ให้เห็นชัดเจนว่าความคงอยู่ของความหลากหลายทางชีวภาพในระยะยาวของพื้นที่นี้ ขึ้นอยู่กับความร่วมมือของ 3 ประเทศ ในการป้องกันป่าสมบูรณ์คงเหลือและถิ่นที่อยู่อาศัยของสัตว์ป่าที่เหมาะสม โดยเฉพาะในพื้นที่ประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชนลาว ถึงแม้ว่า ประเทศไทยมีระบบการจัดการพื้นที่ป่าอนุรักษ์ที่มีประสิทธิภาพมากกว่าประเทศกัมพูชาและสาธารณรัฐประชาธิปไตยประชาชนลาว แต่ขนาดของพื้นที่ป่า

อนุรักษ์ในประเทศไทย มีขนาดเล็กไม่เพียงพอต่อการรองรับจำนวนขนาดของสัตว์ป่าเหมาะสมและกระบวนการทางนิเวศในการรักษาความหลากหลายทางชีวภาพ ของผืนป่าอนุรักษ์สามเหลี่ยมมรกต

ดร. ยงยุทธ ไตรสุรัตน์
รองศาสตราจารย์ และผู้เชี่ยวชาญด้านระบบสารสนเทศภูมิศาสตร์
คณะวนศาสตร์ มหาวิทยาลัยเกษตรศาสตร์

I. INTRODUCTION OF THE EMMERALD TRIANGLE PROJECT

1.1 Background

Khao Yai National Park was established as the country's first national park in Thailand in 1962. More than 280 protected area units have been established as national parks and wildlife sanctuaries, covering approximately 18% of the country's terrestrial area (Trisurat, 2007) and exceeding the global target of 10% recommended by The World Conservation Union (IUCN). These protected areas can be grouped into 19 complexes and four complexes are linked with neighboring countries, including Western Forest complex to the west, and Kaeng Krachan to the west, Halabala to the south and Pha Taem to the east. Within these protected areas, there are several landscape wildlife species, categorized in rare and endangered status within their habitats shared with neighboring countries. For instance, the Southeastern Indochina Dry Evergreen Forests ecoregion occurs in a broad band across northern and central Thailand into Laos, Cambodia, and Vietnam, covering approximately 124,300 km^2. The ecoregion is globally outstanding for the large vertebrate fauna it harbors within large intact landscapes. Among the impressive large vertebrates are the Asian elephant, and tiger. The list includes the second known population of the critically endangered Javan rhinoceros, Eld's deer, banteng, gaur, clouded leopard, etc. About two-third of the original forest of this ecoregion has been cleared or seriously degraded (Wikramanayake *et al.*, 2000). A few large forest blocks also remain in Thailand and Laos.

Recent years have seen an increasing interest in the creation of trans-boundary protected areas for more effective management of politically fragmented ecosystems. With the financial assistance from the International Tropical Timber Organization (ITTO), the Royal Forest Department (RFD) of Thailand initiated a project on the "*Management of the Pha Taem Protected Forests Complex to Promote Cooperation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (PPFC) Phase I*" as a pilot project (project PD 15/00 Rev.2 (F)) because of an increasing pressure on biodiversity from trade in plants and animals across the border with Cambodia and Laos (RFD/ITTO, 2000). The objectives of the project phase I (2001-

2004) were to strengthen the management of the PPFC and to initiate cooperation in trans-boundary biodiversity conservation among the three countries. Specific objectives involved establishing an effective organization and management system and Geographic Information System (GIS) database (Trisurat, 2004), and the commencement of a cooperative process between the three countries. It is noted that most activities in phase I were largely undertaken in Thailand.

After completion of the PPFC Project Phase I, the RFD of Thailand and Forestry Administration (FA) of Cambodia jointly developed the Project Phase II Proposal and modified the project name to "*Management of the Emerald Triangle protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II)*" because it has extended the implementation to cover protected forests in Cambodia and possibly Laos. The Project Phase II [PD 289/04 Rev.1 (F)] was for two years (2008-2009) and it built on the achievements of project phase I and resolved some pending issues. It was co-financed through the ITTO organization by Japan, Switzerland and USA (Trisurat, 2006).

1.2 Project Objectives

The target condition in the *Emerald Triangle* or adjoining forest areas along the tri-national borders is trans-boundary biodiversity. This condition can be described in terms of wild animal population and secured trans-boundary ecosystems. Therefore, it is essential to reinforce this landscape conservation initiative and implement biodiversity conservation activities through the involvement of local residents in the buffer zone because protected areas alone are not sufficient to conserve biodiversity or sustain the ecosystem services that human life depends on (Sandwith *et al.*, 2001; Gasana *et al.*, 2003). The overall objective is thus to conserve trans-boundary biodiversity in the Emerald Triangle and the specific objectives are:

1) To strengthen existing cooperation among the three countries,
2) To enhance protection of biological resources along the tri-national borders, and

3) To strengthen the involvement of local communities and stakeholders in sustainable use and management of natural resources in the buffer zone.

1.3 Role Statement of the GIS Consultant

The Royal Forest Department had invited the Forestry Research Center of the Faculty of Forestry, Kasetsart University to render professional services assigned to 1) GIS Consultant, 2) Botany Consultant and 3) Forest Ecology Consultant.

Based on the contract agreed upon between the RFD and the Forestry Research Center, the GIS consultant had an overall responsibility to plan and establish the information management system using GIS technology combined with other database systems. The purpose of these systems was for management planning, implementation and monitoring of the biodiversity conservation activities at the project and to be the model for Trans – boundary biodiversity conservation. The consultant worked with project technical staff and other scientists under the supervision of Technical Advisor (TA) and Project Manager (PM) to develop the system and program for biodiversity information management and to accomplish various tasks needed in the Project. Specific duties of the GIS Consultant, outlined in the Term of Reference (TOR), are as follows:

1) Work with the project team and other consultants to develop as additional GIS database as required.
2) Continue updating the data.
3) Work with GIS consultants in Cambodia and Laos to ensure that both countries develop GIS using standardized design.
4) Propose mechanism and guideline for data sharing among the three countries.
5) Conduct GIS/GPS training for PA staff.
6) Assist in the site demarcation of selected communities.
7) Prepare and implement public information systems on PPFC.
8) Analyze results and prepare reports as specified in the designed schedule.

II. PROJECT AREA

2.1 Physical Features

The Emerald Triangle Protected Forest Complex landscape comprises of protected areas and adjoining forested landscape across Thailand, Cambodia and Laos. Protected area complex in Thailand is named the Pha Taem Forest Complex. It is located between latitude 14° 12.5′- 15° 13.9′ N and longitude 104° 58.5′- 105° 8.5′ E in Northeast Thailand. This protected area complex is comprised of Pha Taem National Park, Kaeng Tana National Park, Phu Jong-Na Yoi National Park and Yot Dom Wildlife Sanctuary, as well as Bun Thrik-Yot Mon, a newly proposed Wildlife Sanctuary (Figure 2.1). Pha Taem is in the north and followed by Kaeng Tana, Bun Thrik-Yot Mon, Phu Jong - Na Yoi and Yot Dom, respectively. Phu Jong - Na Yoi is the largest reserve while the sizes of Pha Taem and Bun Thrik-Yot Mon Proposed Wildlife Sanctuary are quite similar. All together, this complex constitutes 1,736 km^2 and its total perimeter is 730 km. Approximately 317 km or 43% of total border length is adjoining with Laos (298 km or 40.96%) and Cambodia (18 km or 2.5%). The shape of Kaeng Tana and Yot Dom is relatively simple while the shapes of the remaining areas are complex. Currently, 18 ranger stations have been established and eight park officials as well as 350 temporary employees are deployed to safeguard the PPFC (Table 2.1).

Table 2.1 Summary of key features of the Pha Taem Forest Complex

Name	Established 1/	Area (km^2) 2/	Perimeter (km) 2/	Country bound. Km (%) 4/	Shape Index 5/	Ranger Station	Officials 6/
Pha Taem NP	31 Dec 91	353.16	242.67	63.32 (27%)	3.64	5	3/100
Kaeng Tana NP	13 Jun 81	84.62	62.52	29.96 (48%)	1.92	4	2/90
Phu Jong Na Yoi NP	1 Jun 87	697.38	215.88	93.87 (43%)	2.31	4	1/90
Yot Dom WS	11 Oct 77	235.93	88.21	33.21 (37%)	1.62	4	1/60
Bun Thrik-Yot Mon	Proposed	365.86	186.15	96.40 (52%)	2.75	1	1/15
Total		1736.95	730.04 3/	316.76 (43%)		18	8/355

Notes: 1/ Royal Gazette
2/ Calculated by GIS
3/ Excluding shared border
4/ Length of country boundary
5/ Perimeter/2(π x a)
6/ Government Official/temporary employee

The landscape feature of PPFC is flat to undulating terrain. Elevation is ranging from 100 m to 732 m above sea level and the dominant altitude is between 100-400 m. The terrain level in the west and northwest is relatively low and is rising to the east and to the south of the complex, and immediately declines to Mae Khong River. Besides Mae Khong River, Nam Mun River also drains from the west to the east and passes through Kaeng Tana before joining Mae Khong River, while Lam Dom Noi and Lam Dom Yai Streams originating in Phu Jong - Na Yoi and Yot Dom, drain to the north. These rivers and streams are the main water resources for Pak Mun and Sirinthon Hydropowers reservoirs, respectively.

Nearby protected areas in neighboring countries are Phouxeingthong National Biodiversity Conservation Area (NBCA) (120,000 ha) in Laos situated to the left of Pha Taem, and to the south is the Protected Forest for conservation of Genetic Resources of Plants and Wildlife in Preah Vihear Province (190,000 ha) located to the north of Virachey National Park in Cambodia (Galt *et al.*, 2000).

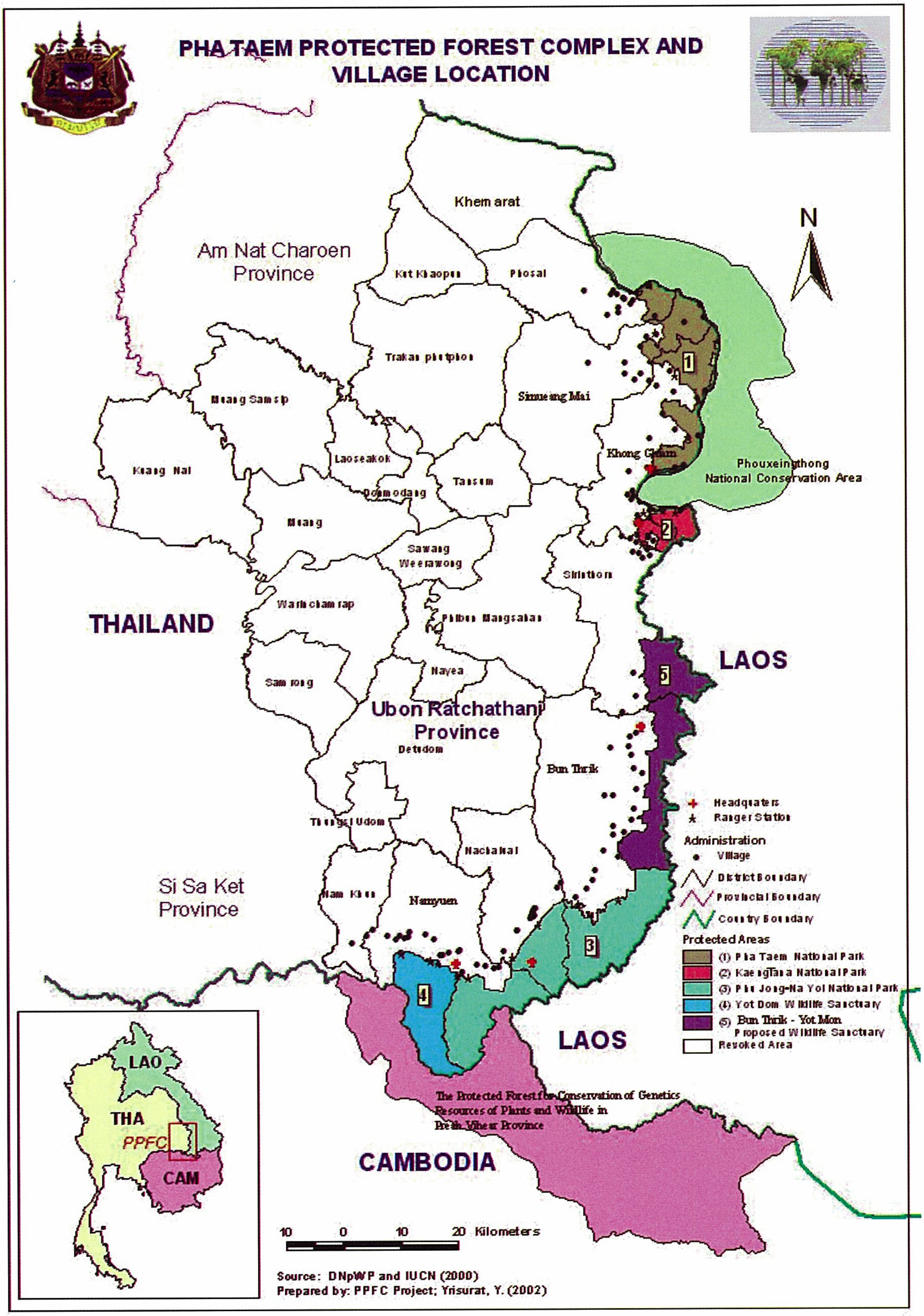
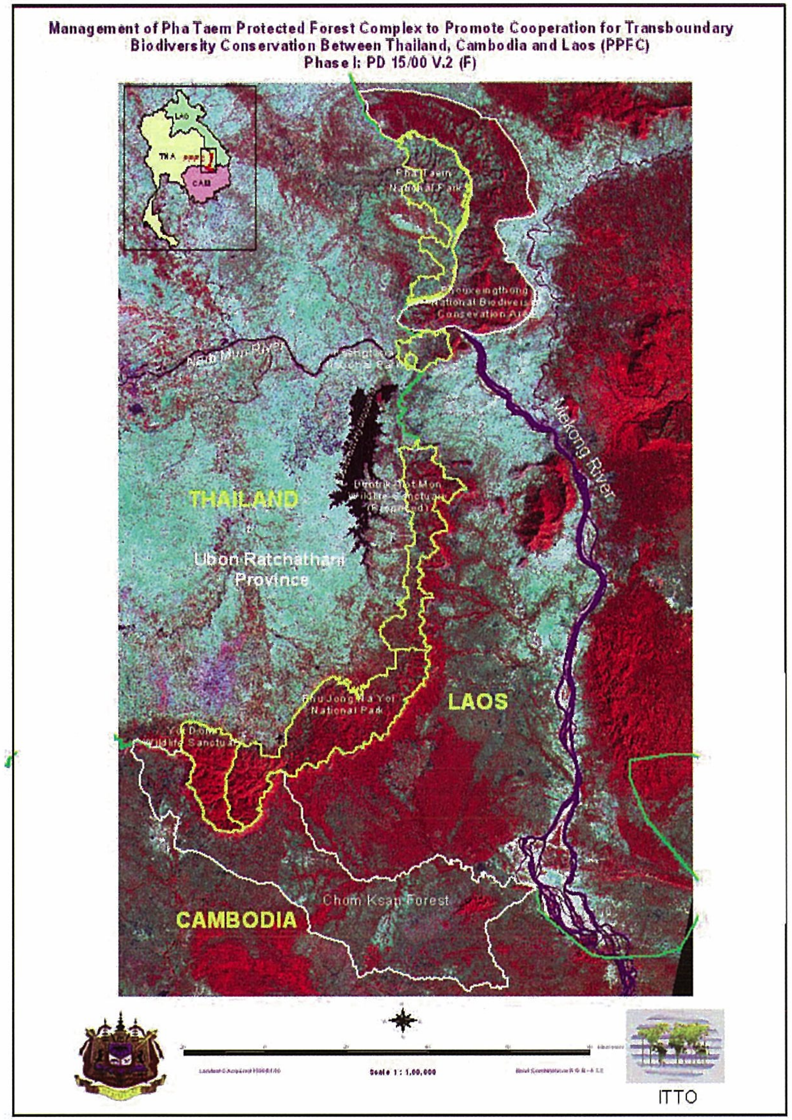


Figure 2.1 Location of Pha Taem Protected Forest Complex and nearby Conservation Areas

2.2 Biological Features

Three main vegetation types were described based on the interpretation of Landsat satellite images in 2002 (Figure 2.2): dry evergreen forest, mixed deciduous forest, and dry dipterocarp forest. More than 288 tree species are identified and at least 49 mammal, 145 bird, 30 reptile and 13 amphibian species are recorded but large wildlife species such as the wild elephant, banteng, freshwater crocodile and tiger are observed only along the tri-national borders (Marod, 2003; Phumpakphan, 2003). Biological features of protected areas in Cambodia and Laos were not assessed during the Project Phase I. However the on-going *UNDP/GEF Medium-size Project for the Northern Plain "Establishing Conservation Areas through Landscape Management" CALM* reveals an abundance of the populations of *Eld's* deer, Surus crane and Giant Ibis inhabiting and breeding in Preah Vihear and areas adjoining Laos (Sonnon, 2003; Chheng, 2004). In addition, detailed assessment of biological features was conducted under the Project Phase II.

During the Project Phase I, eight focal wildlife species were selected to monitor their distributions and habitats using rapid ecological assessment (REA) (Sayer et al., 2000). These species were Asian elephant, leopard, sambar *(Cervus unicolor),* Southern serow (*Naemorhedus sumatraensis*), banteng, Siamese crocodile *(Crocodylia siamensis),* pig-tailed macaque *(Macaca nemestrina),* and Siamese fireback pheasant *(Lophura diardi,* (Bhumpakphan, 2003). In addition, the wildlife habitat modeling and Geographic Information System (GIS) were employed to extrapolate known requirements to the spatial distributions of wildlife habitat factors. Four physical factors and three anthropogenic factors were selected to form the basis of natural wildlife habitats (Patton, 1992). These factors included 1) land use/land cover, 2) accessibility to permanent water, 3) elevation, 4) slope, 5) distance to road, 6) distance to ranger station, and 7) distance to village.



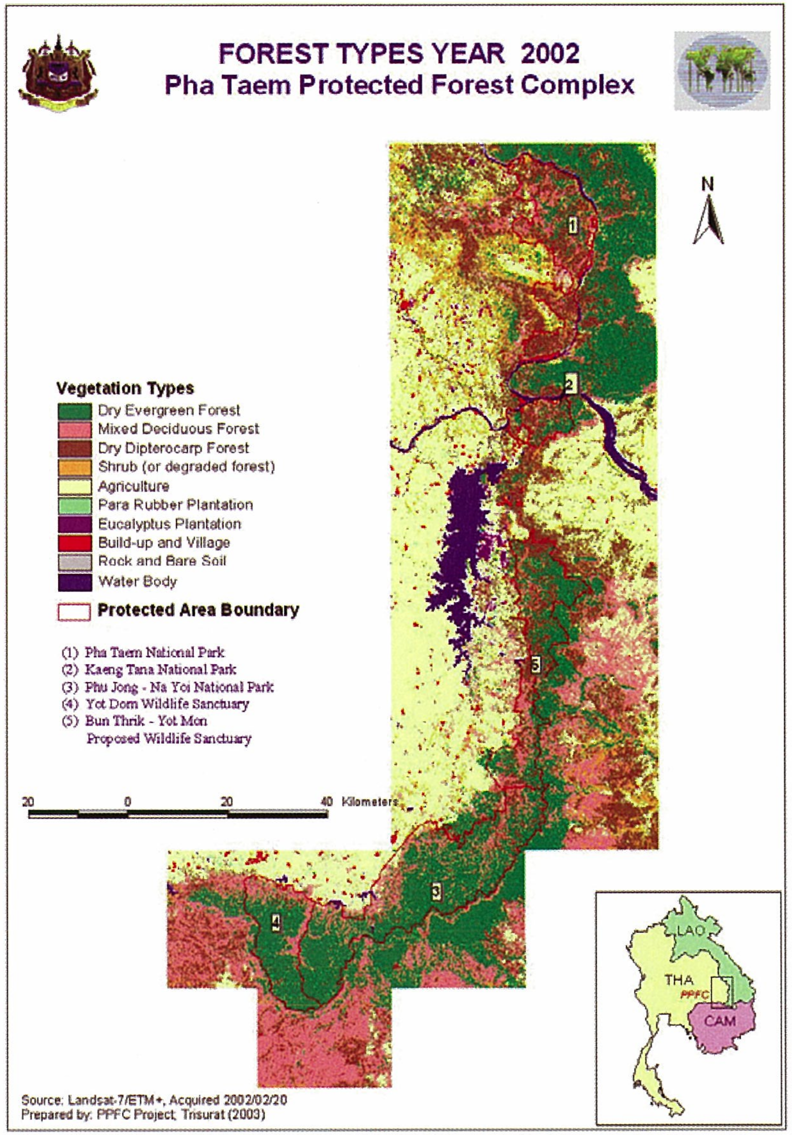
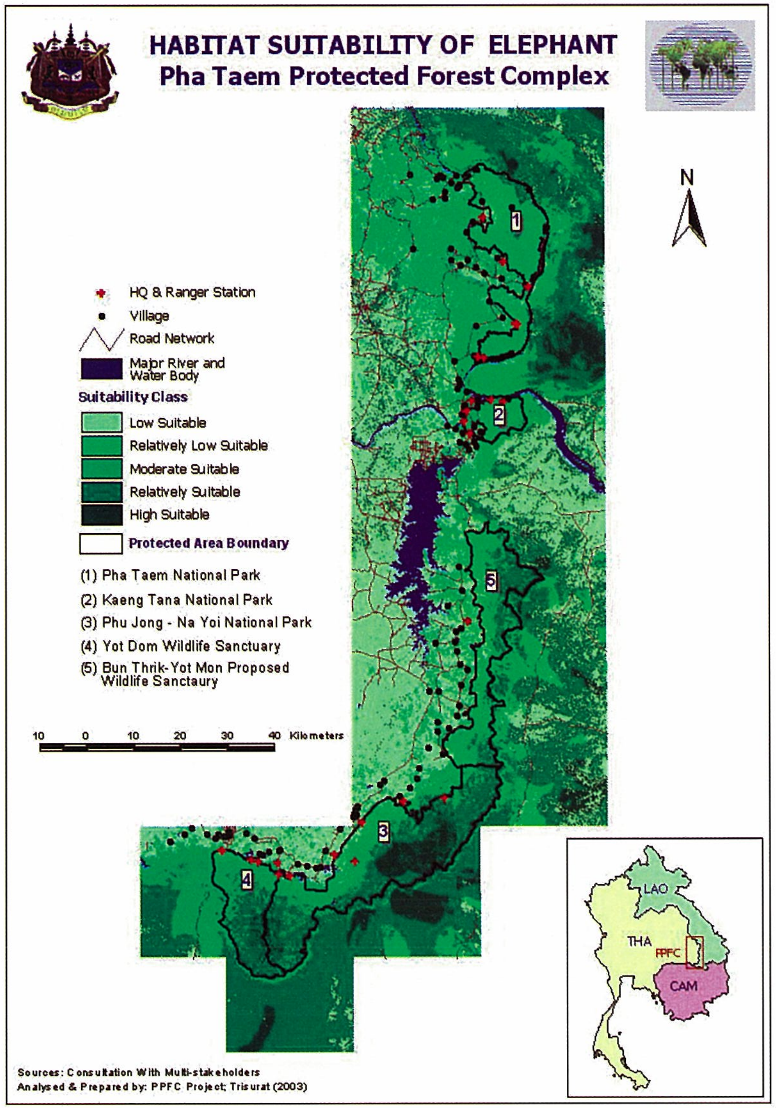


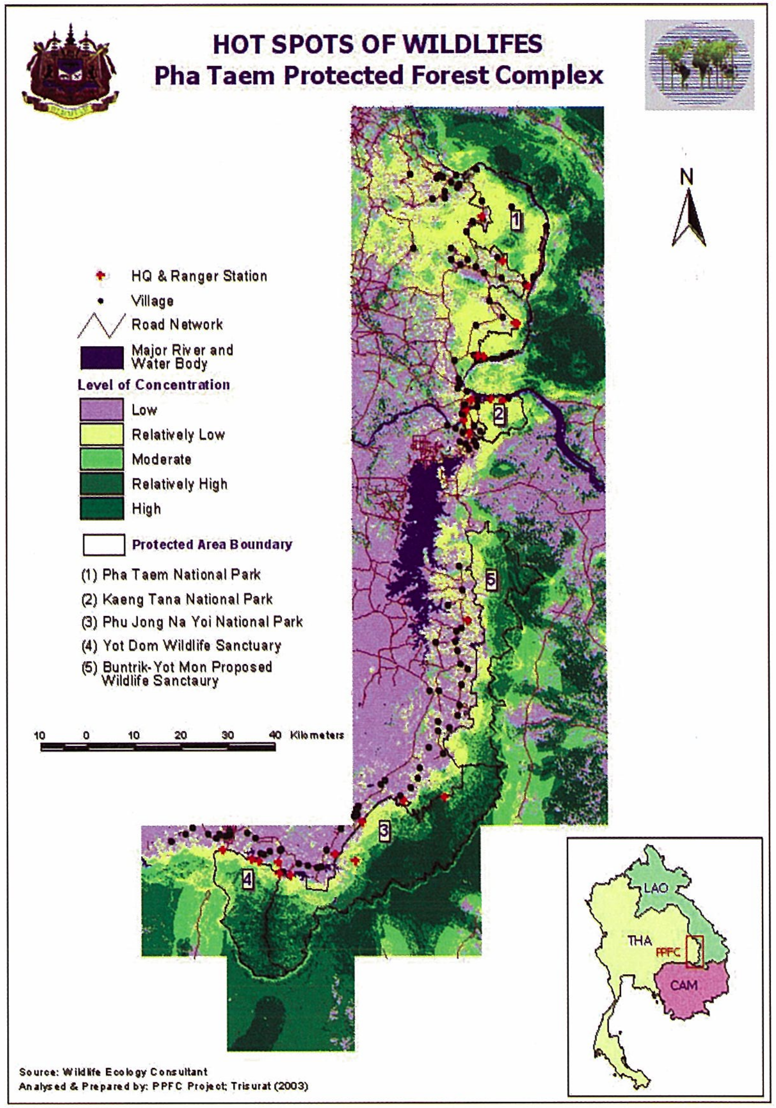
Figure 2.2 Satellite image Landsat -7 ETM^{+} year 2002 and vegetation types

The results of habitat modeling indicated that Phu Jong-Na Yoi and Yot Dom contain relatively high to high suitability for eight wildlife species while Pha Taem and Kaeng Tana provide relatively low suitability. For instance, relatively high to highly suitable habitats of Asian elephant extend along the national borders and in the southern portion of Phouxeingthong NBCA (Figure 2.3a). In these areas, paved roads are few, human settlements are distant and dry evergreen forest is dominant. Habitat suitability of the other wildlife species is similar to Asian elephant. On the other hand, the distributions of domestic cattle and domestic water buffalo are opposite to those of selected wildlife species. Highly suitable habitats are located in human-induced landscape but remote areas, especially in the rugged forests of southern Phu Jong-Na Yoi and Yot Dom, are of relatively low to low suitability for cattle and buffalo.

Overlying suitable habitats of the eight focal wildlife species shows that high concentrations of all species or "*hotspots*" are found along the tri-national borders and clustered in three places. The highest and largest area is located along the western border of Phu Jong-Na Yoi adjoining Laos. The second region is found in Phouxiengthong NBCA in Laos and the third area extends along the northern border of Bun Thrik-Yot Mon. In considering the trans-boundary biodiversity conservation among three countries, the first concentration area is recognized as the most important critical habitat because protected areas in Thailand alone cannot support the survival of these migratory species (Figure 2.3b).



a)



b)

Figure 2.3 Habitat suitability for Asian Elephant (a) and wildlife hotspots (b) in the PPFC landscape

2.3 Ecological Management Zones

The PPFC Project had defined four ecological management zones as the means for trans-boundary biodiversity conservation between Thailand, Cambodia and Laos, namely core zone, buffer zone, corridor and matrix. The management zone of the PPFC includes attention to the border landscape encompassing both the protected areas themselves and the surrounding areas. The zoning concept was modified from the zoning scheme of the UNESCO Biosphere Reserves (Phillips, 1998; Miller and Hamilton, 1999). Four ecological quality factors were selected to define management zone, including critical wildlife habitat, erosion sensitivity index, naturalness and remoteness. The ecological management zones of the PPFC are shown in Figure 2.4 and the descriptions of each zone are as follows.

1) Core zone. This is a natural area with high ecological integrity and is far from disturbances and human settlements. This core area is basically managed for the conservation, and maintenance of biological diversity and the wide range of ecosystem services (Orsdof, 1987). This zone covers approximately 27% of the total PPFC landscape. It is found in Phouxiengthong NBCA and along the southern border joining Thailand, Laos and Cambodia. Considering the five protected areas in Thailand, core area is dominant in the Phu Jong-Na Yoi NP, and Yot Dom WS and moderate in the Bun Thrik-Yot Mon Proposed WS. An integrated joint task force should be established among the three countries to combat encroachment, poaching and illegal logging. In remote areas where accessibility is limited due to landmines, cooperation with military and border patrol police is essential.

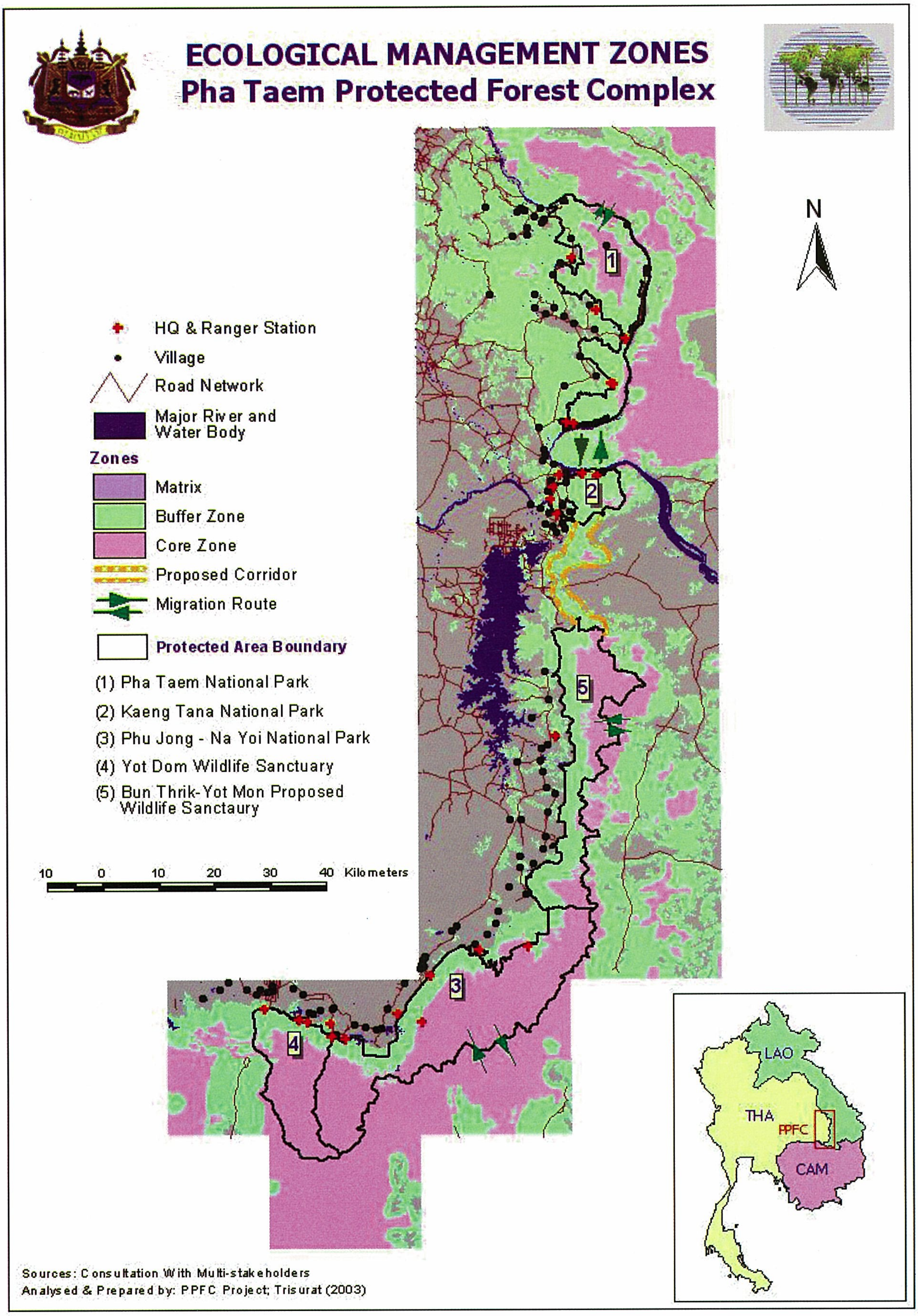


Figure 2.4 Ecological management zones of the Pha Taem Complex

2) Buffer zone. This zone surrounds the core area to manage unfavourable impacts that flow between the core area and its surrounding landscape. The percentage of buffer zone is 37% of the PPFC area. The large patch is situated in the west of Pha Taem NP and to the westward of Bun Thrik-Yot Mon WS in Laos. Approximately 75% of Pha Taem NP and 92% of Kaeng Tana NP is classified as buffer zone of the PPFC complex because these two protected areas contain low suitability habitats for wildlife and most areas are accessed by the local people and used for cattle grazing. In addition, the forested area in Laos situated to the west of Bun Thrik-Yot Mon proposed WS, where commercial logging is practiced, is also defined as buffer zone. Management of a buffer zone aims at promoting training, education and agro-forestry or environmental-friendly activities such as ecotourism. If local communities can benefit from tourism activities, pressure on encroachment and poaching will be greatly reduced.

3) Corridor. It is a linear assemblage of mainly continuous vegetation that connects critical ecosystems to encourage and facilitate migration and dispersal of plant and animal species in fragmented landscapes. The proposed biodiversity corridor covers vegetation remnants along the gap between Kaeng Tana NP and Bun Thrik-Yot Mon WS and is approximately 17 km in length. The project phase I recommends both Thai and Laotian wildlife scientists with local assistance to conduct a rapid wildlife survey and rehabilitate the degraded areas. Besides, the park rangers of the Kaeng Tana NP must regularly patrol the area in the north and raise local awareness on conservation, as well as promote alternative occupations to the local people in order to reduce dependence on forest resources.

4) Landscape matrix. The remaining areas in the PPFC landscape dominated by extensive agriculture and human settlement are classified as landscape matrix. The legal status of this land is either national reserved forest or privately - owned land. Park officials should promote community-based conservation activities that lead to biodiversity-friendly land and water uses such as activities related to ecotourism and para rubber plantation instead of cash crop production. In addition, it is essential to enhance community awareness and their participation in the trans-boundary conservation area (TBCA).

2.4 The Emerald Triangle for Biodiversity Conservation

After completion of the PPFC Project Phase I, the Project faced a number of threats and challenges to its effectiveness and these obstacles should be addressed if the project is to meet its trans-boundary biodiversity conservation and socioeconomic objectives in the second phase (Trisurat, 2003). For biodiversity conservation, the results of PPFC Phase I revealed that protected areas along the border in Thailand face conservation and development challenges due to limited suitable habitat to maintain viable populations of rare large mammal species, and due to forest cover in the buffer zone has been significantly encroached for agriculture. The situation in Laos and Cambodia is substantial different. Even though forest is being degraded in both countries, they still have relative large forests that offer opportunities to minimize habitat fragmentation and maintain intact fauna assemblages. However, both countries face a diversity of threats, for example, poor protected area management, wildlife poaching and trade of animal and plant products.

By extending the project scope from the PPFC to cover protected forests in Cambodia and possibly Laos, the so called Emerald Triangle Protected Forests Complex using the Trans-boundary Conservation Area (TBCA) concept could play an essential role in minimizing such stresses by allowing the coordination of the efforts of the three countries. With such coordination, a joint task force has been created by the three countries to combat illegal activities. In addition, local development initiatives, such as provision of alternative sources of income by domesticating and commercializing local products in the buffer zone for subsistence living and reducing dependency on natural resources, have been implemented. Protected area staffs from Laos and Cambodia will also have opportunities to increase their capacities by participating in a series of training workshops in Thailand, so that, they can effectively manage protected areas to meet the TBCA standards.

III. APPLIED METHODOLOGY

3.1 Justification

The Emerald Triangle Protected Forests Complex project aims to conserve trans-boundary biodiversity across Thailand, Cambodia and Lao PDR in a framework of a trans-boundary biodiversity conservation area. This conservation condition can be described in terms of wild animal population and secured trans-boundary ecosystems. After completion of the PPFC Project Phase I, the Project has faced a number of threats and challenges to its effectiveness and these obstacles should be addressed if the project is to meet its biodiversity, trans-boundary and socioeconomic objectives in the second phase. These problems include moderate international cooperation, continued forest encroachment and poaching, cattle grazing, forest fire, and lack of resources and capacities.

The project phase I has achieves level 2 of 5 of cooperation: i.e. consultation (Sandwith *et al.*, 2001; Trisurat, 2006). This is due to the fact that most activities of the project phase I were been implemented mainly in Thailand; as Cambodia and Laos took less part in the phase I. Forest in the buffer zone outside the PPFC has been encroached for unsustainable agriculture and the results from GIS analysis indicate that future forest-clearing could jeopardize the viability of rare large mammals living in this region (Trisurat, 2007, 2009). In addition, the results from the wildlife survey clearly show that long-term survival of landscape species such as Asian elephant, gaur, banteng and tiger in this region requires better cooperation and commitment between the three countries to conserve trans-boundary biodiversity. This is because these species seasonally migrate across tri-national borders (Bhumpakphan, 2003).

High intensity of cattle grazing in the PPFC is found, especially in Pha Taem and Kaeng Tana National Parks. In addition, cattle owners also burn large tracts of grasslands to promote growth of new pasturage for their animals. Cambodia and Laos both lack the capacity at all levels to manage their protected areas effectively. All protected area staff, including those in Thailand lack capacity to read map and use GPS or have limited ability to read maps. This consequence generates unclear demarcations and stimulates new forest encroachment for agriculture and especially for rubber plantations which have increased significantly in the last 10 years.

The GIS Consultant reviewed the achievements of the project phase I and the project phase II document, and discussed with the Project Manager and other consultants, as well as protected area staff at the beginning of the project in order to identify serious threats to trans-boundary biodiversity conservation in the project areas. The six environmental threats defined in the project phase I (encroachment, land-mines, raising domestic animals (pasture), forest fire, wildlife/log poaching and proposed development projects) still remain, and in addition high land demand for agriculture, especially rubber plantations, unclear demarcation and lack of capacity to use spatial technology (GIS, GPS and map reading) were highlighted as issues by stakeholders in the project phase II. This is because the consequences of these issues are likely to impair the long-term viability of trans-boundary biodiversity conservation in the Emerald Triangle Protected Forests Complex as mentioned in the project document (RFD/ITTO, 2007). Figure 3.1 shows the "Problem-Tree" with the relationship between conservation targets, stresses, sources of stresses, and consequences, and including the "Objective-Tree" with the approach to solve the problems.

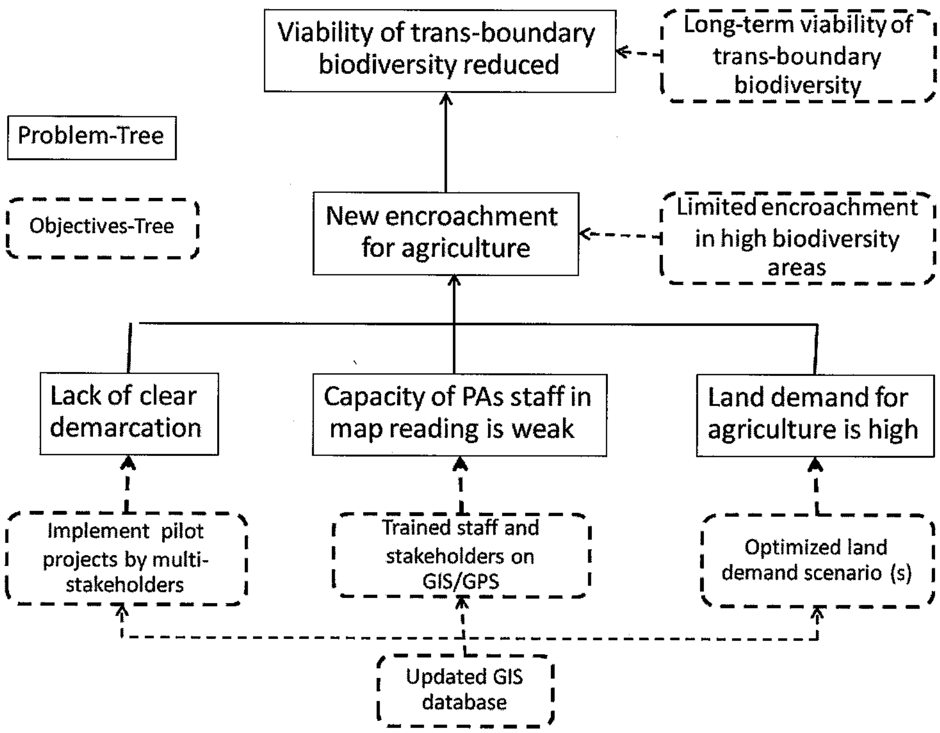


Figure 3.1 Problem-Tree and Objectives-Tree related to the encroachment issue

3.2 Approach

Based on the contract agreed upon between the RFD and the Forestry Research Center, the GIS Consultant had eight specific activities as outlined in the Terms of Reference (TOR) under the Emerald Triangle Protected Forests Complex or PPFC Project Phase II as below:

1) Work with the project team and other consultants to develop an additional GIS database as required.
2) Continue updating the data.
3) Work with GIS Consultants in Cambodia and Laos to ensure that both countries develop GIS using standardized design.
4) Propose mechanism and guideline for data sharing among the three countries.
5) Conduct GIS/GPS training for PA staff.
6) Assist in the site demarcation of selected communities.
7) Prepare and implement public information systems on PPFC.
8) Analyze results and prepare reports as specified in the designed schedule.

According to the problem-tree as discussed in previous section, the GIS Consultant transformed the problem-oriented to the encroachment into the "objectives-tree" describing the desired situation in the future when the encroachment problems would have been resolved through project activities.

The eight activities assigned for GIS Consultant were grouped into four outputs, including 1) updated GIS database, 2) trained protected area staff and stakeholders in GIS/GPS, 3) pilot projects (villages) in participatory demarcation implemented, and 4) optimized land demand scenario developed and its consequence on trans-boundary biodiversity quantified. Table 3.1 shows the relation between these outputs under the GIS component and the project outputs & activities.

Table 3.1 Relationship between GIS outputs & activities, and project outputs & activities

Activity No.	Description	GIS activities
***Specific Objective II:* Enhance protection measures and monitoring of the biological resources along tri-national borders**		
Output2.1: Human resources capacity in biodiversity conservation and management strengthened		
A2.1.1	Elaborate and organize training programs for all levels of protected area staff with possibly inclusion of Cambodian and Laotian participants	GIS/GPS training for protected area staff and stakeholders
Output 2.2: Law enforcement and protection measures strengthened		
A2.2.1	Collaborate with border patrol police and military to prevent wildlife poaching, illegal logging, trading and collection of wild plants	GIS/GPS training for protected area staff and stakeholders
A2.2.2	Update and maintain information system to support PA staff and decision makers	Update GIS database
A2.2.4	Undertake participatory on site demarcation of enclaved communities in Pha Taem NP for local use and rehabilitation areas	Implement pilot project on participatory demarcation
Output 2.3: Research programs on wide-ranging species and ecological processes at the proposed corridor carried out and published		
A2.3.1	Conduct research programs on wide-range distribution and habitat utilization between Thailand, Cambodia and Laos with the involvement of academic research	Assess consequences of land demand scenarios on trans-boundary biodiversity conservation and biodiversity corridor
***Specific Objective III:* Strengthen the involvement of local communities and stakeholders to ensure sustainable uses and management of natural resources both inside PAs and in the buffer zones**		
Output 3.2: ICDP or CLDP activities carried out in the Emerald Triangle's buffer zone through pilot activity fund		
A3.2.3	Regularly monitor and evaluate the implementation of pilot activity fund in terms of sustainability and consistence with TBCA as well as propose adjustments if needed	GIS/GPS training for protected area staff and stakeholders

Source: RFD/ITTO (2007)

The proposed outputs would be achieved though the following strategies:

Output 1 GIS database updated

- Extend lessons learned from the project phase I for improvement and standardization of the GIS database design and ecological survey methods both in

Thailand and Cambodia. A copy of the GIS database and data dictionary was sent to the Forestry Administration of Cambodia,

- Convert all existing map layers (point, line polygon and grid) developed during the Project Phase I using the projected coordinate system of Indian 1975 UTM Zone 48N to the projected coordinate system of WGS 1984 UTM Zone 48N. This system is commonly used by all government agencies nowadays,
- Develop additional GIS database only within Thailand to support the expected outputs of the Project Phase II. It is noted that the GIS database for Cambodia is undertaken by the Forestry Administration of Cambodia using standardization of the GIS database design

Output 2 Protected area staff and stakeholders trained in GIS/GPS

- Develop three training courses on 1) Introduction of GIS and Map Reading, 2) Using GIS for Effective Patrolling, and 3) Land Use Allocation and Land Use Change for protected area staff and local multi-stakeholders
- Work with the Project Manager and park Superintendents to identify training participants
- Conduct training programs for target participants through formal, informal lectures and learning-by doing approach (ground activities and home work)
- Encourage participants to actively involve in the training sessions with inputs for developing land demand scenarios

Output 3 Pilot projects (villages) in participatory demarcation implemented

- Support and provide information to the project for organizing meetings, workshops and awareness raising campaigns relevant for trans-boundary biodiversity conservation
- Work with the Project Manager to identify target villages for implementing participatory demarcation
- Encourage and monitor trained multi-stakeholders to participate and work as resource persons in participatory demarcation

Output 4 optimize land demand scenario and quantify its consequence on trans-boundary biodiversity

- Explore the modern land allocation models that have been practices in the region and facilitate the incorporation of socio-economic data and land characteristics in the simulation, as well as in present land use patterns
- Gather multi-stakeholders opinions on land development scenarios in the PPFC landscape in the next 2 decades through training sessions
- Use the results from different land allocation simulations as input for assessing the consequences of land use changes on trans-boundary biodiversity conservation

3.3 GIS Database

3.3.1 Core Dataset and Data Layers

The objective of having core datasets is to provide the basis for all protected areas in the PPFC to support park managers and decision-makers to effectively manage natural resources and as a basis for long-term monitoring of biodiversity conservation between Thailand, Cambodia and Laos.

By considering the existing GIS core dataset and upcoming issues, the GIS Consultant still maintain 11 core datasets for the Emerald Triangle Protected Forests Complex as the PPFC Project Phase I. However, a lot of new layers were added in response to the needs of Superintendents and important issues derived from spatial analyses (Table 3.2). Therefore, the updated GIS database contains 60 layers. Examples of GIS layers are shown in Figure 3.2, while the digital map outputs are stored in CD Rom.

Table 3.2 GIS database development for the Emerald Triangle Protected Forests Complex

Core Dataset	Spatial Layer	Spatial data type	Attribute
1. Administration	Country	Polygon	Name
	Province	Polygon	Name
	District	Polygon	Name
	Sub-district	Polygon	Name
	Village	Point	Name Population
2. Agriculture	Soil	Polygon	Name and texture
	Predicted land use (2030)-trend [1/]	Grid [2/]	Land use class
	Predicted land use (2030)-integrated land use [1/]	Grid [2/]	Land use class
	Predicted land use (2030)-conservation-oriented [1/]	Grid [2/]	Land use class
	Land use types (2008-present) [3/]	Grid [2/]	Land use class
	Land use types (2002)	Grid [2/]	Land use class
	Land use types (1990)	Grid [2/]	Land use class
3. Biodiversity	Ecological management zone [4/]	Polygon	Class
	Wildlife observation	Point	Name and location
	Additional wildlife observation [3/]	Point	Name and location
	Asian elephant (2002)	Grid	Suitability class (1= low; 5=high)
	Leopard (2002)	Grid	Suitability class
	Sambar (2002)	Grid	Suitability class
	Serow (2002)	Grid	Suitability class
	Banteng (2002)	Grid	Suitability class
	Siamese crocodile (2002)	Grid	Suitability class
	Pig-tailed macaque (2002)	Grid	Suitability class
	Siamese fireback pheasant (2002)	Grid	Suitability class
	Domestic cow (2002)	Grid	Suitability class
	Domestic water buffalo (2002)	Grid	Suitability class
	Asian elephant (2030)	Grid	Suitability class
	Leopard (2030)	Grid	Suitability class
	Sambar (2030)	Grid	Suitability class
	Serow (2030)	Grid	Suitability class
	Banteng (2030)	Grid	Suitability class
	Pig-tailed macaque (2030)	Grid	Suitability class
	Wildlife hotspots (2002)	Grid	Suitability class
	Wildlife hotspots (2030)	Grid	Suitability class
	Temporary sample plot	Point	Location
	LTER Plot	Polygon	Site ID
	Tree tagging	Point	Name, data, IVI, girth
4. Geology	Geology	Polygon	Rock type, Litho logy class
5. Infrastructure	Roads	Line	Width, surface type

Core Dataset	Spatial Layer	Spatial data type	Attribute
6. Meteorology	Weather station	Point	Name and measured parameter
	Isohyets	Line	Amount of rainfall
	Rainfall	Grid	Pixel value (annual precipitation)
7. Protect	Protected area	Polygon	Name
	Locations of HQ and Ranger Station	Point	Name
	Attraction location	Point	Name and type
	Community forest	Polygon	Name
8. Threats	Illegal case	Linked to administration areas	Type and number of cases (logging, wildlife poaching, non-wood product collection, and encroachment)
	Deforestation 2002-2008	Grid	Pixel values (1=Yes; 0= No)
9. Topography	Contour	Line	Elevation value
	Spot height elevation	Point	Height and name
	Elevation/DEM 2/	Polygon/Grid	Elevation zone
	Slope 2/	Grid	Class
	Aspect 2/	Grid	Class
10. Water	River and stream network	Line	Name and type
	Water body (e.g. reservoir)	Polygon	Name
11. Images	Satellite image 1990	Image	Pixel value
	Satellite image 2002	Image	Pixel value
	Satellite image 2008	Image	Pixel value

Remark: 1/ derived from spatial analysis; 2/ derived from contour lines

A review of the GIS work to date both at national (Thailand's protected areas and wildlife conservation) and regional levels (Greater Mae Kong Subregion) (ADB, 1998; Loxley Intergraph, 1995) shows that the vector-based model (Shape file) and Grid raster model by ArcView and ArcGIS software are commonly used in the region. Therefore for the PPFC, the spatial elements are restored in the vector model at large and in the raster data too, wherever applicable. The proposed spatial layer and spatial layer types for 11 core datasets including their attributes are shown in Table 3.2.

In addition, the relational database management system (DBM) is selected to manipulate, i.e. import, store, sort and retrieve, data in a database of the core datasets of the PPFC. The system will permit all objects and attributes to be related to each other. The simple structures of the relational database system have also permitted the development of a standard query language, one of which is *Structured Query Language (SQL).* This system is widely used for simple commercial packets such as dBase and FoxPro (Bernhardsen, 1999).

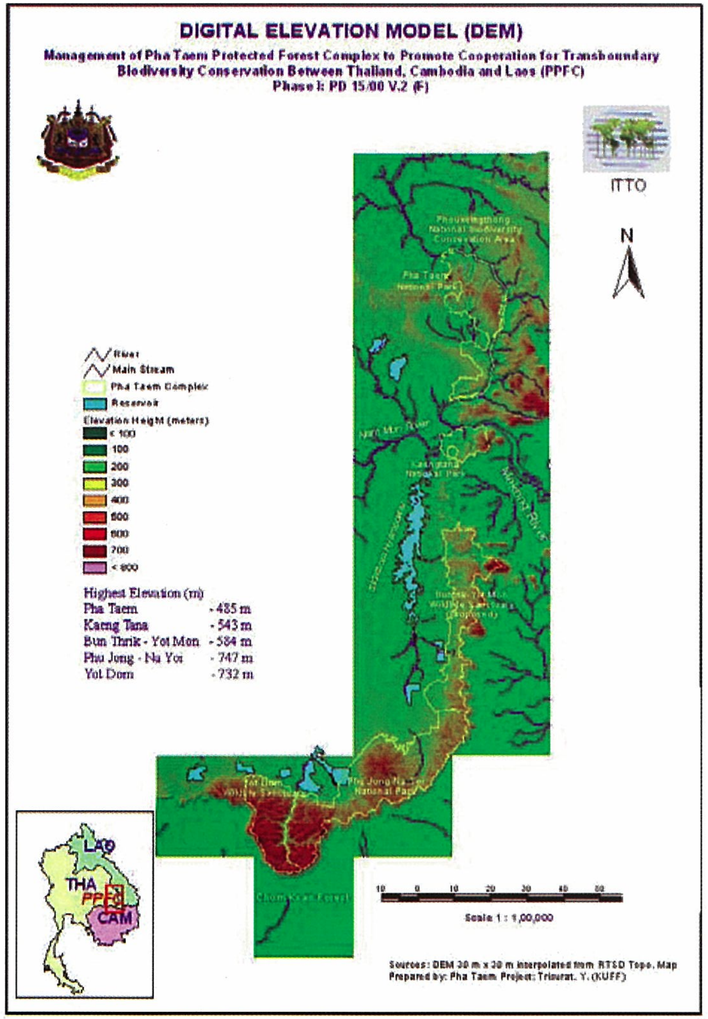
Figure 3.3 presents an example of how spatial elements will be linked to attribute data. The GIS Standard Designs are developed for ArcGIS or ArcView, which are very common software in Thailand and all six countries in the Greater Mae Khong Subregion.

It is noted that this is the physical design of core datasets; but it is not compulsory that all protected areas under the PPFC Project must have these datasets. Availability of spatial data and non-spatial data varies for each protected area. For instance, LTER plots are established inside the Pha Taem National Park and the Yot Dom Wildlife Sanctuary; but they do not exist in Bun Thrik-Yot Mon at the moment.

3.3.2 Data Catalogue and Database Dictionary

A 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 (Thai and English) database dictionary describes all GIS layers, tables, columns and relationships of any dataset notwithstanding their implementation. It also contains the database object names (e.g. administration, elevation, description, data type, length, etc).



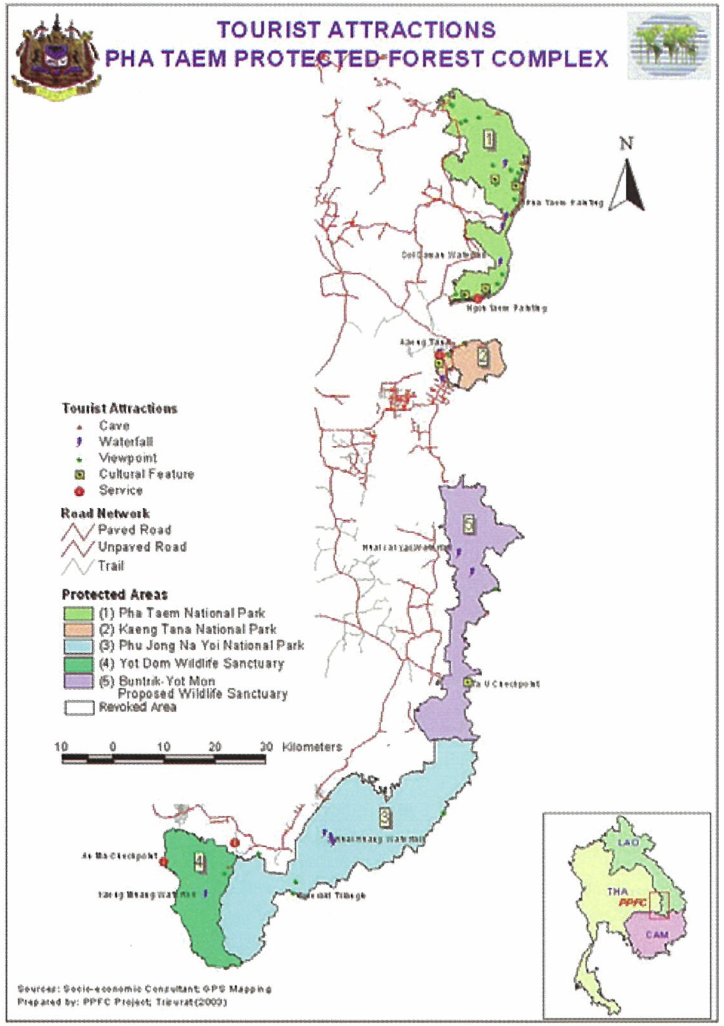
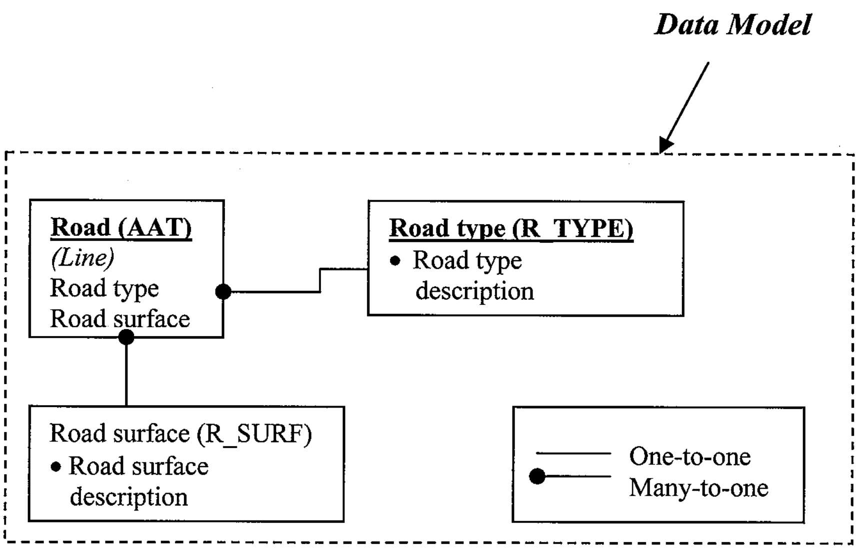


Figure 3.2 Examples of GIS layers in the PPFC landscape



Column name	Description (attribute)	Physical name	Data type	Remark
Road ID	Unique identification code of road	ROAD_ID	B (5)	
Length	Length in meter	LENGTH	F (12,3)	
Road type code	Unique identification code of road type as follows: I = International N = National S = Secondary	ROAD_TYPE	C (1)	
Road surface code	Unique identification codes of road surface are as follows: 1 = Hard surface, two or more lanes wide 2 = Hard surface, one lane wide 3 = Loose surface 4 = Track/trail	ROAD_SUR ***Item or code name***	I (1)	***Data Type and Width***

Tabular data **Road types**

Technical information

Path: INFRA\ROADS

File: R_TYPE

Column name	Description	Physical name	Data type	Remark
Road type code	Unique identification code of road type	ROAD_TYPE	C (1)	
Road type	Road type codes are as follows: International = I National = N Secondary = S	TYPE_NAME	C (20)	

Figure 3.3 Example of GIS standard design for road coverage

3.4 GIS Training

A 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?* while the former answers both *what?* and *where?*

GIS contains four main components: computer hardware, computer software, data and human resources. Among these four components, human resources are recognized as the most important component for effective implementation of GIS in a sustainable manner. Therefore, the GIS Consultant worked closely with the Project Manager of PPFC to arrange training courses aiming at developing human resources with the skills and technical knowledge necessary to effectively and efficiently obtaine, exchange and use core datasets. Three training courses were conducted at the PPFC Project area, namely *1) Introduction to GIS and Map Reading, 2) GIS and MIST: Smart Patrolling,* and *3) Dyna-CLUEs: Land Use Modeling Technique.*

The content and achievements of each training session are summarized below.

3.4.1 Introduction to GIS and Map Reading

The first GIS Training Course on *Introduction to GIS and Map Reading* was organized in two sessions at the PPFC project area: 1) on December 24-25, 2008 for park staff, and 2) on December 26, 2008 for local people. The objectives of the training sessions, course outline and list of participants were as follows:

1) Objectives

- To present the principle of geo-informatics and its capabilities for biodiversity conservation;
- To educate participants to read maps and coordinate systems, and

- To introduce GIS ArcView 3.2 software and its general functions.

2) Course outline

- Introduction to the Emerald Triangle Protected Forests Complex to Promote Trans-boundary Biodiversity Conservation between Thailand, Lao PDR and Cambodia
- Coordinate system, map scale and map reading
- GIS, Remote Sensing, and GPS
- GIS capacities and GIS data model: vector and raster
- Introduction to ArcView 3.2 (data display and query)
- Field practices: GPS tracking and digitizing

The target groups for the 1st GIS Training Session I were multi-stakeholders working inside and outside PPFC projects. They were categorized into two groups as follows:

- Protected area staff including Park Superintendent, park rangers and supporting staff from Pha Taem national Park, Kaeng Tana National Park, Bun Thrik-Yot Mon Proposed Wildlife Sanctuary, Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary (Table 3.3).
- Local multi-stakeholders including Tambon leaders, village leaders, representatives of the Tambon Administrative Organization, community leaders and NGOs (Table 3.4)

3) Results

There were 26 participants from five protected areas in the PPFC and PPFC staff attending this training session. Basically, five participants from each protected area were invited, except for Yot Dome Wildlife Sanctuary and Phu Jong Na Yoi National Park which nominated four and six participants, respectively. More than 50% of participants were park personnel (temporary employees) working as park ranger and supporting staff, while the rest were either permanent workers or park officials. Fortunately, the Superintendent of Phu Jong Na Yoi National Park was able to attend the training, so that he knew the capacities of GIS and has been able to advise his staff effectively. The list of participants and affiliated agencies is given in Table 3.3.

In addition, there were 26 local multi-stakeholders. These people worked as Tambon leaders, village leaders, representatives of Tambom Administration Organization and local people. Their affiliations (Table 3.4) show they were from 7 Tambons (sub-districts) which the PPFC Project identified as target areas for participatory demarcation. The number of participants from Tambon Na Pho Klang, Nam Thaeng, Huai Pai, Huai Yang, Khong Jiam, Sam Rong and Na Loern are 12, 4, 4, 2, 4, 2, and 1 person, respectively. The list of participants and affiliated agencies is shown in Table 3.4.

As a result of the training most participants were able to read maps, generally understand the coordinate system, and the use of GPS. They realize the importance of GIS and GPS for effective patrolling and trans-boundary biodiversity conservation. They were interested in attending the next GIS training on GIS & MIST for Effective Patrolling Technique. A major obstacle that the GIS Consultant observed was their limited English capacity to gain computerized GIS knowledge (ArcView software) because all commands were written in English. Therefore, the GIS Consultant recommended the PPFC Project to select potential participants who were able to read and use computers to attend the advanced training at later stage.

Table 3.3 List of participants attending the 1st GIS Training, 24-25 December 2008

No	Name	Surname	Position	Affiliation
1	Mr. Khonkhun	Khamman	PPFC staff	ITTO
2	Mr. Thamnong	Saengkhaew	Park personnel	Bun Thrik-Yot Mon WS
3	Mr. Praman	Santawong	Park personnel	Bun Thrik-Yot Mon WS
4	Mr. Wichai	Doodduem	Park personnel	Bun Thrik-Yot Mon WS
5	Mr. Samroeng	Karasri	Park personnel	Bun Thrik-Yot Mon WS
6	Mr. Bunmee	Thantasuekdee	Driver	Yot Dom WS
7	Mr. Paitoon	Maneengam	Park ranger	Yot Dom WS
8	Ms. Naphat	Singthong	Park personnel	Yot Dom WS
9	Mr. Thawatchai	Puangsri	Park personnel	Yot Dom WS
10	Mr. Suphap	Uuecha	Permanent worker	Yot Dom WS
11	Mr. Somchai	Komanee	Extension staff	Kaeng Tana NP
12	Mr. Weeraphan	Ruenkhaew	Park Scientist	Kaeng Tana NP
13	Mr. Rungnawee	Chanlee	Temporary worker	Kaeng Tana NP
14	Mr. Thaweesin	Kaenthai	Park personnel	Kaeng Tana NP
15	Mr. Pithak	Leelalerd	Park personnel	Kaeng Tana NP
16	Mr. Srivichai	Nonthawong	Temporary worker	Pha Taem NP
17	Mr. Panumas	Chabasri	Extension staff	Pha Taem NP
18	Mr. Phairote	Pue-on	Driver	Pha Taem NP
19	Mr. Bowon	saenthaweesuk	Park personnel	Pha Taem NP
20	Mr. Sakol	Thonsoo	Park personnel	Pha Taem NP
21	Mr. Thatsana	Nikhom	Park personnel	Phu Jong Na Yoi NP
22	Ms. Orathai	Thanwima	Temporary worker	Phu Jong Na Yoi NP
23	Ms. Archariya	Roonan	Temporary worker	Phu Jong Na Yoi NP
24	Ms. Pitsamai	Puiwong	Park personnel	Phu Jong Na Yoi NP
25	Mr. Boontham	Sing-on	Park personnel	Phu Jong Na Yoi NP
26	Mr. Thirayut	Wongthaisert	Superintendent	Phu Jong Na Yoi NP

Table 3.4 List of participants (local multi-stakeholder) attending the 1st GIS Training, 26 December 2008

No	Name	Surname	Address (Moo, sub-district, district and province)
1	Mr. Somnuk	Phansaeng	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
2	Mr. Jok	Nantharak	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
3	Mr. Sarawood	Srima	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
4	Mr. Khonkhun	Khamman	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
5	Mr. Phitthaya	Khamman	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
6	Mr. Sanphet	Phuthong	Moo 1, Na Pho Klang, Khong Jiam, Ubon Ratchathani
7	Mr. Boonma	Chomsaeng	Moo 3, Na Pho Klang, Khong Jiam, Ubon Ratchathani
8	Mr. Siewsawat	Muangklang	Moo 4, Na Pho Klang, Khong Jiam, Ubon Ratchathani
9	Mr. Sawaeng	Saengsunee	Moo 7, Na Pho Klang, Khong Jiam, Ubon Ratchathani
10	Ms. Khampun	Taemsri	Moo 7, Na Pho Klang, Khong Jiam, Ubon Ratchathani
11	Mr. Srichan	Yitharat	Moo 10, Na Pho Klang, Khong Jiam, Ubon Ratchathani
12	Ms. Nongkran	Sribhuttha	Moo 10, Na Pho Klang, Khong Jiam, Ubon Ratchathani
13	Mr. Satien	Siha	Moo 6, Nam Thaeng, Khong Jiam, Ubon Ratchathani
14	Mr. Subin	Sawaengpol	Moo 6, Nam Thaeng, Khong Jiam, Ubon Ratchathani
15	Mr. Lium	Boonchai	Moo 10, Nam Thaeng, Khong Jiam, Ubon Ratchathani
16	Mr. Somchai	Saengsan	Moo 10, Nam Thaeng, Khong Jiam, Ubon Ratchathani
17	Ms. Nalin	Pongpim	Moo 3, Huai Pai, Khong Jiam, Ubon Ratchathani
18	Mr. Boonsong	Sribhuttha	Moo 3, Huai Pai, Khong Jiam, Ubon Ratchathani
19	Mr. Sukhi	Chanthep	Moo 3, Huai Pai, Khong Jiam, Ubon Ratchathani
20	Mr. Arwut	Booramat	Moo 7, Huai Pai, Khong Jiam, Ubon Ratchathani
21	Ms. Wilaiwan	Duangngam	Moo 5, HuaiYang, Khong Jiam, Ubon Ratchathani
22	Ms. Sunthi	OOnkhaew	Moo 5, HuaiYang, Khong Jiam, Ubon Ratchathani
23	Mr. Somchai	Komanee	Moo 1, Khong Jiam, Khong Jiam, Ubon Ratchathani
24	Mr. Suphisit	Inthong	Moo 7, Sam Roeng, Khong Jiam, Ubon Ratchathani
25	Mr. Somporn	Thanting	Moo 10, Sam Rong, Khong Jiam, Ubon Ratchathani
26	Ms. Suphattra	Lohakul	Moo1, Na Loen, Sri Chiangmai, Ubon Ratchathani

Figure 3.4 Participants listening lecture from the GIS Consultant and practicing afterwards

3.4.2 GIS and MIST for Effective Patrolling

The second GIS Training Course on *GIS and MIST for Effective Patrolling* was organized on 24 January 2009 at the Headquarters of Bun Thrik-Yot Mon Proposed Wildlife Sanctuary. The GIS Consultant also invited staff from the Wildlife Conservation Society – Thailand Program (WSC) to give a lecture and demonstrate how to use MIST. It is noted that the WCS-Thailand has worked closely with the Department of National Park, Wildlife and Plant Conservation on this monitoring technique for three years. Some participants were already trained; therefore these training sessions reinforced those people and educated in the modern monitoring technique to newcomers. The overall goals of this training course were to refresh the skills of the previous GIS trainees and to educate them on how to use GIS and MIST (Monitoring Information System) for effective patrolling and wildlife monitoring. Specific objectives and course outlines were as follows:

1) Objectives

- To refresh GIS trainees and educate new participants on GIS and the coordinate systems;
- To introduce the MIST system and its relationship to ArcView GIS 3.2 software;
- To provide opportunities for participants to familiarize themselves with the MIST system and practices using tutorial materials.

2) Course outlines

- Review of coordinate systems, GIS concepts, and ArcView 3.2 software
- Introduction to the MIST system
- Gathering field data
- Filling field data into MIST format (inventory form, way point, movement form and sighting data, etc)
- Group practices

The target groups for the 2nd GIS Training Session were park staff and relevant government agencies who were involved in natural resources protection and biodiversity monitoring both inside and outside PPFC projects. They were categorized into two groups as follows:

- Protected area staff including Park Superintendent, park rangers and supporting staff from Pha Taem national Park, Kaeng Tana National Park, Bun Thrik-Yot Mon Proposed Wildlife Sanctuary, Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary (Table 3.5).
- Patrol border police and forestry officials working in the PPFC landscape. Local people and other local multi-stakeholders were not invited because this training session required adequate knowledge in map reading and

English competency which were limitation for local multi-stakeholders (Table 3.6).

3) Results

There were 29 participants attending the training session on GIS/GPS for Effective Patrolling Technique. Twenty-one participants were from five protected areas in the PPFC. Basically, five participants from each protected area were invited; however a few invited participants from Pha Taem, Kaeng Tana and Phu Jong Na Yoi National Park had prior commitments, so that they were unable to participate. It is noted that fifteen participants were previous trainees of GIS training session 1. These participants captured the lecture content very fast because they already had basic knowledge in GIS. Meanwhile, the remaining eight participants were border patrol police and RFD officials. The expected benefits from this training were not only to educate protected area staff but also to create collaboration with border patrol police and military in order to prevent wildlife poaching, illegal logging, trading and collection of wild plants as defined in output 2.2 (*Law enforcement and protection measures strengthened*) of the project document. The list of participants and affiliated agencies is given in Table 3.5.

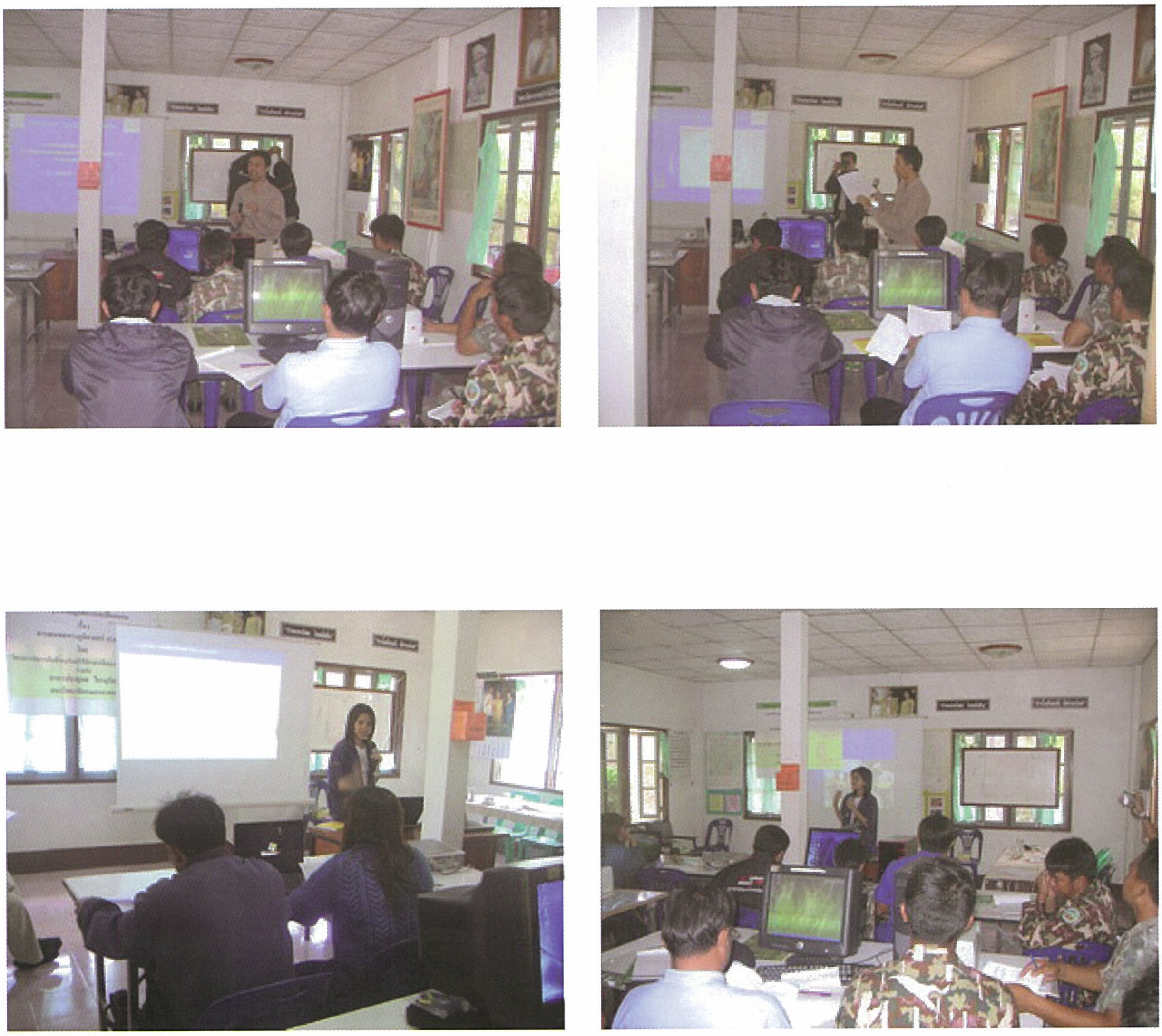
Table 3.5 List of participants attending the training on GIS/MIST for Effective Patrolling, 24 January 2009

No.	Name-Surname	Position	Affiliation
1	Ms. Archariya Roonan [1/]	Temporary worker	Phu Jong Na Yoi NP
2	Ms. Orathai Thanwima [1/]	Temporary worker	Phu Jong Na Yoi NP
3	Ms. Thatsana Nikhom [1/]	Park personnel	Phu Jong Na Yoi NP
4	Mr. Boontham Sing-on [1/]	Park personnel	Phu Jong Na Yoi NP
5	Mr. Somchai Komanee [1/]	Extension staff	Kaeng Tana NP
6	Mr. Rungnawee Chanlee [1/]	Temporary worker	Kaeng Tana NP
7	Mr. Weeraphan Ruenkhaew [1/]	Park Scientist	Kaeng Tana NP
8	Mr. Bowon Saenthaweesuk [1/]	Park personnel	Pha Taem NP
9	Mr. Sakol Thonsoo [1/]	Park personnel	Pha Taem NP
10	Mr. Phaisan Polsak	Park personnel	Pha Taem NP
11	Mr. Phairote Pue-on [1/]	Driver	Pha Taem NP
12	Mr. Paitoon Maneengam [1/]	Park ranger	Yot Dom WS
13	Mr. Somkit Khamso	Park ranger	Yot Dom WS
14	Mr. Manit Paramat	Park personnel	Yot Dom WS
15	Mr. Thawatchai Puangsri [1/]	Park personnel	Yot Dom WS
16	Ms. Naphat Singthong [1/]	Park personnel	Yot Dom WS
17	Mr. Oon Pongchu	Park personnel	Bun Thrik-Yot Mon WS
18	Mr. Thamnong Saengkhaew [1/]	Park personnel	Bun Thrik-Yot Mon WS
19	Mr. Samroeng Karasri [1/]	Temporary worker	Bun Thrik-Yot Mon WS
20	Mr. Muen Chairach	Park personnel	Bun Thrik-Yot Mon WS
21	Mr. Khanpracha Khamla	Park personnel	Bun Thrik-Yot Mon WS
22	Mr. Chrestha Prathummas	Forest Official	Forest Protection Unit 8
23	Mr. Sompong Yolsuk	Forest Ranger	Forest Protection Unit 14
24	Mr. Khachatpai Khanthong	Driver	Forest Protection Unit 14
25	POL.SEN.SGT.MAJ. Pairee Taemwan	Squad Leader	Border Patrol Police, 225 Company
26	POL.SEN.SGT.MAJ. Waekin Sairach	Assistant Squad Leader	Border Patrol Police
27	POL.SEN.SGT.MAJ. Roongrot Thanee	Assistant Squad Leader	Border Patrol Police
28	POL.SEN.SGT.MAJ. Khampol Saenthawee	Assistant Squad Leader	Border Patrol Police, Ban Pamai Station
29	Mr. Weera Amornchai	Senior Technical Forestry Official	Community Forest Management Region 9

1/ Participants attending previous training sessions

The results of the training revealed that most participants realized the importance of GIS, GPS and MIST for effective patrolling and trans-boundary biodiversity conservation. In addition, it is in-line with DNP policy to integrate MIST in patrolling work of all protected areas. A few protected areas in Thailand have been selected as pilot projects and the DNP will extend the system throughout the country soon.

Two obstacles that the GIS Consultant and Project Manager observed during and after training sessions were the technical knowledge gap between participants and barrier in English knowledge. In this training, there were both participants who already had knowledge in GIS and MIST, and participants who were new in these modern technologies. English language barrier is common for both former and new trainees. Nevertheless, all participants showed interest and energy to learn. For the sustainability of this technology, it is recommended that the DNP always reinforce this policy to park superintendents and embed it into routine work of all protected areas even after the project is terminated.



<u>Figure 3.5</u> GIS Consultant and invited resource persons giving lectures to participants

Figure 3.6 Participants locating wildlife sighting data on the topographic map and closing remarks by Project Manager

3.4.3 Dyna-CLUEs: Land Use Modeling Technique

The third GIS Training Course on *Dyna-CLUEs: Land Use Modeling Technique* was organized on 6 November 2009 at the PPFC Project. This training session was organized quite some time after the second training because the updated land use map in 2008 was an essential input for the third training. In addition, the GIS Consultant had explored practical land use modeling techniques that is recognized by scientists and land use practitioners in the region. In the project phase I, the GIS Consultant used the Markov Chain Model to predict future land use change. However, there are a lot of limitations to this mathematic model because it cannot incorporate socio-economic data and land characteristics to determine location of land use type. In addition, this model simply predicts future land use based on previous trends but ignores land use change drivers. Detailed simulation was presented in Chapter 4.

1) Objectives

The overall goal of this training course was to introduce land use modeling to participant. Specific objectives and course outlines were as follows:

- To refresh the previous GIS training for all participants;
- To educate participants on spatial analysis using grid-modeling;
- To introduce land use modeling techniques using Dyna-CLUEs model, and
- To obtain realistic land demand scenarios from participants who were multi-stakeholders of the PPFC project.

2) Course outlines

- Briefly review the GIS concepts, and ArcView 3.2 software
- Raster data model and data conversion
- Spatial modeling
- Introduction to Dyna-CLUEs and tutorial
- Participant opinions on land demand scenarios in 2030

3) Result

Twenty-eight participants were trained in GIS Analysis and Land-Use Modeling Sessions. Five participants were from the PPFC project, and land use modeling, the remaining 23 participants were from five protected areas situated in the PPFC area. Among this number, nine trainees were former participants either in the first or second GIS training that were organized by the project in last year. The list of participants and affiliated agencies is given in Table 3.6.

This training was not directly aimed at educating park staff to be able to use land use modeling technique but to provide them with land use planning perspective and consequences of land use change on trans-boundary biodiversity conservation in the Emerald Triangle. This is due to the fact that it requires not only advance knowledge in GIS but also multivariate statistic analysis and land use planning. By producing of this training, the project was able to obtain realistic land demand scenarios in 2030 from participants who have lived in this area for more than 20 years and know the land use history and trends.

Nevertheless, about 10 staff were able to use GIS software (ArcView) and understand land-use modeling because their English language skill was good and they had previously participating in a series of training sessions. The remaining staff had limited English knowledge and computer skills, thus they just listened to the contents and provided their thoughts for future development scenarios.

Detailed methodologies and results of land use modeling, as well as its consequences on trans-boundary biodiversity conservation are presented in the following chapter.

Table 3.6 List of participants attending the 3rd training on Dyna-CLUEs Land Use Modeling, 6 November 2009

No.	Name - Surname	Position	Affiliation
1	Ms. Umthong Saengnet	Project staff	PPFC Project
2	Ms. Wiliawan Duangngam	Project staff	PPFC Project
3	Ms. Soontri Oonkhaew	Project staff	PPFC Project
4	Mr. Khonkhun Khamman	Project staff	PPFC Project
5	Mr. Phitthaya Khamman	Project staff	PPFC Project
6	Ms. Somnpit Mimamphan	Project staff	Phu Jong Na Yoi NP
7	Ms. Orathai Thanwima 1/	Temporary worker	Phu Jong Na Yoi NP
8	Mr. Wihan Lathong	Park ranger	Phu Jong Na Yoi NP
9	Mr. Kitkul Tonbun	Temporary worker	Phu Jong Na Yoi NP
10	Mr. Somboon Ruengwong	Temporary worker	Kaeng Tana NP
11	Mr. Weeraphan Ruenkhaew 1/	Park Scientist	Kaeng Tana NP
12	Mr. Somchai Komanee 1/	Extension staff	Kaeng Tana NP
13	Mr. Wichianchid Khamsri	Temporary worker	Kaeng Tana NP
14	Mr. Wichai Diidduem	Park ranger	Bun Thrik-Yot Mon WS
15	Mr. Muen Chairach	Park personnel	Bun Thrik-Yot Mon WS
16	Mr. Samroeng Karasri 1/	Temporary worker	Bun Thrik-Yot Mon WS
17	Mr. Thamnong Saengkhaew 1/	Park personnel	Bun Thrik-Yot Mon WS
18	Mr. Pramuk Promta	Park personnel	Bun Thrik-Yot Mon WS
19	Mr. Manas Kuedsomboon	Security guard	Pha Taem NP
20	Mr. Phaisan Polsak	Park personnel	Pha Taem NP
21	Mr. Prachum Khamsai	Park ranger	Pha Taem NP
22	Mr. Phairote Pue-on 1/	Driver	Pha Taem NP
23	Mr. Panumas Chabasri	Extension staff	Pha Taem NP
24	Ms. Pranom Thason	Park personnel	Yot Dom WS
25	Ms. Boonsong Boongthong	Temporary worker	Yot Dom WS
26	Ms. Naphat Singthong 1/	Park personnel	Yot Dom WS
27	Mr. Thawatchai Puangsri 1/	Park personnel	Yot Dom WS
28	Mr. Manit Paramat 1/	Park personnel	Yot Dom WS

1/ Participants attending previous training sessions

IV. PROJECTING LAND-USE AND LANDSCAPE CHANGES

4.1 Introduction

Deforestation and land-use change are critical threats to biodiversity in Southeast Asia (Fox and Vogler, 2005). FAO (2005) estimated that tropical regions lost 15.2 million hectares of forests per year during the 1990s and Southeast Asia had experienced the highest rate of net cover change (0.71% per year) compared to other continents. Forest loss in Thailand was ranked the highest of all countries in the Greater Mekong Sub-region and as fourth in the "Top 10" of tropical countries in terms of annual rate of loss in 1995 (CFAN, 2005). According to Charuphat (2000), forest cover in Thailand declined from 53% of the country area in 1961 to approximately 25% in 1998. The total loss of forest area during this 37-year period was 14.4 million ha, and the average annual loss was 400,000 ha or 2.0%.

The Southeastern Indochina Dry Evergreen Forests ecoregion occurs in a broad band across northern and central Thailand into Laos, Cambodia, and Vietnam, covering approximately 124,300 km^2. The ecoregion is globally outstanding for the large vertebrate fauna it harbors within large intact landscapes. Among the impressive large vertebrates are the Asian elephant, and tiger. The list includes the second known population of the critically endangered Javan rhinoceros, *Eld's deer*, banteng, gaur, clouded leopard, etc. About two-third of the original forest of this ecoregion has been cleared or seriously degraded (Wikramanayake et al., 2000). A few large forest blocks also remain in Thailand, Laos and Cambodia, the so called Emerald Triangle Complex. In Thailand, five protected areas entitled Pha Taem Protected Forest Complex have been established in this forest block.

A recent study on land-use change in the Pha Taem Protected Forest Complex (PPFC) indicated that forest cover in this area declined from approximately 63% in 1990 to 57% in 2002 (Trisurat, 2009). Eucalyptus and para rubber plantations have greatly expanded in the last 12 years; however, these two categories constitute only a low percentage of the

PPFC landscape. The impacts of deforestation are well known and observed. Of primary concern are impacts on biodiversity (genes, populations, species, communities, ecosystems) (Redford and Richter, 1999) and the ability of biological systems to support human needs (Lambin et al., 2003). Not only does deforestation cause habitat loss but also habitat fragmentation, diminishing patch size and core area, and isolation of suitable habitats (MacDonald, 2003). In addition, fragmentation provides opportunities for pioneer species (light-demanding species) to invade natural habitat along the forest edge (Forman 1995; McGarigal and Marks, 1995). Pattanavibool et al. (2004) found that the fragmented forest in Mae Tuen Wildlife Sanctuary in northern Thailand contained lower densities of large mammals (e.g. Asian elephant, gaur) and hornbills compared to the relative intact Om Koi Wildlife Sanctuary. In addition, recovery of degraded ecosystems to their original state is extremely difficult and time consuming.

Models of land-use change can address two separate questions: where are land-use changes likely to take place (location of change) and at what rates are changes likely to progress (quantity of change). The first question requires the identification of the natural and cultural landscape attributes which are the spatial determinants of change. The rate or quantity of change is driven by demands for land-based commodities and are often modeled using economic models accounting for demand-supply relations and (international) trade (Verburg and Veldkamp, 2004). Land-use change models range from simple system representations including a few driving forces to simulation systems based on profound understanding of situation-specific interactions among a large number of factors at different spatial and temporal scales, as well as environmental policies. The classical Markov Chain Models use previous land use trends to envisage what will happen in the future without considering the role of changes in the controlling natural, political and sociological factors (Trisurat, 2009). Significant progress in the quantification and understanding of land-use/land-cover changes has been achieved over the last decade. The dyna-CLUE model (Trisurat (inpress); Verburg *et al.*, 2004; Overmars *et al.*, 2007) was used to project land use transitions for different scenarios in Asia. This model is an effective tool that yields land use information important for environmental assessment and planning (Verburg and Veldkamp, 2004). In addition, it deals with both the location and quantity issues in an integrated way (Verburg and Veldkamp, 2001). Reviews of different land use models are provided by Verburg *et al.* (2004), Matthews *et al.* (2007) and Priess and Schaldach (2008).

Deforestation and biodiversity loss is causing concern to policy makers at national, regional and global levels. Recent years have seen an increasing interest in the creation of trans-boundary protected areas for more effective management of politically fragmented ecosystems. With the financial assistance from the International Tropical Timber Organization (ITTO), the Royal Forest Department (RFD) of Thailand has initiated a program of managing trans-boundary biodiversity conservation areas (TBCA) and selected the Pha Taem Protected Forests Complex (PPFC), one of the four protected forests complexes as a pilot project because there is an increasing pressure on biodiversity from trade in plants and animals across the border with Cambodia and Laos (ITTO/RFD, 2000). The objectives of project phase I (2001-2004) were to strengthen the management of the PPFC and to initiate cooperation in trans-boundary biodiversity conservation among the three countries. One of the key significant activities leading toward the management planning of biodiversity was to develop geospatial information of the PPFC, to assess the consequences of land-use change on biodiversity and to propose biodiversity corridors to link fragmented ecosystems.

4.2 Objectives

The overall objective of this chapter was to predict forecast land-use change and land-use patterns across the PPFC landscape based on different land demand scenarios. The expected outputs of this scientific research were used to analyze consequences for trans-boundary biodiversity conservation across Thailand, Lao PDR, and Cambodia. They are presented in Chapter 5.

4.3 Materials and Methodology

4.3.1 Study Area

The study area includes five protected areas in the Pha Taem Protected Forest Complex (PPFC) and surrounding landscape in Ubon Ratchathani Province in northeast Thailand and covers an area of totally 5,937 km^2. This protected area complex comprises - Pha Taem, Kaeng Tana, and Phu Jong-Na Yoi National Parks (IUCN Category II), Yot Dom Wildlife Sanctuary (IUCN Category Ia), and Bun Thrik-Yot Mon proposed Wildlife Sanctuary (Figure 2.1 and Table 2.1). The total size of the protected area complex is 1,737 km^2, and the surrounding area in the buffer zone encompasses approximately 4,200 km^2. The PPFC's buffer zone contains 82 villages populated by 89,000 people (Trisurat, 2006). The major occupations of the residents are agriculture, livestock keeping, and fisheries.

On the Lao side, the 1,200 km^2 Phouxeingthong National Biodiversity Conservation Area (NCBA) is located adjacent to the northern part of the PPFC, while the 1,900 km^2 Protected Forest for Conservation of Genetic Resources of Plants and Wildlife abuts the border on the Cambodian side. The tripartite border area has been dubbed, in Thailand at least, the Emerald Triangle because of its extensive tracts of monsoon forests.

This study did not update forested area in Lao PDR and Cambodia because the Forestry Administration of Cambodia is responsible for this work and encroachment in these two countries is relatively low. In addition, the GIS Consultant and multi-stakeholders did not know or had no clue on land demands in the neighboring countries. However, the final land use map for year 2008 covering also the whole Emerald Triangle landscape but assumes that the patterns of land use in Laos and Cambodia remained unchanged as in year 2002.

4.3.2 Dataset

Land-use map

The relatively cloud-free Landsat TM-5 digital imageries were acquired from the Geo-informatics and Space Technology Development Agency (GISTDA). A subscene of images covering the PPFC landscape was therefore extracted and was geometrically registered to the UTM coordinate system WGS Zone 48 using the topographic map (scale 1;50,000) as a base map and a number of ground control points (GCPs). Then, a false color composite image (band combination 4 5 3 – R G B) was produced as a base map for interpretation (Figure 4.1).

Visual interpretation technique was employed for land-use/land cover mapping based on tone, shape, size, pattern, texture, shadow, and association (Lillesand and Kiefer, 1987). Before interpretation, the image signatures were compared with the training signature of each land use class that was obtained during reconnaissance survey. The preliminary land-use map 2008 was classified into four major classes, including forest, agriculture & settlement, water and rubber plantation. In addition, field validation and accuracy assessment was done using a classification matrix. Then, the corrected major land use map was used to update the 10-classes of the land-use map in 2002 to derive the land use map in 2008. These 10 categories or classes were 1) evergreen forest, 2) mixed deciduous forest, 3) dry deciduous forest, 4) scrub and disturbed forest, 5) plantation, 6) para rubber plantation, 7) agriculture, 8) build-up area, 9) bare soil and miscellaneous land uses, and 10) water body.

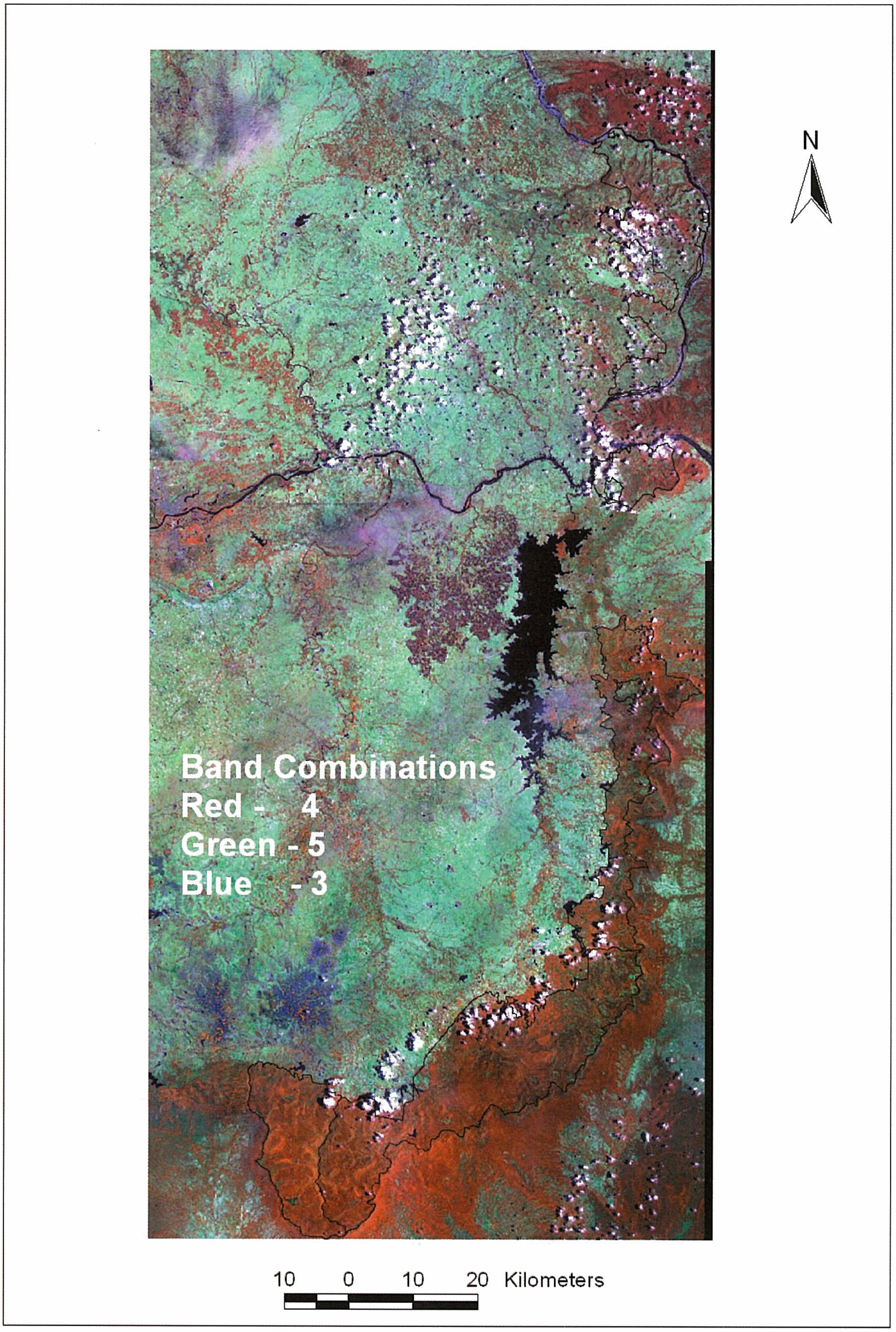


Figure 4.1 Landsat TM-5 year 2008

Bio-physical data

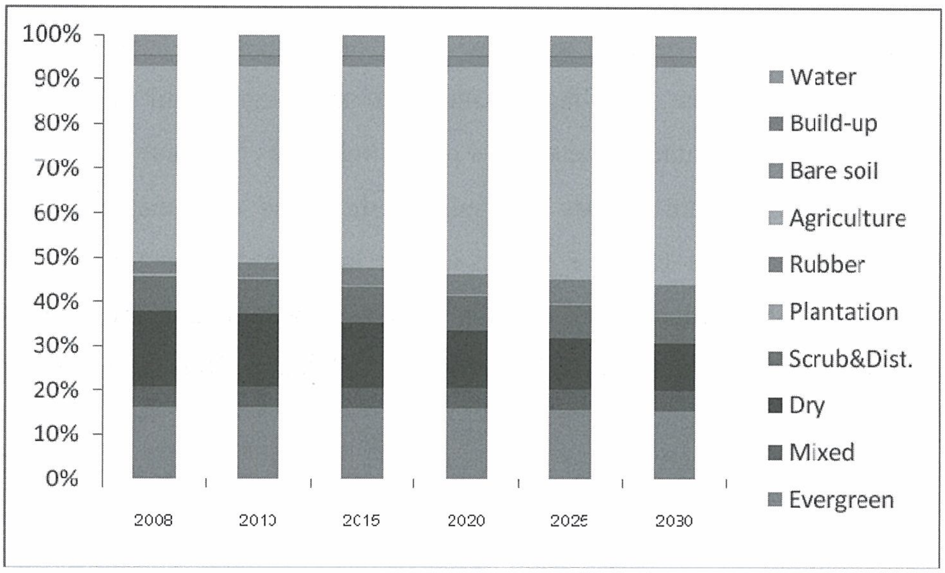
In addition, a small set of biophysical and anthropologic factors, describing the spatial variability of location characteristics relevant for different land use types, were developed. These factors included soils, topography and drainage characteristics corresponding to each land class. Twenty-meter contour lines were digitized from the topographic map and thereafter interpolated to generate elevation and slope. Main road and stream networks were also extracted from the topographic map. In addition, village locations were recorded by using the Global Positioning System (GPS). Proximities to road, stream and village were calculated using the spatial analysis function of the ArcView program. Annual precipitation was generated from rainfall data recorded in the meteorological stations across the PPFC landscape. The current populations of each sub-district (Tambon) and soil maps at scale 1:100,000 were obtained from the Department of Local Administration (DOLA) and the Land Development Department, respectively. In addition, protected area coverage was digitized from the National Gazette map. All spatial data were entered into a Geographic Information System (GIS) database using grid format of 100-m resolution, and later exported to ArcGIS ASCII format for land use and landscape change analyses in the next steps.

4.3.3 Predicting Land Use Transitions from 2008-2030

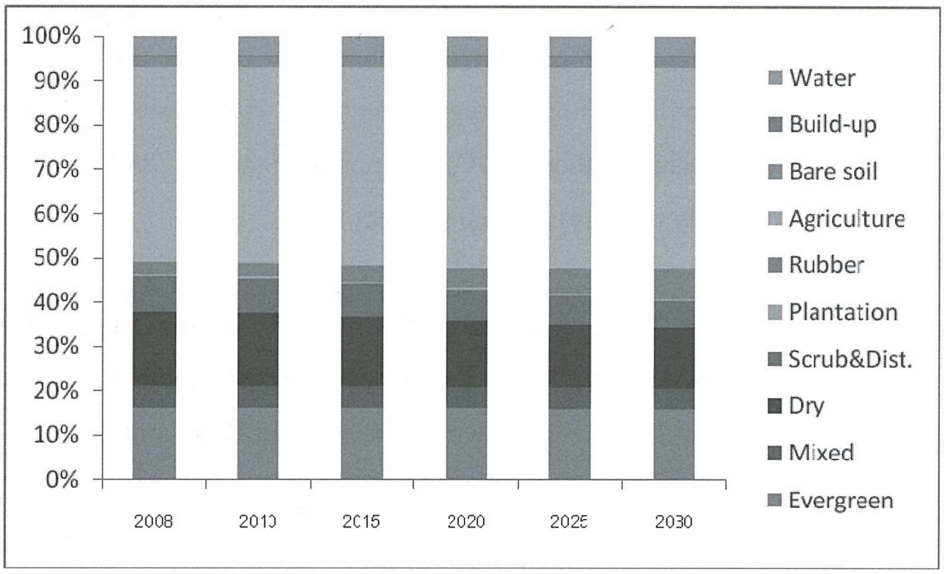
The Clue-s model was used in this study because it was developed for the spatially explicit simulation of land use change and based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between spatial and temporal dynamics of the land use system (Verburg and eldkamp, 2004). This model can integrate different land use change trajectories in the environmental and socio-economic context. The model requires four inputs that together create a set of conditions and possibilities for which the model calculates the best solution in an iterative procedure. These inputs are 1) land use requirements (demand), 2) location characteristics, 3) spatial policies and restrictions, and 4) land use type specific conversion settings.

Land use requirements or demands are calculated at the aggregate level as part of a specific scenario. The land use requirements constrain the simulation by defining the totally required change in land use. In this study, three land demand scenarios were developed. The *trend scenario (baseline)* is based on a continuation of the trends of land use conversion of recent years (2002-2008). The analyses were done both in the PPFC landscape and within Thailand. It is noted that the simulation of land allocation was carried out only in the Thailand territory, and we therefore used the annual change in Thailand as a baseline to calculate demand for year 2030. The annual loss of forest cover in this period was between 0.28-3.79%. On the other hand, the change rates of plantation, rubber, agriculture, build-up area, bare soil and water body were -3.81%; 35.11%; 1.08%; 11.12%; -12.30%; and -0.28%, respectively. If these trends are stable, natural forest cover will be 37% in 2030. The estimated land requirements are shown in Figure 4.2a. In this trend scenario, forest encroachment may occur in protected areas as there are no restriction policies.

The second land requirement scenario is named *integrated-management land use*. Under this scenario, the spatial policies are included. It is assumed that no further encroachment is allowed in national parks and wildlife sanctuaries, which are established as strict nature reserves for biodiversity conservation and watershed protection. However, it possibly occurs in the Bun Thrik-Yot Mon Proposed Wildlife Sanctuary because it is in the process of establishment and the number of park rangers is not adequate to protect remaining forest cover. The simulation is also directed by the National Forest Policy, which aims to maintain 40% of the country area under forest cover. In addition, it is assumed that the total area of rubber plantation will be 34,500 ha by 2030 or two-times of the existing area. However, the increment rate of agriculture will only increase little (Figure 4.2b). Urban area, bare soil and water body will be the same as the trend scenario. The conservation scenario is gneerally the same as the integrated-management scenario, except the restriction area is larger. This scenario anticipates effective protection of remaining forest in both existing and proposed protected areas as encroachment is not allowed for both categories.



a) Trend scenario



b) Integrated management and conservation scenarios

<u>Figure 4.2</u> Land requirements for scenarios 1, 2 and3 from 2008-2030

Location characteristics determine the relative suitability of a location for the different land use types. According to FAO (1995), land suitability classes are evaluated based on physical conditions (crop requirements and limitations) and economic conditions within any given area. Altitude and slope represent limiting factors for agriculture, while on the other hand, annual precipitation, distance to available water and soil texture are primary land characteristics for agricultural systems. The anthropologic factors that influence deforestation include distance to village, distance to main road, and population density. Distances to village and population density are proxy indicators for local consumption, while distance to road is important factors determining the costs of transporting agricultural commodities to market. The CLUE-s model uses a logit model function to quantify the relationship between the probabilities of each land use location and the biophysical and socio-economic location characteristics (Verburg and Veldkamp, 2004) as follows:

$$\text{Log}\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_0 X_{1,i} + \beta_1 X_{2,i} + \ldots + \beta_n X_{n,i}$$

Where Pi is the probability of a grid cell for the occurrence of the specific land use type and X_i variables are the location factors. The coefficients (ßi) are estimated through a logistic regression model using the actual land use pattern as dependent variable and location factors as independent variables. The fit of a logistic regression model is evaluated using the Relative Operating Characteristic method (ROC; Hosmer and Stanley, 2000). ROC values range between 0.5 (completely random) and 1.0 (perfect fit).

Spatial policies and restrictions indicate areas where land use changes are restricted through policies. In this study, existing national parks and wildlife sanctuaries are designated as restriction areas so that further encroachment or changes in these areas are not allowed. The existing protected areas cover approximately 1,361 km^2 or 23% of the PPFC landscape under the integrated-management scenario and 1,737 km^2 or 29% under the conservation scenario (Trisurat, 2006).

Land use type specific conversion settings determine the temporal dynamics of the simulations. Two sets of parameters are essential to characterize each land use type: conversion elasticities, and land use transition consequences. The *conversion elasticities* represent the reversibility of land use change based on capital investment and the investigation of expert judgement, ranging from 0 (easy conversion) to 1 (irreversible change) (Verburg and Veldkamp 2004). In this study, the values of conversion elasticities for evergreen forest, mixed deciduous forest, dry diptercarp forest, scrub and disturbed forest, forest plantation, rubber plantation, agriculture, build-up area, bare soil, and water body were 0.8, 0.8, 0.7, 0.5, 0.7, 1.0, 0.6, 1.0, 0.5 and 1.0, respectively. For example, scrub land and disturbed forest easily shifts when location becomes more suitable for other land use types.

Land use transition consequences determine possibility and sequence of land use transitions. Not all land use changes are possible and many land use conversions follow certain steps. For instance, it is impossible to convert a water body (dam) into agriculture, and agriculture cannot be converted directly to primary forest. Figure 4.3 shows the possible land use transition matrix for this research.

		Future Land Use									
	Land-use	Evergreen forest	Mixed deciduous	Dry dipterocarp	Scrub & distubed forest	Plantation	Rubber	Agriculture	Build-up	Bare soil	Water
Present Land Use	Evergreen forest	1	0	0	1	0	1	1	1	0	0
	Mixed deciduous	0	1	1	1	0	1	1	1	0	0
	Dry dipterocarp	0	1	1	1	0	1	1	1	0	0
	Scrub & dist.forest	0	1	1	1	1	1	1	1	1	1
	Plantation	0	1	1	1	1	1	1	1	1	1
	Rubber	0	0	0	0	0	0	1	0	0	0
	Agriculture	0	0	0	1	1	1	1	1	1	1
	Build-up	0	0	0	0	0	0	0	1	0	0
	Bare soil	0	0	1	1	1	1	1	1	1	1
	Water	0	0	0	0	0	0	0	0	0	1

Figure 4.3 Land use transition matrix (1 = conversion possible; 0 = conversion not possible)

When all inputs are provided, the CLUE-s model calculates the total probability for each grid cell of the specific land use type based on the suitability of location derived from the logit model and the conversion elasticity. The total allocated area of each land use is compared to the total land requirements and restrictions (Verburg and Veldkamp, 2004).

4.3.4 Calculation of Fragmentation Indices

The present land use 2008 and predicted land use 2030 maps were exported to ASCII format and used as the basis for the fragmentation calculation. FRAGSTATS 3.0 software was used to assess landscape structure and fragmentation indices (McGarigal and Marks, 1995). The following indices were calculated to indicate landscape patterns that may have a direct impact on biodiversity:

Area indices: (1) Total area (TA): the total area that the land use class occupies in the study area. (2) Number of patches (NP): the number of patches of a particular land use class. (3) Mean patch size (MPS): average area of a patch of a particular class. (4) Largest patch index (LPI): the percentage of a landscape area occupied by the largest patch of a particular land use class.

Edge indices: Only the total edge length index (TE) was chosen for calculation. The TE is defined as the total length of all edge segments in the corresponding land use class. The edge represents an outer boundary that is environmentally and biologically different from the core area.

Shape index. The mean shape index (MSI) attempts to quantify patch complexity, which can be important for different ecological processes (Forman 1995). It is the ratio of perimeter to area adjusted to account for a particular patch shape (circular or square). The MSI is ≥ 1, without an upper limit.

Core area indices: (1) Mean core area (MCA): the area within a fragment located beyond a specified edge distance (1 km for this study). (2) Total core area (TCA): the sum of the total surface of all areas of a particular land use class (in hectares). A higher total core area indicates less fragmentation.

4.4 Results and Discussion

4.4.1 Land Use Map 2008

The GIS Consultant used stratified random sampling to determine the number of samples classified in preliminary land use classes and compares them with the actual (known) classes during field validation. The total number of sample locations for water, rubber, evergreen forest, deciduous forest and agriculture was 5, 17, 12, 17 and 20 respectively. The contingency table or classification matrix (Table 4.1) shows that three sample locations of water from the total of five were correctly classified (60%), while two samples were misclassified as deciduous forest. This is because water situated in dry diptercarp forest was totally dry in dry season when the images were taken. To avoid misclassification, the water body shown in the final land use map was simply delineated from the updated topographic map at scale 1:50,000. The classification accuracy of rubber, evergreen forest and agriculture was greater than 90%. It is observed that 2, 1, 2, and 1 sample should have been classified as water, rubber, evergreen forest and deciduous forest, respectively and agriculture was not correctly interpreted but added to other classes. The overall accuracy for preliminary land use interpretation was 87%, which is acceptable for most remote sensing scientist.

Table 4.1 Contingency table resulting from field validation

Known classes	No. of samples	Percentage correct	Number of samples classified into class				
			Water	Rubber	Evergreen	Deciduous	Agriculture
Water	5	60%	3	0	0	2	0
Rubber	17	100%	0	17	0	0	0
Evergreen	12	92%	0	0	11	0	1
Deciduous	17	88%	0	0	1	15	1
Agriculture	20	95%	0	0	0	1	19

The land use map for the year 2008 derived from updating the land use map 2002 with the major land use map for the year 2008 is shown in Figure 4.4 and the area for each class is tabulated in Table 4.2 A brief description of each land-use category is given as follows:

Table 4.2 Forest types inside and outside the PPFC Project and their coverage (ha)

Type of land-use	Area in ha			Change in Percentage		Thai.
	2002	2008	+/-	6 yrs.	Yearly	Yearly
Dry evergreen forest	223,877 (20.93%)	223,304 (20.78%	-1,573	-0.70	-0.12	-0.28
Mixed deciduous forest	136,447 (12.75%)	135,870 (12.70%)	-577	-0.42	-0.07	-3.34
Dry dipterocarp forest	211,130 (19.73%)	188,994 (17.67%)	-22,136	-10.48	-1.86	-3.42
Scrub & disturbed forest	134,208 (12.54%)	118,921 (11.12%	-15,287	-11.39	-2.04	-3.79
Forest plantation	3,341 (0.31%)	2,669 (0.25%)	-672	20.11	-3.81	-3.81
Para rubber	1,522 (0.14%)	20,393 (1.91%)	18,871	1,239.88	35.11	35.11
Agriculture	307,251 (28.72%)	322,193 (30.12%)	14,942	4.86	0.79	1.08
Village	9,774 (0.91%)	18,348 (1.71%)	8,574	87.72	9.96	11.12
Bare soil	7,476 (0.70%)	5,895 (0.55%)	-1,581	-21.15	-4.04	-12.30
Water body	34,829 (3.26%)	34,268 (3.20%)	-561	-1.61	-0.27	-0.28
Total	1,069,855	1,069,970	-	-	-	

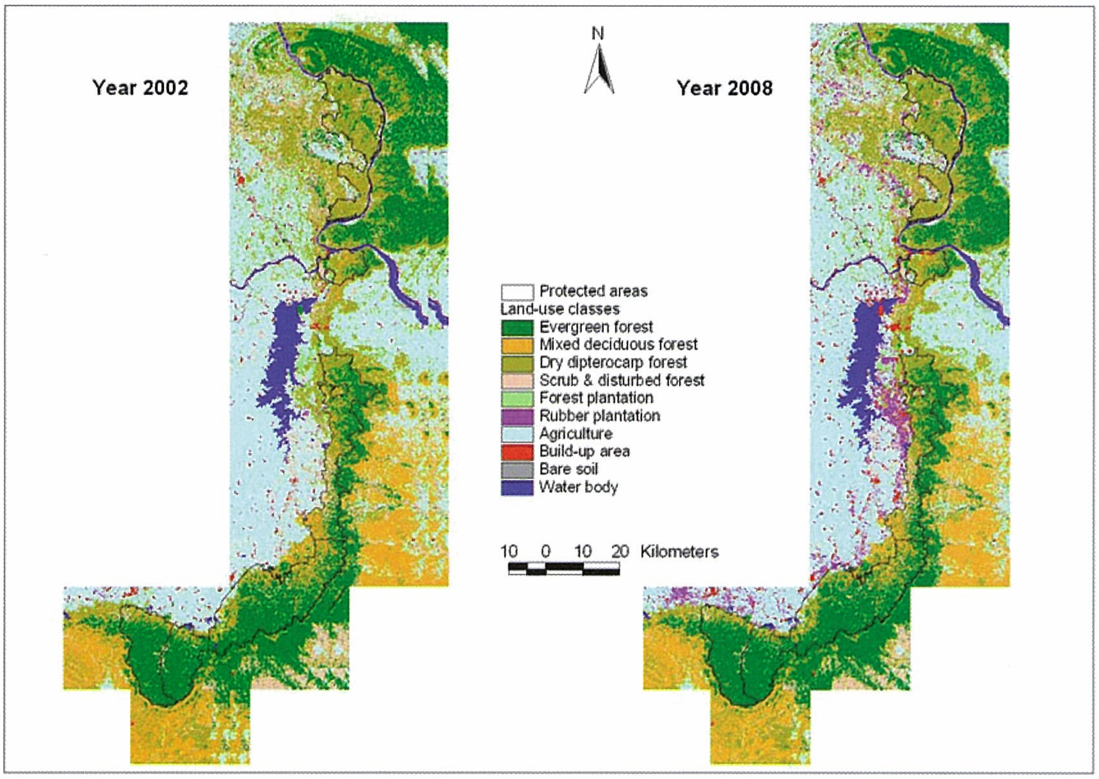


Figure 4.4 Forest types, years 2002 and 2008 in the Pha Taem Protected Forest Complex

Dry Evergreen Forest: According to remote sensing and GIS analysis, it is found that in 2002 dry evergreen forest covered an area of 223,877 ha or 20.93% of the PPFC landscape, and in 2008 it was slightly changed to 223,308 ha or 20.78%. Approximately 1,570 ha were converted to other land uses, especially agriculture and rubber plantation and most of the conversion occurred in the buffer zones of Pha Taem National Park and partially in Bun Thrik-Yot Mon proposed Wildlife Sanctuary.

Mixed Deciduous Forest: Mixed Deciduous Forest basically exists in Lao and Cambodia. In Thailand, it is found along the peripheries of Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary. This forest covered 136,446 ha in 2002 and declined to 135,870 ha in 2008.

Dry Dipterocarp Forest: This forest type usually occurs on dry shallow and lateritic soils and is dominant in Pha Taem and Kaeng Tana National Parks. In 2002, the Dry Dipterocarp Forest covered an area of 221,130 ha or 19.73%. The existing area in 2008 was estimated at 188,994 ha or 16.67%. Thus approximately 22,136 ha or 10.48% of the total area have been converted to agriculture and rubber plantations in 6 years or it has declined 10.48% annually.

Scrub Forest and degraded forest: Scrub Forest has developed extensively on flat areas and well-drained slopes along the stream banks. This forest type has very low economic value. Scrub Forest is mainly scattered to the west of the Pha Taem and to the right of Phu Jong Na Yoi in Lao. The total area in 2008 was 118,921 ha. In the last 6 years, approximately 15,287 ha of scrub forest have been encroached for agriculture, especially inside the buffer zones.

Agricultural area: Agricultural activities are widespread in the PPFC landscape, especially in Thailand. In the PPFC landscape, agriculture constituted nearly 28.72% in 2002 and substantially increased to 30.12% in 2008. However, the increase of agricultural area is fairly small inside the protected areas, except for Bun Thrik-Yot Mon proposed wildlife sanctuary.

Forest plantation: The Forest Industrial Organization (FIO) is the main agency to plant eucalyptus in the PPFC landscape. In addition, a few reforestation stations under the Royal Forest Department have established plantations. Most of the eucalyptus plantations are sited in Bun Thrik District between the Bun Thrik-Yot Mon Proposed Wildlife Sanctuary and the Sirinthon Reservoir. Remote sensing analysis reveals that in 2002 there were about 3,341 ha and they decreased to 2,669 ha in 2008 as land demand for agriculture has been high in the last decade and will continue in the future. Approximately 672 ha of plantations have been cleared for agriculture.

Para rubber plantation: Para rubber cultivation is a new agricultural practice in the PPFC landscape. However, it has increased rapidly in the last decade. Rubber plantation covered an area of 1, 522 ha in 2002 and rapidly increased to 20,393 ha in 2008 or 35% annually during this period. Most plantations are sited in the buffer zone to the west of Bun Thrik, Phu Jong-Na Yoi and Yot Mon. A few patches are observed inside Bun Thrik-Yot Mon Proposed Wildlife Sanctuary.

Bare soil and rock outcrops: This land cover class includes a drawdown zone along the river bank and rock out crop in the PPFC landscape. An area of 1,581 ha of this class was changed to other classes such as seasonally agriculture or water body in the wet season.

Build-up area: As discussed in Chapter 2, there are 82 villages situated within a 3-km buffer of the PPFC and 4 villages are located inside the PPFC. In the last 6 years (2002–2008), human settlements have expanded and almost doubled in size from 9,774 to 18,348 ha. This significant increment is possibly from misclassification among bare soil, agriculture and settlement because these three classes show similar image signatures.

Water bodies: This class includes reservoirs, ponds and major rivers. In 2002, the overall water surface of both reservoirs and major rivers covered approximately 34,829 ha. Based on remote sensing analysis, it was found that the water body covered 34,268 ha in 2008 or decreased 561 ha. This may be due to the fluctuation of water level during wet and dry season and omission error of image classification.

4.4.2 Land Use Allocation for Year 2030

Logit models were used to determine the relations between the locations of eight land use classes (evergreen forest, mixed deciduous forest, dry dipterocarp forest, scrub and disturbed forest, forest plantation, rubber plantation, agriculture and build-up area) and a set of location factors. The results indicate which location factors are positively or negatively correlated with land use distribution (Table 4.3). For instance, nine variables are considered as important determinants of the remaining forest cover in the PPFC landscape. Table 4.3 indicates that forest patches are more likely to be found in high altitude, marginal land, far from village, low population density, and in rugged and slope complex terrain. These areas contain many limiting factors for agriculture. In contrast, areas that are close to a stream network, low altitude, flat terrain, high population density, and accessible from main roads are a prime target for agriculture. High ROC values were found for evergreen forest (0.945), forest plantation (0.850), agriculture (0.858) and build-up area (0.889).

Moderate and relatively high values were found for mixed deciduous forest (0.828), dry dipterocarp forest (0.803) and rubber plantation (0.812). In addition, low value was observed for scrub and disturbed forest (0.670). This is because remaining forest cover is mainly concentrated in rugged terrain and protected areas (Trisurat, 2006), which is similar to agriculture and build-up area in requiring specific land characteristics (e.g. good drainage, easy accessibility). Clay loam soil and annual rainfall are not systematic choices for agriculture because agricultural practices were lumped for analysis. In addition, the location of agriculture area was a result of opportunity to encroach forest. On the other hand, scrub and disturbed forest are relatively randomly distributed in all altitude zones in the PPFC landscape because the areas were left over after illegal logging and encroachment (Trisurat, 2009), thus their ROC value was lower than for other land use classes.

Table 4.3 Significant location factors related to each land use location

Variables	Evergreen forest	Mixed deciduous	Dry dipterocarp	Disturbed forest	Plantation	Rubber	Agriculture	Build-up
Constant	-3.42228	3.89345	-16.42153	-4.94543	-12.45950	2.41928	2.37573	2.69280
Distance to stream	-0.00024	0.00020	0.00160	-0.00110	0.00055	0.00023	0.00015	0.00015
Distance to main road		-0.00055	-0.00020	0.00004	-0.00407	-0.00305	-0.00197	-0.00704
Distance to village	0.00036	0.00019	0.00019	-0.00011	-0.00038	0.00031	-0.00020	-0.00089
Altitude (m)	0.00799		0.00396	0.00208	-0.00560	-0.02673	-0.01075	-0.00092
Slope (%)	0.01866	0.03421	0.01432		0.01372	-0.51215	-0.00730	0.00567
Soil texture *								
• 5 Sandy clay loam	-0.10385	0.07156	1.60175	-0.09764	1.79725	-1.58241	0.35760	
6 Clay loam	-	-0.91541	2.06671	-0.60925	4.16110	-0.12136		0.28074
• *7 Clay*	-0.47745		2.10795	-0.25319	3.04918			
• *8 Sandy loam*	-1.56774	-1.49732	2.61832				-0.23200	
• *9 Loamy sand*	-0.43048		1.28731			-0.20122		
• *10 Slope complex & others*		0.23293	2.55342		2.48797		0.54988	
11Rainfall			0.00784	0.00321	0.00761			
12 Population density	-0.00024	-4.87062	-0.85250	-0.95363	-2.47474	-2.23858	2.37573	
ROC	0.945	0.828	0.803	0.670	0.850	0.812	0.858	0.889
R^2	0.731	0.387	0.337	0.117	0.502	0.399	0.521	0.568

Note: * category variable

4.4.3 Predicted Land Use Changes

The predicted land use/land cover maps in 2030 derived from trend scenario, integrated-management scenario and conservation scenario are shown in Figure 5, while areas of remaining forest cover (natural forest) in 2008 and 2030 and outside protected areas are presented in Table 4.4 The results show that the percentage of remaining forest cover in all protected areas in the PPFC in 2008 was greater than 90%. Forest cover is predicted to decline significantly in Kaeng Tana National Park and Bun Tharik-Yot Mon Proposed Wildlife Sanctuary under the trend scenario without spatial policies and restriction (Figure 4.5). For instance, forest cover in Kaeng Tana will decline from 90.83% in 2008 to 63.49% in 2030, a loss of approximately 27% during 22 years (Table 4.4) because there are a lot of villages residing inside and close to the park. In addition, the population density in Tambons Khong Jiam is higher than for other Tambons in the PPFC landscape.

Approximately 13% of remaining forest in Bun Tharik-Yot Mon proposed wildlife sanctuary will be converted to agriculture. In addition, approximately 10% of the natural forest in the buffer zone is predicted to be converted to additional rubber plantations and agriculture. On the other hand, the percentage of forest cover in Pha Taem, Phu Jong Na Yoi and Yot Dom is only predicted to changed slightly from to other land use types from 2008 to 2030. This is due to Phu Jong Na Yoi and Yot Dom have a rather complex terrain or accessibility to these area is difficult, so opportunities for agriculture are very restricted by natural barriers. In addition, Pha Taem national park is surrounded by scrub and degraded forest, which act as a buffer and absorb human pressures before reaching the park.

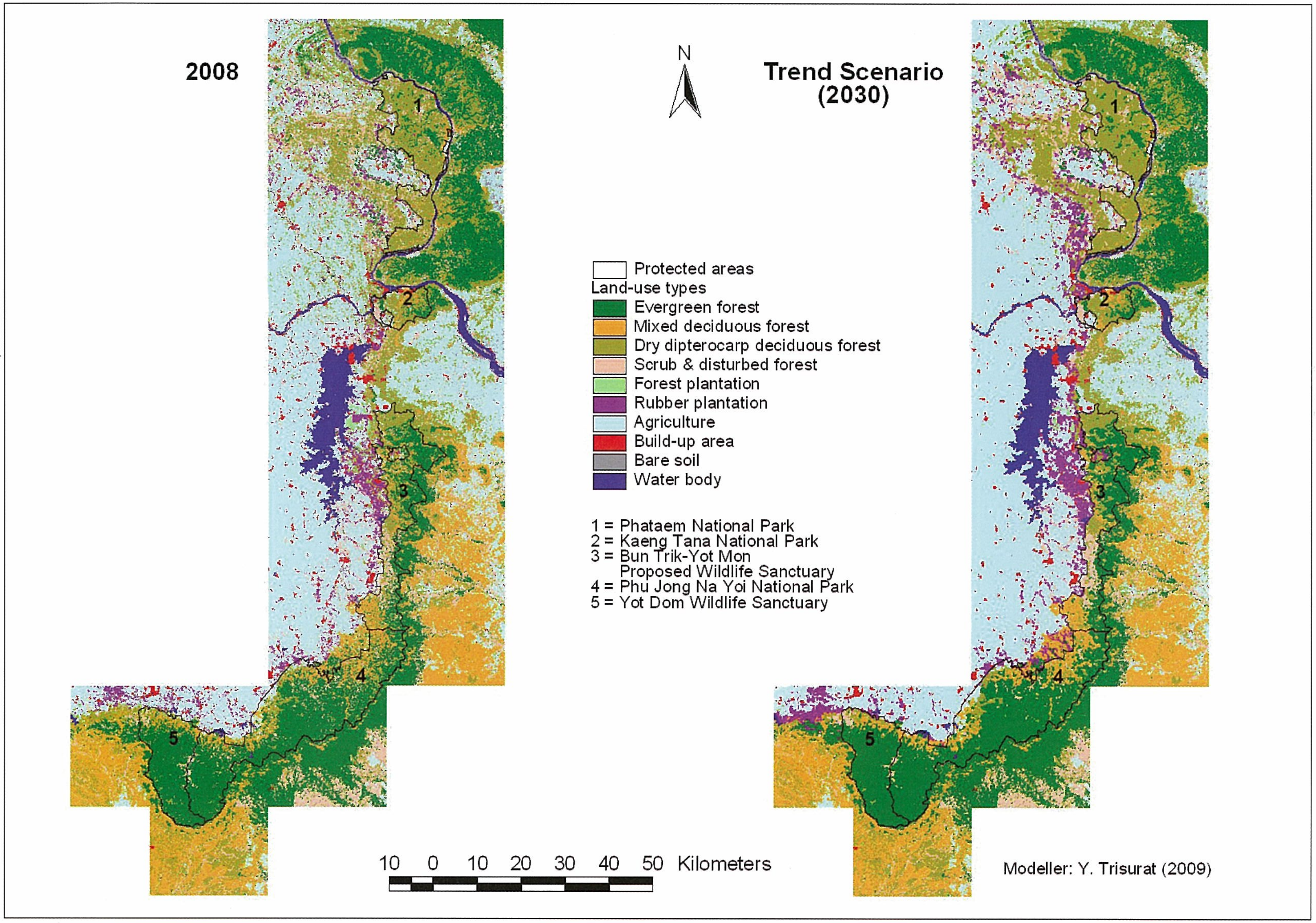


Figure 4.5 Land use in 2008 and predicted land uses in 2030 under trend scenario

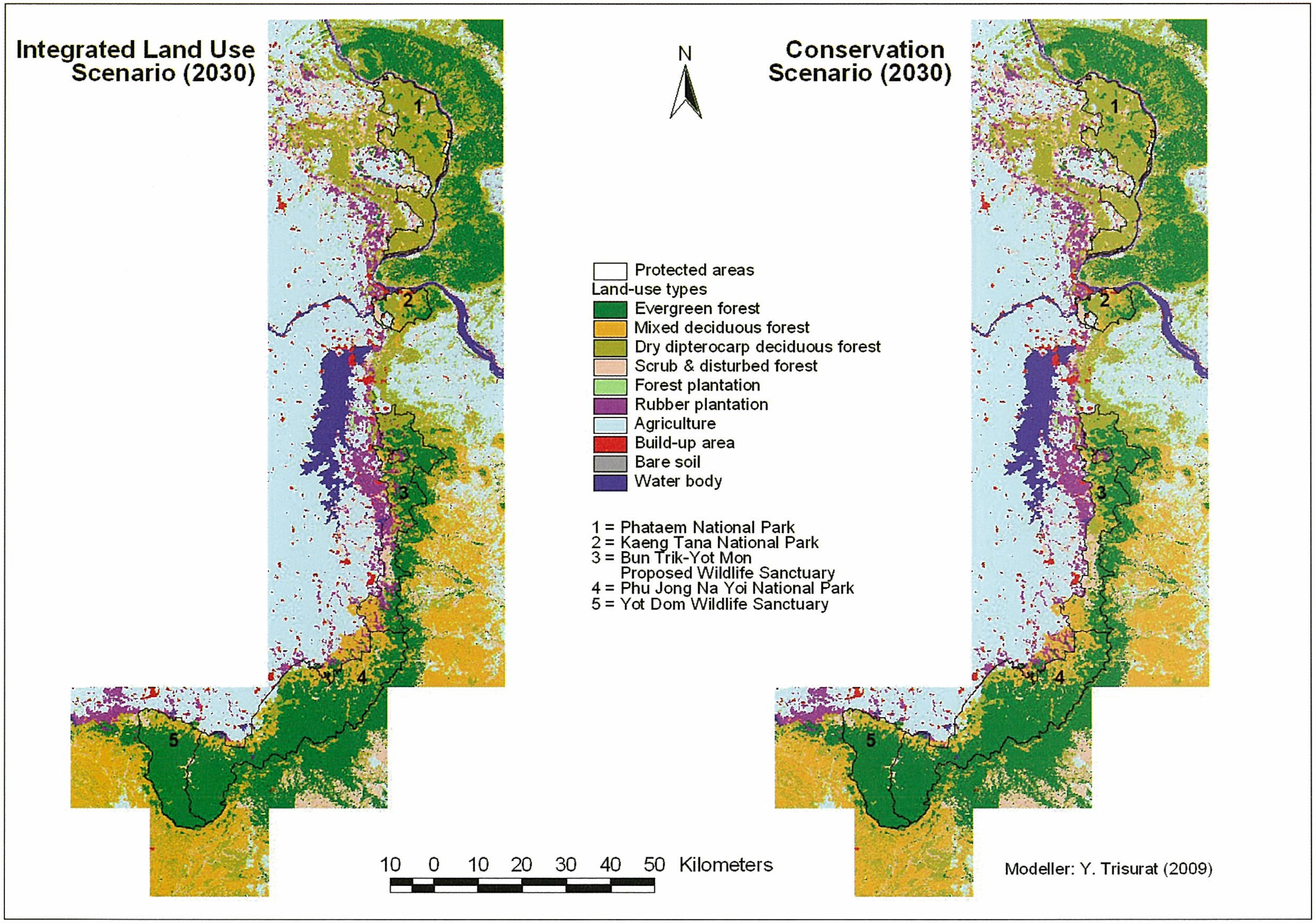


Figure 4.6 Prediction in 2030 of integrated land use and conservation-oriented scenarios

Table 4.4 Land use transitions between 2008 and 2030 based on different land demand scenarios

No.	Protected area name	Total area (km^2)	% forest (2008)	Trend scenario	Integrated mgt. scenario	Conservation scenario
1	Pha Taem National Park	353.2	91.44	89.75	92.51	92.51
2	Kaeng Tana national Park	84.6	89.23	63.49	89.46	89.41
3	Phu Jong-Na Yoi National Park	697.4	96.58	90.61	96.06	96.05
4	Yot Dom Wildlife Sanctuary	235.9	99.49	94.13	99.06	99.03
5	Bun Tharik-Yot Mon Wildlife Sanctuary	365.9	96.41	85.62	85.53	96.73
6	Outside protected areas	4,200.0	25.40	15.63	17.91	17.90
	Total	5,937	45.90	36.81	40.43	40.43

Scenario 2 (integrated land use), with protection of all protected areas except Bun Tharik-Yot Mon proposed wildlife sanctuary, shows different land use patterns. The integrated land use scenario assumes less demand for agriculture, and the increment of rubber plantation is approximately 17,000 ha, leading to a higher remaining forest cover. It is expected that approximately 40% of the PPFC landscape would be under forest cover in 2030. Pha Taem National Park, Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary have more that 90% forest cover in 2030 (Figure 4.6) equivalent to year 2008 because encroachment is not allowed. The substantial increment of forest cover compared to the trend scenario is mainly caused by higher forest cover demand and natural regeneration. Table 4 shows that the percentage of forest cover for Bun Thrik Yot Mon under trend and integrated scenarios is generally the same because encroachment is possible under these two scenarios. Land use patterns for protected areas under the conservation scenario are generally the same as year 2008 because encroachment in protected areas is restricted by spatial policies. The percentage of forest cover in Bun Thrik Yot Mon increases approximate 11% from the trend and integrated land use scenarios. In addition, a few patches of disturbed forest have regenerated to the original stage.

4.4.4 Forest Fragmentation

The results of forest fragmentation indices for forest cover in 2008 and the simulated patterns for 2030 for three scenarios are shown in Table 4.5.

The number of remaining forest patches will decrease significantly for all land use transition scenarios over the next two decades. The total number of patches will decrease from 618 patches in 2008 to 541 patches for scenario 1, 533 for scenario 2 and 536 patches for scenario 3 (Table 4.5). This index and Figure 5 reveal that remnant forests, especially in the west of Pha Taem National Park would be converted to agriculture. The mean patch size of forests decreases from 440 ha in 2008 to 404 ha for scenario 1 and increases slightly for scenarios 2 and 3 in 2030. In addition, the largest patch of forest cover substantially declines from 25% in 2008 to 22% for scenario 1 and 19% for scenario 2 due to fragmentation but remains relatively similar for scenario 3.

The total edge length substantially decreases and the mean shape index is relatively stable and forest patches remain of relatively regular shape (mean shape index ranging from 1.21 – 1.26) (Forman, 1995; Rutledge, 2003), while most of the remaining patches will contain less core area coverage, except for scenario 3. The total core area declines approximately 35% for the trend scenario, 20% for the integrated land use scenario and 10% for the conservation scenario. Small fragmented forest patches surrounded by agricultural land uses can be considered as disturbed forest or sink habitat (Forman, 1995) due to the fact that the whole surface corresponds to a border area.

The area and core area indices derived from FRAGSTATS imply that the projected land use transitions will cause more negative impacts on key wildlife species in the PPFC landscape such as Asian elephant, bear and banteng as they are sensitive to human disturbance. In addition, the mean distance to their nearest neighbors for year 2008 and 2030 are relatively the same (700 m). However, this index considers all patch sizes both small and large. However, it should be realized that the number of patches and mean patch size for the 2030 simulations are substantially different from the current situation and will definitely have negative effects on biodiversity conservation in the PPFC in the future. The overall fragmentation indices derived from FRAGSTATS show that scenarios 2 and 3 will cause less impact on ecological processes than scenario 1. The consequences of land use change on trans-boundary biodiversity conservation and wildlife migration is presented in Chapter 5.

Table 4.5 Landscape indices of forested area in 2008 and 2030

Landscape indices		2030			Change (+/-)		
	2008	Scenario 1	Scenario 2	Scenario 3	08-Scn1	08-Scn2	08-Scn3
Total area (ha)	272,508	218,396	240,052	240,008	-54,112	-3,2456	-32,500
Total core area (ha)	130,968	84,184	105,096	117,144	-46,784	-25,872	-13,824
Mean core area (ha)	222	156	197	218	-66	-25	-4
Number of patches	618	541	534	536	-77	-84	-82
Mean patch size (ha)	440	404	449	447	-36	9	7
Mean shape index	1.21	1.24	1.25	1.26	0.03	0.04	0.05
Landscape shape index	20.26	20.29	20.22	18.93	0.03	-0.04	-1.33
Largest patch index (%)	24.99	21.95	19.03	23.41	-3.04	-5.96	-1.58
Edge length (km)	4238	3797	3963	3709	-441	-275	-529
Mean nearest neighbor (m)	697	702	701	680	5	4	-17
Mean proximity index (10 km)	1104	1062	786	858	-42	-318	-246
Interspersion juxtaposition	44.50	44.37	44.13	46.20	-0.13	-0.37	1.70

4.5 Conclusion

The major land use map year 2008 was interpreted from Landsat imageries using visual interpretation. The derived map was used to update the land use map year 2002 to derive 10 general land-use/land-cover types, namely Dry Evergreen Forest, Mixed Deciduous Forest, Deciduous Dipterocarp Forest, Scrub, eucalyptus plantation, para rubber plantation, agriculture, settlement, bare soil and water body. Meanwhile, land-use changes between 2002 and 2008 were investigated using GIS overlay technique. The results show that forest cover in the buffer zone thus substantially decreased, while rubber plantation increased rapidly in the last 6 years.

It is expected that deforestation will continue, especially outside protected areas unless strict protection measures are seriously undertaken. In this chapter, the CLUE-s model was employed to simulate land use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems at regional level. The model consists of four inputs: 1) land use requirements (demand), 2) location characteristics, 3) spatial policies and restrictions, and 4) land use type specific conversion settings. Three scenarios of land use transitions are predicted in 2030 for the PPFC. In addition, landscape patterns are determined using FRAGSTATS software. This study presents three major findings:

1. The trend scenario is based on a continuation of the trends of land use conversion of recent years. The existing forest cover of 46% of the region in 2008 is expected to decrease to 37% by 2030. The remaining forest cover will be found mainly in Pha Taem National Park, Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary as accessibility to these areas is difficult and land is not suitable for agriculture. Forest cover in Kaeng Tana National Park, Bunthrik Yot Mon Wildlife Sanctuary and buffer zone will decline significantly from year 2002. The lowest loss and highest percentage of forest cover will be found in Yot Dom Wildlife Sanctuary.

2. The integrated land use scenario is directed by the spatial policies and driven by multi-stakeholders in the PPFC that aim to maintain 40% natural forest cover and accommodate 34,500 ha of para rubber plantations in suitable areas. Under this scenario, much forested land in rugged terrain and protected areas will remain due to the fact that the land not suitable for agriculture and a restriction policy being undertaken in the existing protected area network, but despite there being a high demand for rubber plantation in the area. The results of simulation also reveal that all protected areas contain high forest cover and the lowest cover is found in Bunthrik Yot Mon, where land conversion for agriculture and human settlement is allowed. In addition, the estimated forest covers in protected areas derived from scenario 2 are substantially different from the ones obtained from scenario 1 because of higher occurrence of for forest cover and natural regeneration in scenario 2.

3. The conservation scenario produces similar results as the scenario 2. The difference is that a higher percentage of forest cover is found in the Bunthrik Yot Mon proposed wildlife sanctuary due to the restriction policies in all protected areas. It is note that the predicted forest covers in all protected areas are nearly the same in 2030 as year 2008.

Besides forest losses, the landscape indices clearly indicate that scenario 1 will result in more forest fragmentation than scenarios 2 and 3. The continuation of current land use trend will generate more forest fragmentation and remaining patches will contain less core area and consequently will have a negative impact on biodiversity in particular on landscape species that require large areas for survival. Thus, it is essential to take immediate action to reverse the current trend.

V. CONSEQUENCES OF LAND-USE CHANGE ON WILDLIFE DISTRIBUTIONS

5.1 Introduction

Deforestation has been given much attention worldwide in land use and landscape changes because of the alarming rate of forest change and the ecological importance of forest ecosystems. The results of different land use development scenarios presented in Chapter 4 indicate that forest cover in the PPFC landscape will decrease from 45% in 2008 to approximately 37% by 2030 under the trend scenario and 40% under the integrated land use and the conservation-oriented scenarios. In addition, remaining forest cover in the buffer zones will substantially decline due to high land demand for rubber plantations and cash crops. Deforestation causes a number of effects on biological and physical environment such as habitat loss, habitat fragmentation, species extinction, deterioration of soil properties, drought, flooding, etc.

A *habitat* is defined as any part of the biosphere where a particular species can live, either temporarily or permanently (Krebs, 1994). Wildlife habitat can be defined by the quality of resources including food, cover and water, which are necessary to maintain basic physiological functions of animals to survive and reproduce (Patton, 1992). There are several techniques that can be used to assess habitat quality but a promising technique is to use GIS to develop a habitat suitability map which presents the gradient of habitat suitability in the landscape.

Habitat fragmentation is the process of dissecting large and contiguous areas of similar native vegetation types into smaller unites separated by different vegetation types and/or areas of intensive human activity (Saunders *et al*., 1991). Fragmentation occurs in conjunction with loss of area and includes changes in composition, shape and configuration of resulting patches (Rutledge, 2003). A number of landscape indices have been developed to measure the effects of fragmentation. Increased fragmentation often results in the subdivision of the natural environment into isolated patches of different sizes and shapes (Turner and Corlett, 1996). The effects of fragmentation include decreased species richness, increased habitat edges, thus favoring species adapted to edge habitats but preventing species living in core areas (Yahner, 1988), diminished species distribution and gene flow (Raabova *et al.*, 2007). Another consequence of habitat fragmentation is alteration of physical fluxes of radiation, wind and water across the landscape (Saunders et al., 1991). Sahunalu *et al.*, (1993) investigated the effects of reforestation, abandoned area and natural forests on biological and physical environments in the Sakaerat Environmental Research Station. The studies revealed that although reforestation was limited to a single tree species, causing lower species diversity than abandoned area and natural forests, the relative humidity, air and soil temperature and relative light intensity in reforested areas were kept at comparable level with dry evergreen forest in wet and dry seasons. In addition, storage of organic matter increased with stand age of plantation and would be comparable to natural forests in the future.

5.2 Objectives

The objective of this chapter is to assess the consequences of predicted land-use and landscape change on wildlife species distribution and trans-boundary biodiversity conservation across the Emerald Triangle Protected Forests Complex, especially the proposed biodiversity corridor.

Specific objectives are as follows:

- to generate wildlife suitability maps using habitat models derived from the Project Phase I;
- to predict high concentrations of wildlife or hotspots in the PPFC landscape by 2030 under different land demand scenarios; and
- to assess the potential impacts of land use change on each wildlife distribution and biodiversity hotspots, as well as the potential biodiversity corridor.

5.3 Methodology

The GIS Consultant used Geographic Information Systems (GIS) to develop wildlife habitat maps showing location where a particular species can live, either temporarily or permanently in the landscape (Krebs, 1994). The wildlife habitat mps were developed using the deductive approach that extrapolated known habitat requirements that were given by wildlife experts. This approach was used due to limited sightings from the ground and security issues. Therefore, the GIS output product of the deductive approach only identifies potential habitat, but does not imply that the species is actually present at a given location.

Eight wildlife species were selected as key species for trans-boundary biodiversity conservation. These species included leopard, Asian elephant, banteng, sambar, serow, pig-tailed macaque, Siamese-fireback pheasant and Siamese crocodile. The general approach to define habitat suitability of each species and assess consequence of land use change is as follows:

- Update spatial data related to wildlife distribution;
- simulate the wildlife distribution model for each species using the wildlife habitat model developed in Project Phase I under different land demand scenarios;
- generate hotspots of selected wildlife species in the PPFC landscape; and
- assess the extent and magnitude of the changes of wildlife distributions and wildlife hotspots .

Figure 5.1 shows the framework of data analysis, and further details of each step are described in the following sections.

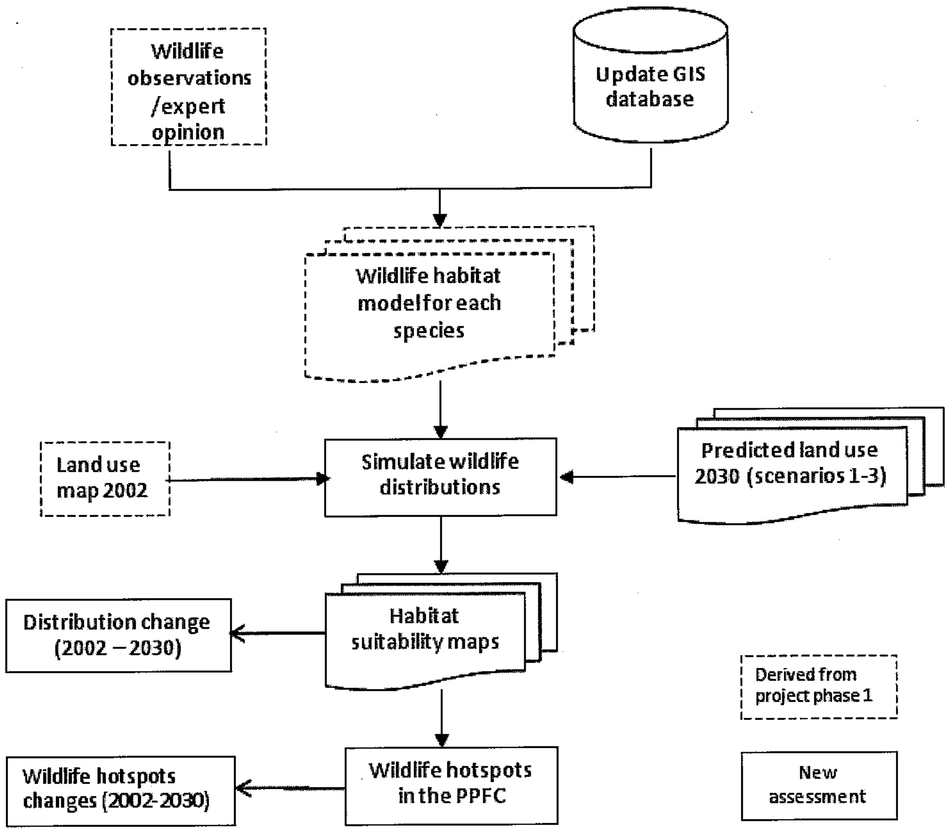


Figure 5.1 Flowchart of the assessment framework for wildlife suitability habitats

5.3.1 Update Wildlife Habitat Factors

During the project phase I, the GIS Consultant worked closely with the Wildlife Consultant to determine important habitat factors for wildlife distribution in the PPFC landscape. Four biophysical factors were selected to form the basis of natural wildlife habitats and three anthropogenic factors. These factors include land use/land cover, accessibility to permanent water, elevation and slope. Land use type is a significant factor to provide hiding cover and forage for herbivore species while water is a resource necessary for animals to survive, especially in the dry season, and to reproduce (Patton, 1992). Elevation and slope are physical barriers for wildlife migration because most species prefer to inhabit lowland area rather than rugged terrain. In addition, prey layer derived by combining likely presence of sambar, serow and banteng was added to determine habitat suitability of leopard.

Human factors were identified as distance to road, distance to ranger station and distance to village. All roads (paved and, unpaved road, and trails) were digitized and head-up digitized.

The GIS Consultant did not update elevation and slope because they are stable geographical features and are expected not to change in the next three decades. On the other hand, other variables have been changes during 2002-20008 and changes are expected to continue due to future development. For instance, more paved roads, water bodies and villages were found during 2002-2008. Therefore, the GIS Consultant updated these layers by digitizing from topographic maps of 1:50,000 scale and satellite images. In addition, locations of villages and ranger stations were both digitized from the topographic maps and data obtained from field surveys. The predicted land use map in 2030 was derived from land allocation model (dyna-CLUE). All GIS data were projected to a geo-referenced coordinate system WG1984 UTM zone 48N (see details in Chapters 2-4).

5.3.2 Developing wildlife habitat models

The GIS Consultant employed the *deductive model* and mathematic combination method developed in the Project Phase 1 to generate wildlife distribution in 2030. This was done as the objective of wildlife modeling was to compare wildlife distributions and wildlife hotspots between 2002 and 2030. Therefore, the GIS Consultant used the previous models in order to be consistent with previous analysis.

After all spatial data had been updated and classified, ranking scores to determine habitat suitability were assigned to all spatial criteria: 3 (suitable), 2 (moderate) and 1 (not suitable), as shown in Table 5.1. These ranking scores were given by the Wildlife Expert and GIS Consultant during the Project Phase 1.

Table 5.1 Spatial criteria and ranking scores for wildlife habitat suitability

Theme	Classes	Leopard *	Asian elephant	Banteng	Sambar	Southern serow	Pig-tailed macaque	Siamese fireback pheasant	Siamese crocodile
Land use	Dry Evergreen Forest	3	3	2	2	3	3	3	3
	Mixed Deciduous Forest	2	2	3	3	2	3	2	2
	Deciduous Dipterocarp Forest	2	2	3	3	2	1	1	1
	Scrub	2	2	2	3	1	1	1	2
	Eucalyptus plantation	1	1	1	1	1	1	1	1
	Para rubber	1	1	1	1	1	1	1	1
	Agriculture	1	1	1	1	1	1	1	1
	Settlement	1	1	1	1	1	1	1	1
	Bare soil	1	1	1	1	2	1	1	1
	Water body (reservoir)	1	1	1	1	1	1	1	1
Elevation (m)	0–200	3	3	3	3	1	3	3	3
	200–400	3	3	3	3	2	3	3	3
	400–600	2	3	2	2	3	3	2	2
	600–800	1	2	1	2	3	2	2	1
Slope (%)	0–10	3	3	3	3	1	3	3	3
	10–20	3	3	2	2	1	3	3	3
	20–30	2	2	2	2	2	3	2	2
	30–50	1	1	1	1	3	2	2	1
	>50	1	1	1	1	3	1	1	1

* Leopard – also includes prey distribution.

Table 5.1 Spatial criteria and ranking scores for wildlife habitat suitability (cont.)

Theme	Classes	Leopard	Asian elephant	Banteng	Sambar	Southernserow	Pig-tailed macaque	Siamese fireback pheasant	Siamese crocodile
Accessibility	<500	3	3	3	3	3	3	3	3
To permanent water (m)	500–1,000	3	3	3	2	3	3	3	2
	1,000–2,000	2	2	2	2	2	3	2	1
	2,000–3,000	2	2	1	1	2	2	1	1
	>3,000	1	1	1	1	1	2	1	1
Distance to main road (km)	< 2	1	1	1	1	1	1	1	1
	2–5	1	1	1	2	2	2	2	1
	5–7	2	2	2	3	3	3	3	2
	> 7	3	3	3	3	3	3	3	3
Distance to ranger station (km)	< 1	1	1	1	1	1	1	1	1
	1–3	2	2	2	3	2	3	3	2
	3–5	3	3	3	3	3	3	2	2
	>5	3	3	3	2	2	2	2	3
Distance to village (km)	< 3	1	1	1	1	1	1	1	1
	3–5	1	1	1	2	2	2	2	1
	5–10	2	2	2	2	2	3	3	2
	> 10	3	3	3	3	3	3	3	3

* Leopard–also includes prey distribution.

5.3.3 Simulating Wildlife Distribution Models

After the ranking scores were assigned to all habitat factors of all species, the original attribute data of the GIS database were recoded to the given ranking scores. For example, the data in Table 5.1 shows that dry evergreen forest is suitable for the leopard; therefore this class is recoded as score 3. Meanwhile, score 2 is assigned for mixed deciduous forest, dry dipterocarp forest and scrub while score 1 is given to the remaining classes which are naturally not suitable for the leopard.

The next step was to convert individual habitat factor from vector format to raster format, and a pixel resolution of 100 m x 100 m was chosen to represent the value of ranking scores. Then all habitat factors were superimposed into one layer using raster-based GIS ArcView and ArcGIS softwares. The output map contained accumulated scores of seven habitat factors (except for the leopard which also comprised prey coverage, e.g. banteng, sambar and serow).

Finally, the accumulated scores were categorized into five classes to represent habitat suitability index: (1) low suitability, (2) relatively low suitability, (3) moderate suitability, (4) relatively high suitability and (5) high suitability. In addition, high concentrations of focal wildlife species or *hotspots* were also evaluated. The superimposed maps of eight species, viz. the leopard, Asian elephant, banteng, sambar, southern serow, pig-tailed macaque, Siamese fireback pheasant and Siamese crocodile, were again overlaid using grid-based modeling, and the output map was also classified into five classes to represent species richness in the PPFC landscape.

5.3.4 Statistical Analysis

The GIS Consultant calculated the predicted extent of wildlife distribution change between 2002 and 2030. The relatively high suitability and high suitability were combined and renamed as likely presence, while the remaining classes were grouped and categorized as likely absence. The total area of likely presence in 2002 and 2030 under different land demand scenarios were compared. In addition, the GIS Consultant also used a descriptive statistics, a paired samples correlation and a paired-samples T-test to test temporal different in species distributions and wildlife hotspots under different land demand scenarios. Means ± standard deviation (SD) were also reported throughout with statistical significant of $P < 0.05$ using a statistical analysis package.

5.4 Results

5.4.1 Habitat Suitability Assessment

Leopard *Panthera pardus*

Estimated areas under trend scenario of low suitability, relatively low suitability, moderate suitability, relatively high suitability and high suitability for the leopard in 2030 are 27.02, 18.62, 13.87, 24.15 and 16.34% respectively. Leopard is likely found in three places: Phuxiangthong NBCA, the eastern border of Bun Thrik-Yot Mon Proposed Wildlife Sanctuary, and the forested patch along the western border of Phu Jong-Na Yoi National Park (Figure 5.2). The last area contains the largest portion of high suitability. The likely presence location (relatively high and high suitable classes) covers 40.48% of the PPFC landscape (Table 5.2). The natural habitats in Thailand's protected areas are estimated as having moderate suitability for the leopard. Areas along the western border are classified as relatively low to low suitability. This is due to the fact that most areas are disturbed by humans, and preys of the leopard, e.g. sambar, serow and banteng are limited.

Asian elephant *Elephas maximus*

The suitable areas for Asian elephant covers approximately 38% in 2030. Most suitable habitats extend along the national border areas, while the western Phu Jong-Na Yoi and Bun Thrik-Yot Mon shows moderate suitability, In these areas paved roads are few, human settlements are distant and dry evergreen forest is dominant. In addition, data from the field survey show a number of migratory routes that elephants from Laos use to migrate to Thailand in the wet season and back to Laos in the dry season. On the other hand, most areas situated in the western part of the PPFC complex are predicted as having low to relatively low suitability for the elephant. These areas have been totally converted to farmland or human settlement and a dense road network has been constructed (Figure 5.3).

Banteng *Bos javanicus*

Highly suitable habitats are found in lowland deciduous forests in Cambodia and Laos in the southern PPFC landscape. They are also scattered in the northern and western portions but these patches are not extensive (Figure 5.3). In Thailand, the banteng can possibly be discovered in the western Phu Jong-Na Yoi National Park because the adjacent areas next to these regions are covered with large contiguous deciduous forests and human disturbances are few. In fact, the PPFC was originally suitable for the banteng because it contained lowland deciduous forest. However, its habitats and population have been greatly reduced by human presence and illegal hunting. The estimated likely occurrence in 2030 covers 34-37% of the PPFC landscape (Table 5.2).

Sambar *Cervus unicolor*

Estimated areas of likely presence of sambar cover 46-49% of the PPFC landscape in 2030. Highly suitable habitats are found in the Phuxiangthong NBCA in the lowland deciduous forest in Cambodia, Laos and along the national border in Phu Jong Na Yoi where dry dipterocarp forest is dominant. It is observed that Yot Dom wildlife sanctuary was classified as of moderate to low suitability for sambar because dry evergreen forest is dominant. Even though, Pha Taem and Kaeng Tana national parks are covered with deciduous dipeterocarp forest, which is bio-physically suitable for the sambar, the spatial analysis shows that it is classified as moderately suitable. This is due to the fact that the area is significantly disturbed by human presence (Figure 5.5).

Southern serow *Naemorhedus sumatraensis*

Estimated areas of relatively high to high suitability for the serow are 14 and 4.5% respectively. Highly suitable habitats are found in steep forested areas or rugged terrains, mainly in Yot Dom and Phuxiangthong NBCA. The remaining areas in Cambodia and Laos and the western PPFC landscape are not suitable for the serow because these areas are flat (Figure 5.6). By considering the individual protected areas, Yot Dom and Phu Jong-Na Yoi are predicted as highly and moderately suitable for serow, respectively.

Pig-tailed macaque *Macana nemestrina*

Estimated area of likely habitat (relatively high and high suitability) for this macaque is 46.57% of the PPFC landscape. This species prefers dense forest; therefore it is potentially common in Bun Thrik-Yot Mon, Phu Jong-Na Yoi and Yot Dom where dry evergreen forest is dominant. Most areas in Loas and Cambodia are moderately to highly suitable (Figure 5.7).

Siamese fireback pheasant *Lophura diardi*

Predicted areas of low suitability, relatively low suitability, moderate suitability, relatively high suitability and high suitability for this pheasant in 2030 are approximately 12, 12, 29, 30 and 15% respectively. Thus, the likely occurrence covers 46%. The distribution of the pheasant is quite similar to that of the pig-tailed macaque but it extends further in deciduous forest (Figure 5.8).

In Thailand, Siamese-fireback pheasant is possibly found in Phu Jong-Na Yoi and in parts of Yot Dom. Based on the habitat model, the forested areas in Cambodia and Laos are predicted to have relatively high to high suitability because this species prefers dense forest. As for the macaque, the natural landscapes of Pha Taem and Kaeng Tana are not suitable for the pheasant (Figure 5.8). A number of Siamese fireback pheasants have been reduced because of poaching for bush meat.

Siamese crocodile *Crocodylia siamensis*

High quality habitats of the crocodile extend along riparian habitats where water is available all year round. The likely occurrence of the crocodile covers 33.4% of the PPFC landscape in 2030. Originally, large areas of the PPFC contained suitable habitats but the crocodile population has been greatly reduced in these areas due to illegal poaching. It is predicted that highly suitable habitats can be found along the Lam Dom Yai River and in parts of western Phu Jong-Na Yoi (Figure 5.9). The riparian habitats in Laos and Cambodia were classified as highly suitable due to limited human disturbance. The PPFC is one of the few protected areas in Thailand that still sustain the fresh water crocodile (Trisurat, 2003).

Table 5.2 Percentage of suitability class of each species in the PPFC landscape under different land use development scenarios

Statistic	Leopard	Asian elephant	Banteng	Sambar	Southern serow	Pig-tailed macque	Siamese fireback pheasant	Siamese crocodile	Hotspots
2002									
Low	24.00	7.33	7.47	18.46	33.59	11.26	11.99	18.07	18.78
Rel. low	19.30	19.00	16.83	15.72	25.08	20.70	12.35	15.85	21.93
Moderate	16.29	35.71	37.10	16.56	23.98	21.47	29.65	32.66	19.25
Rel. high	24.12	23.74	24.92	32.29	12.86	25.25	30.77	22.95	24.20
High	16.29	14.22	13.69	16.97	4.50	21.32	15.24	10.46	15.84
Likely presence	**40.41**	**37.96**	**38.60**	**49.26**	**17.36**	**46.57**	**46.02**	**33.41**	**40.04**
Land use trends (scenario 1)									
Low	27.02	9.53	15.74	23.07	32.59	11.38	12.12	19.58	21.79
Rel. low	18.62	19.98	15.61	16.05	24.18	20.97	12.51	15.44	21.49
Moderate	13.87	32.58	34.01	14.36	24.86	21.15	29.33	31.58	17.26
Rel. high	24.15	23.59	22.64	29.75	13.80	24.85	30.56	22.82	24.28
High	16.34	14.36	12.00	16.78	4.57	21.65	15.48	10.57	15.19
Likely presence	**40.48**	**37.85**	**34.64**	**46.53**	**18.37**	**46.50**	**46.04**	**33.40**	**39.47**
Integrated land use (scenario 2)									
Low	26.31	9.53	11.10	18.46	34.25	11.38	12.12	19.58	20.16
Rel. low	18.01	19.98	18.61	15.72	22.53	20.98	12.52	15.44	21.73
Moderate	15.17	32.58	33.54	16.56	24.64	21.14	29.33	31.58	18.26
Rel. high	24.16	23.55	24.09	32.29	13.91	24.84	30.56	22.82	24.22
High	16.35	14.36	12.66	16.97	4.65	21.66	15.48	10.57	15.62
Likely presence	**40.51**	**37.91**	**36.75**	**49.26**	**18.56**	**46.50**	**46.03**	**33.40**	**39.84**

Statistic	Leopard	Asian elephant	Banteng	Sambar	Southern serow	Pig-tailed macque	Siamese fireback pheasant	Siamese crocodile	Hotspots
Conservation-oriented land use (scenario 3)									
Low	26.29	9.55	11.08	18.65	34.31	11.38	12.12	19.61	20.35
Rel. low	17.99	19.96	18.62	15.70	22.44	20.97	12.51	15.38	28.22
Moderate	15.20	32.57	33.58	16.36	24.67	21.15	29.33	31.59	15.21
Rel. high	24.16	23.56	24.06	32.16	13.93	24.85	30.56	22.84	23.74
High	16.36	14.36	12.66	17.13	4.65	21.65	15.48	10.57	12.49
Likely presence	**40.51**	**37.92**	**36.73**	**49.29**	**18.58**	**46.50**	**46.04**	**33.41**	**36.22**

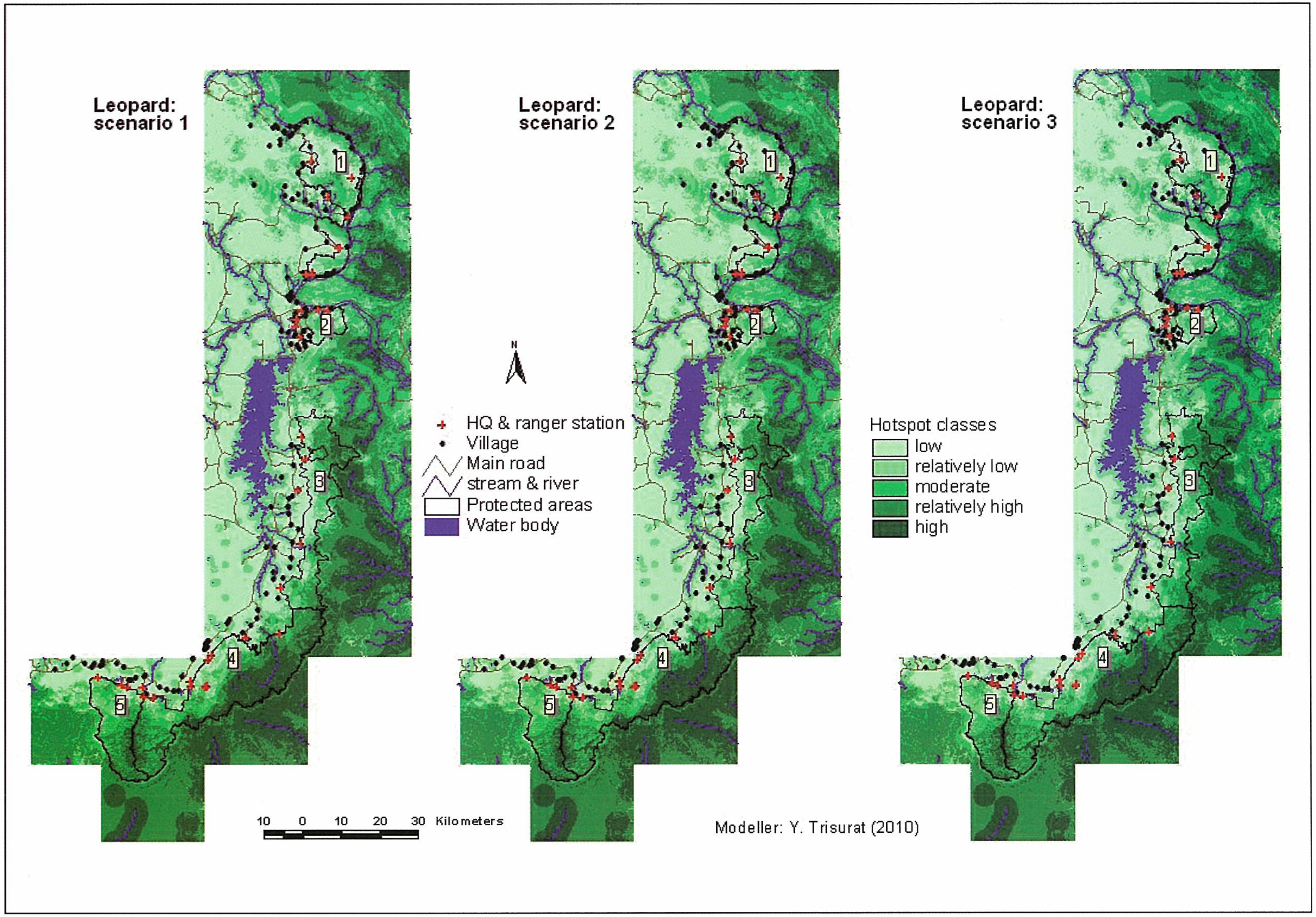


Figure 5.2 Predicted suitable habitats for leopard in the PPFC landscape by 2030

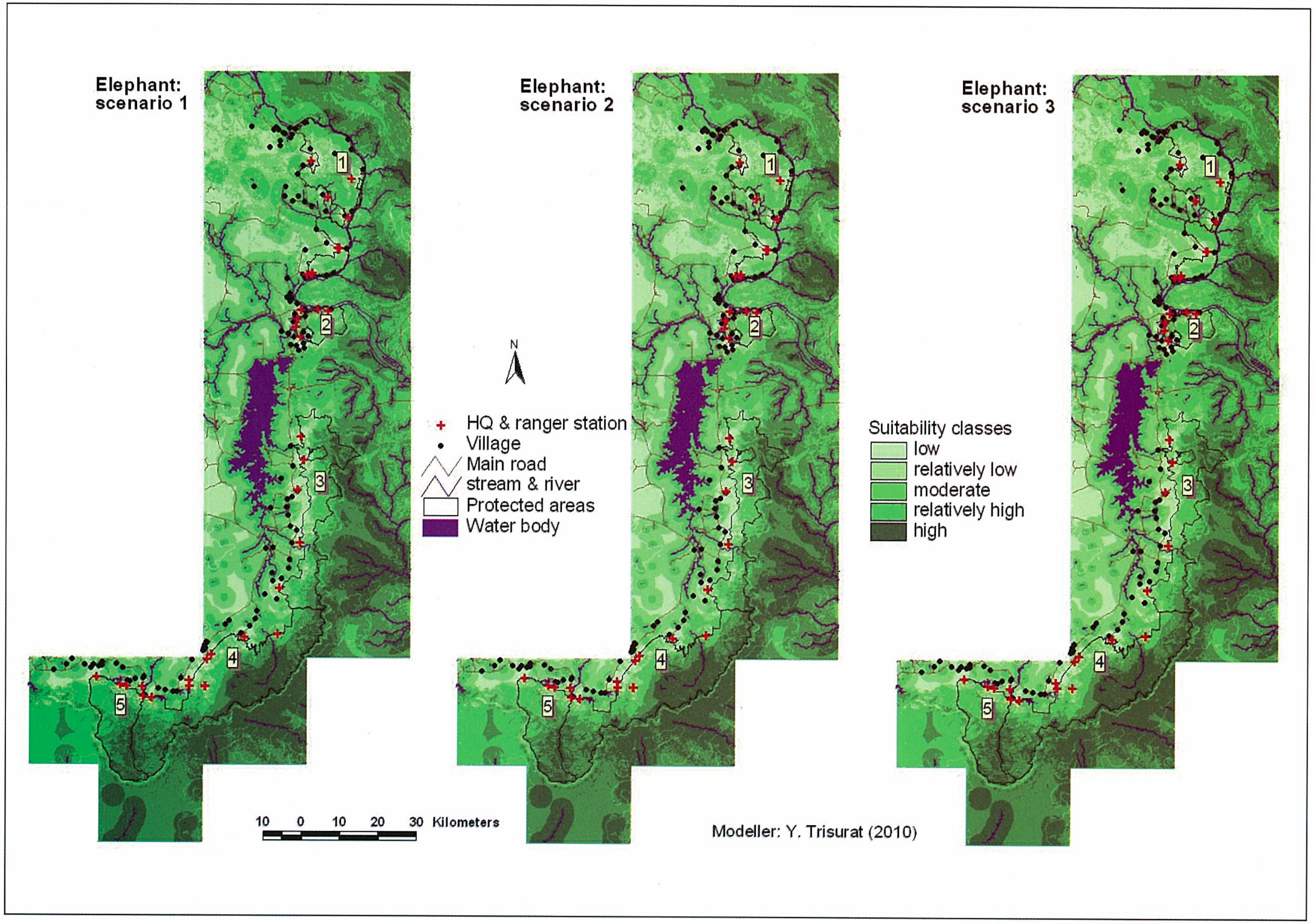


Figure 5.3 Predicted suitable habitats for Asian elephant in the PPFC landscape by 2030

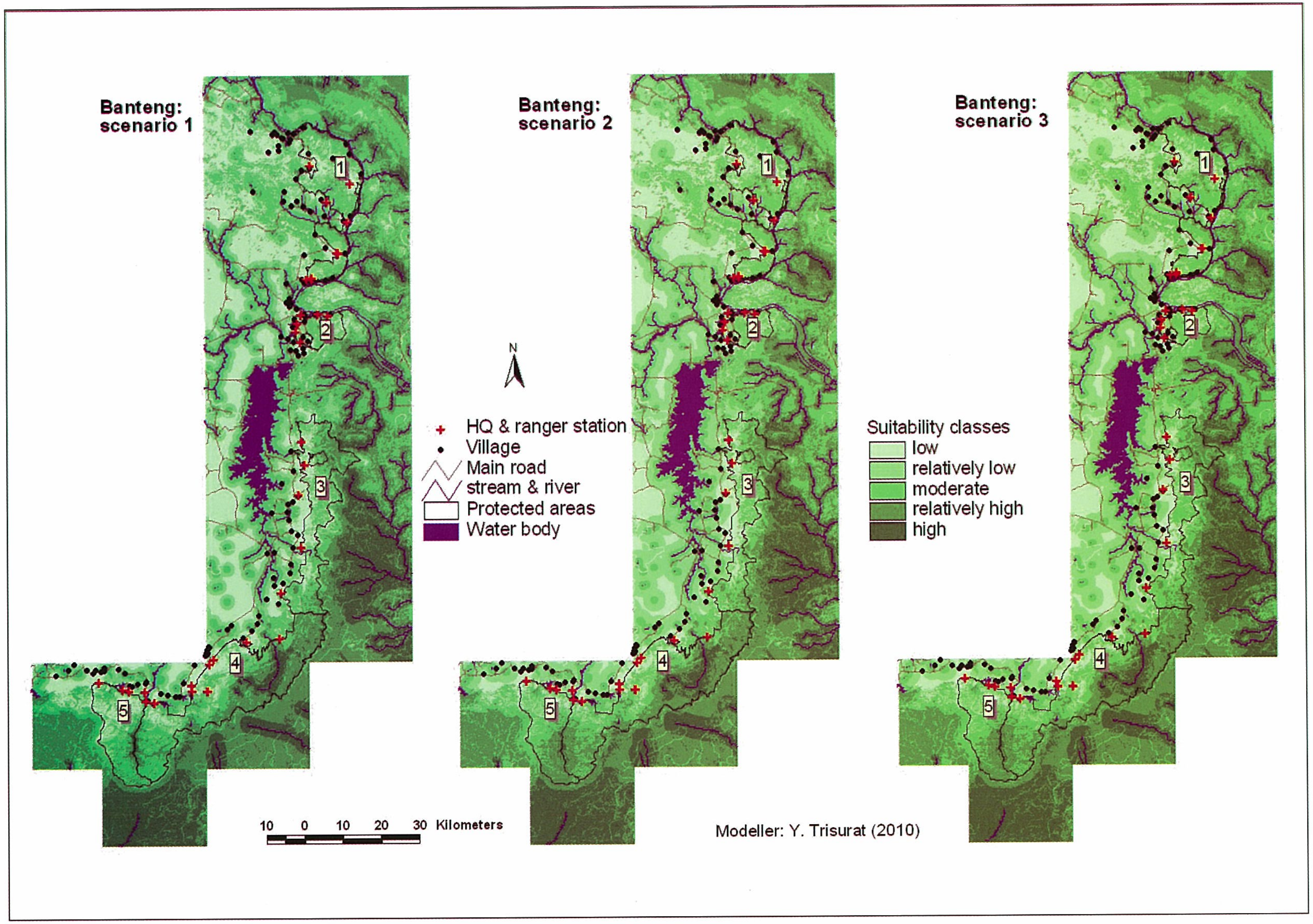


Figure 5.4 Predicted suitable habitats for banteng in the PPFC landscape by 2030

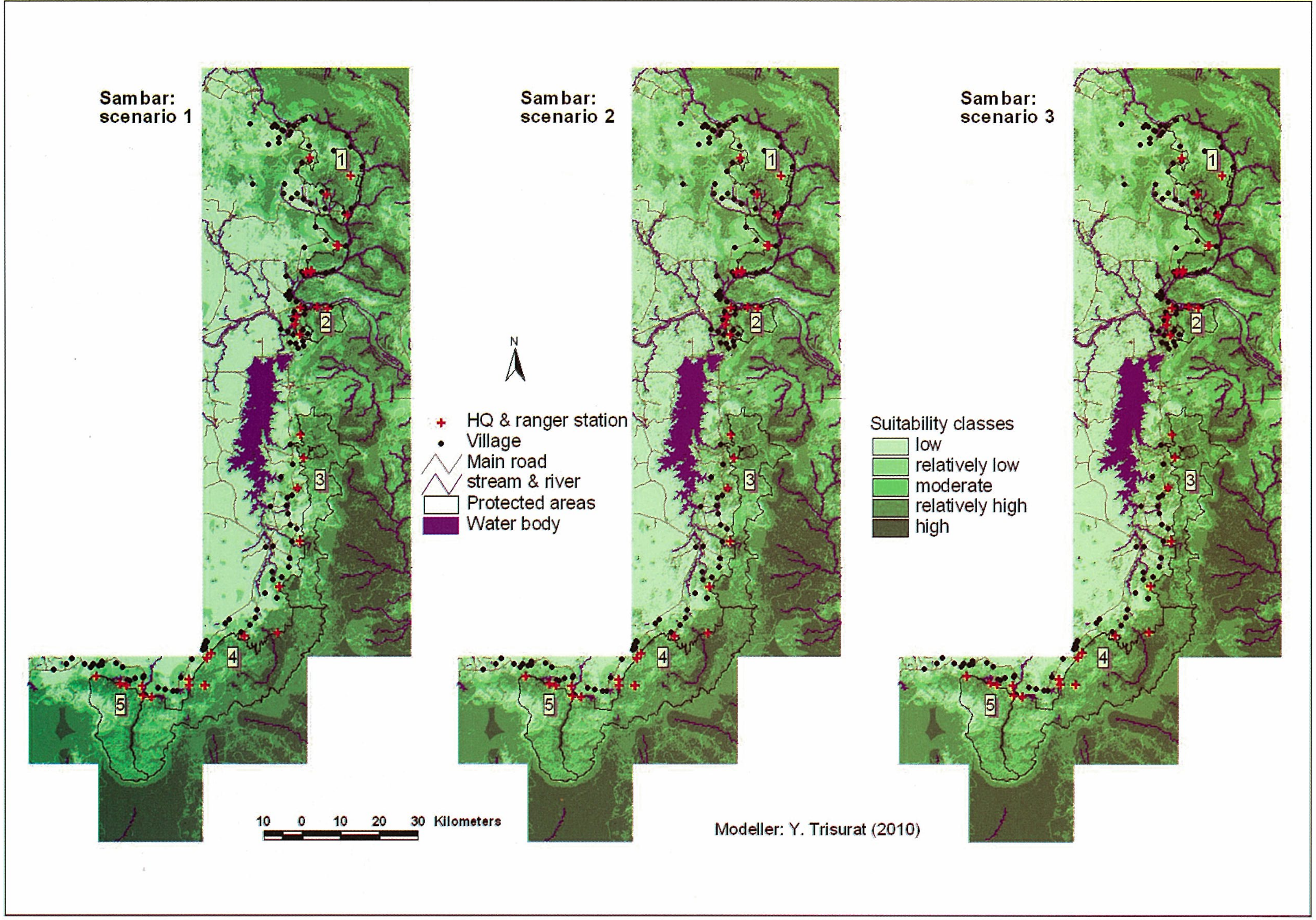


Figure 5.5 Predicted suitable habitats for sambar in the PPFC landscape by 2030

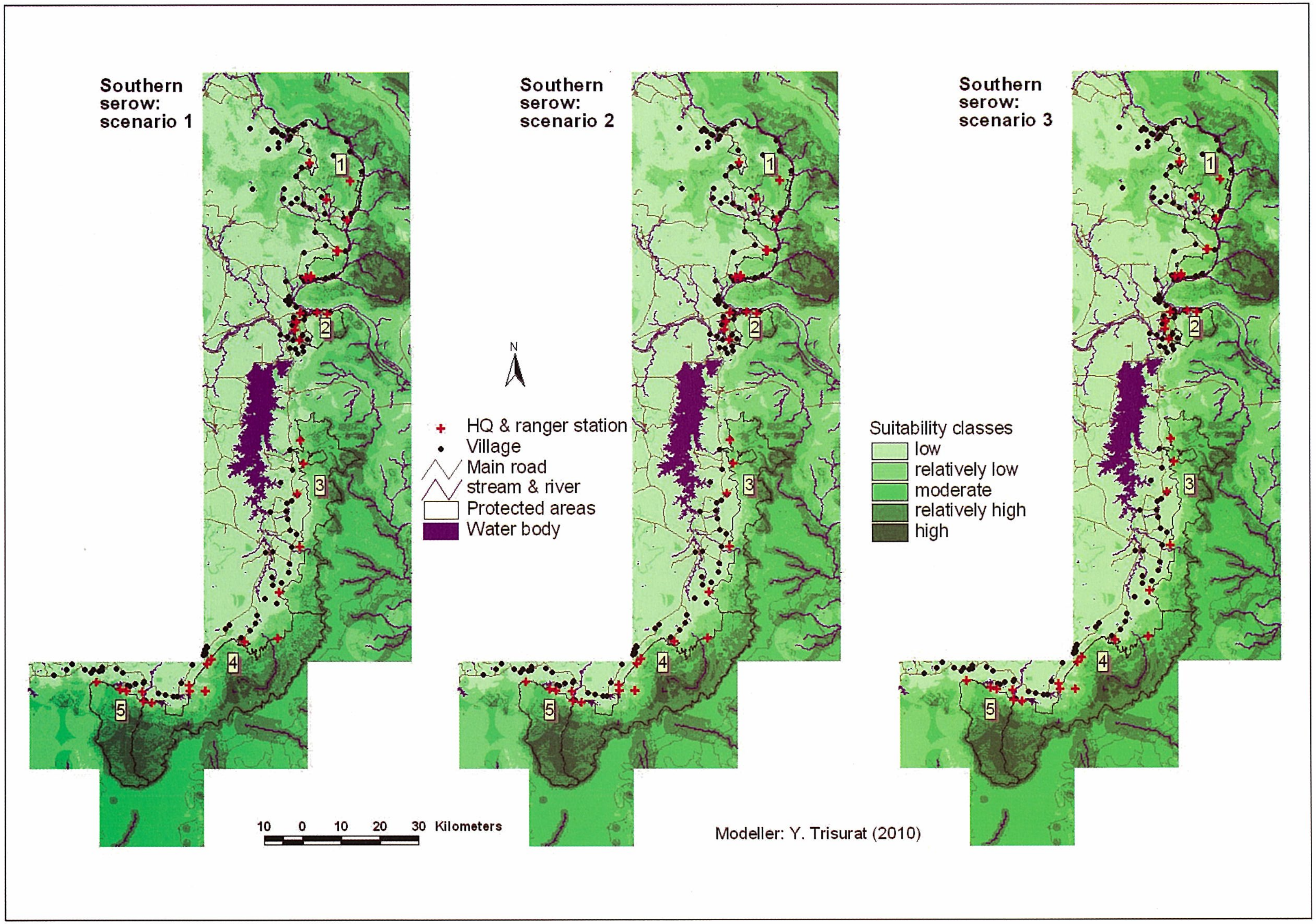


Figure 5.6 Predicted suitable habitats for Southern serow in the PPFC landscape by 2030

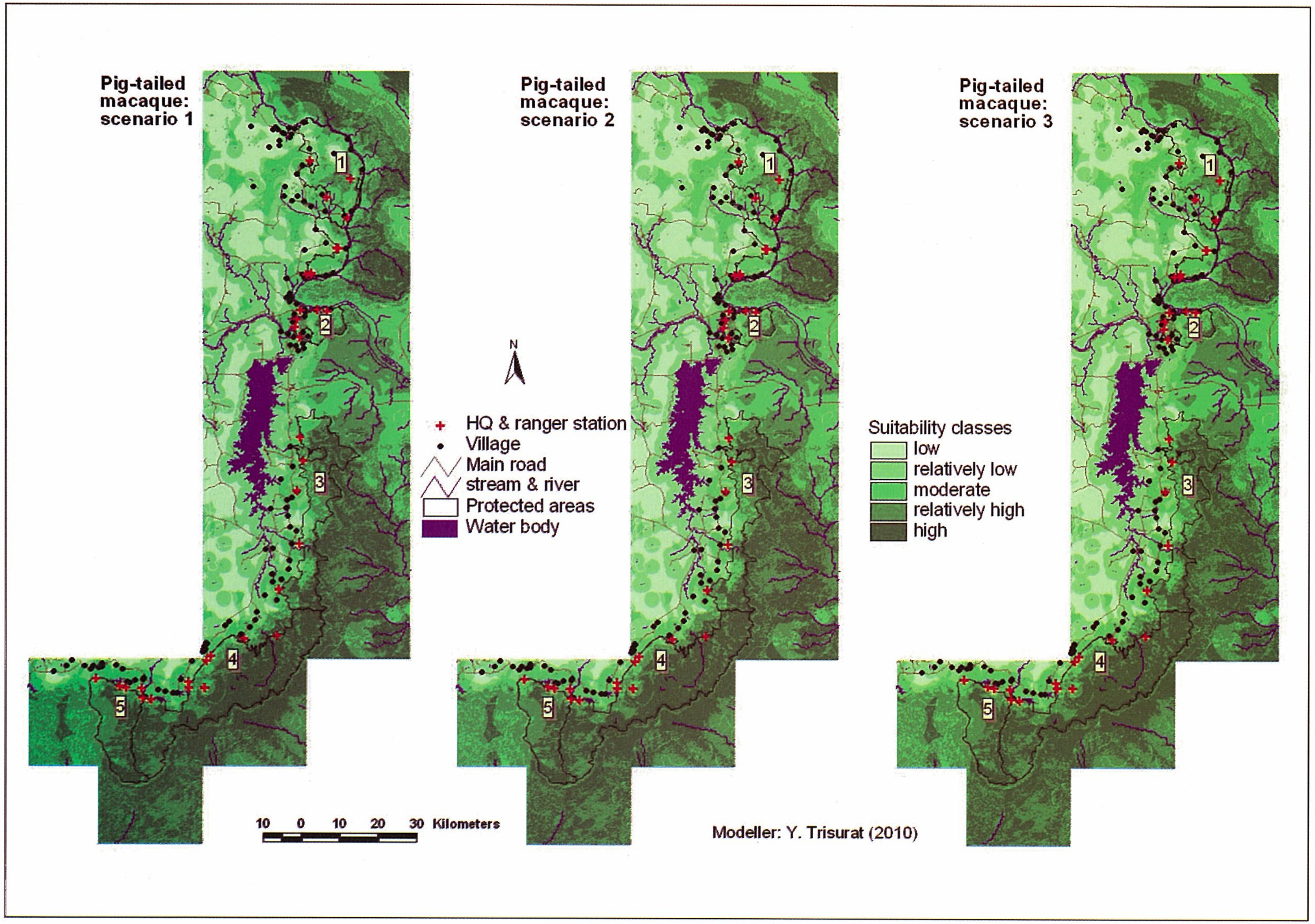


Figure 5.7 Predicted suitable habitats for pig-tailed macaque in the PPFC landscape by 2030

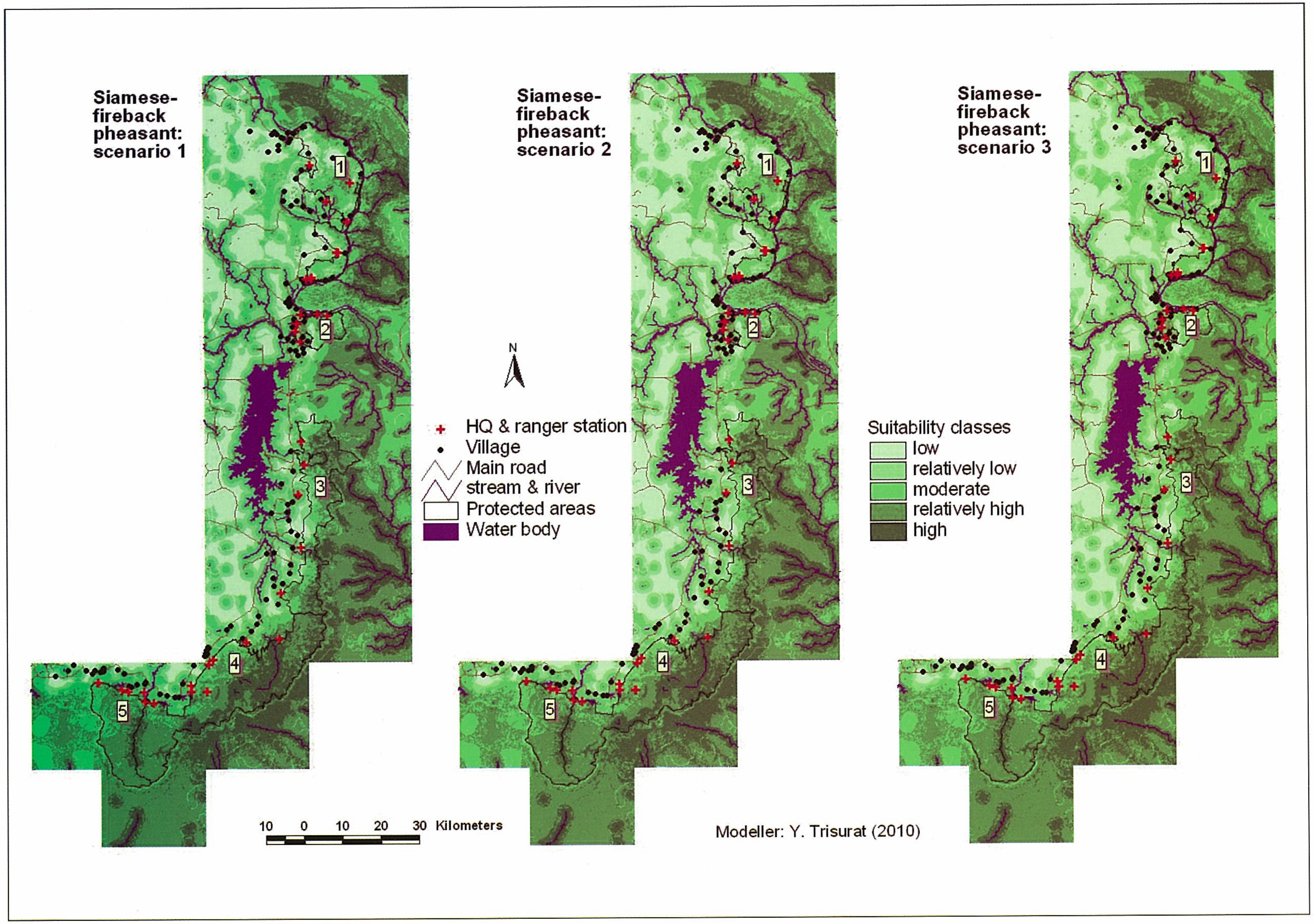


Figure 5.8 Predicted suitable habitats for Siamese-fireback pheasant in the PPFC landscape by 2030

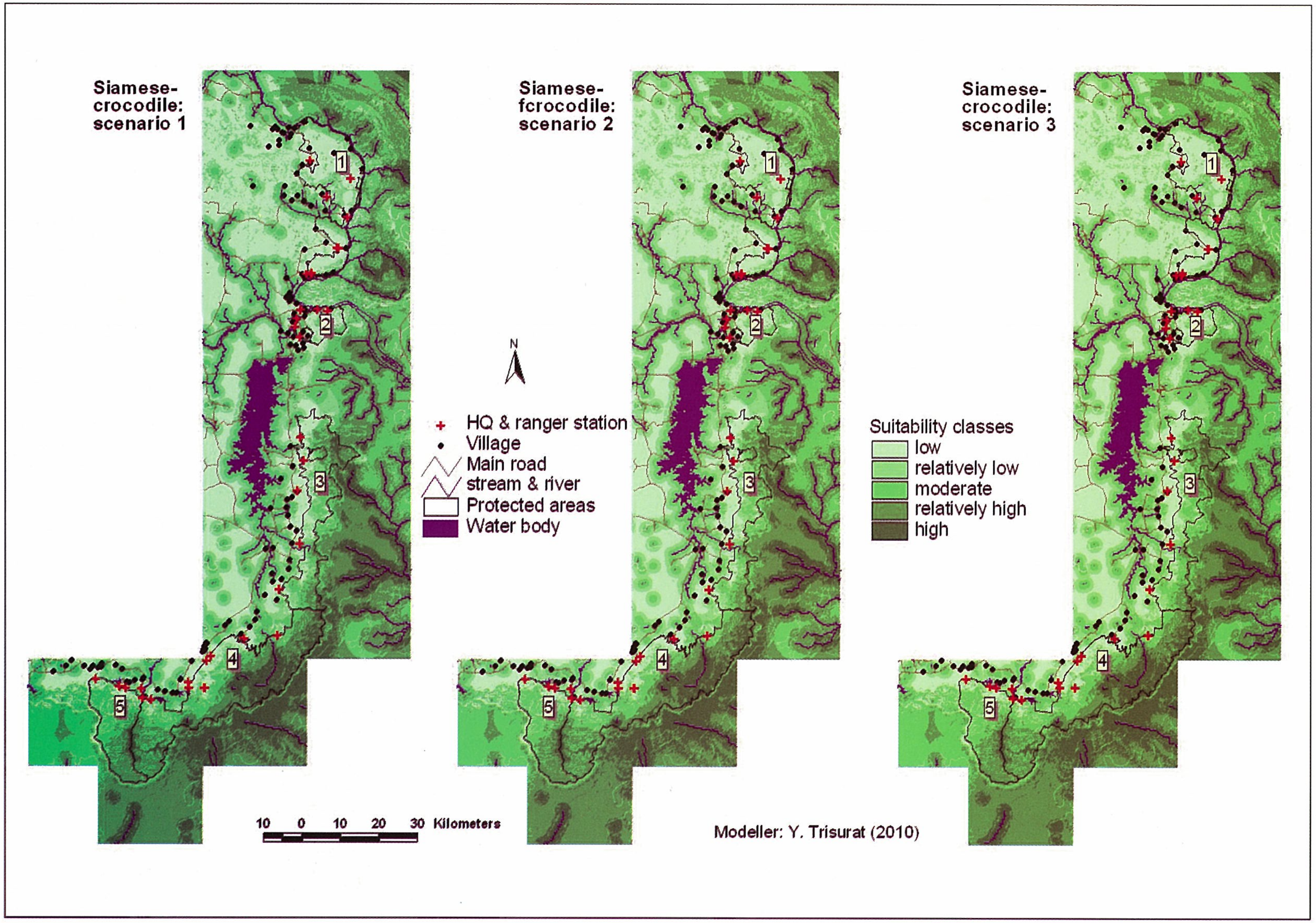


Figure 5.9 Predicted suitable habitats for Siamese crocodile in the PPFC landscape by 2030

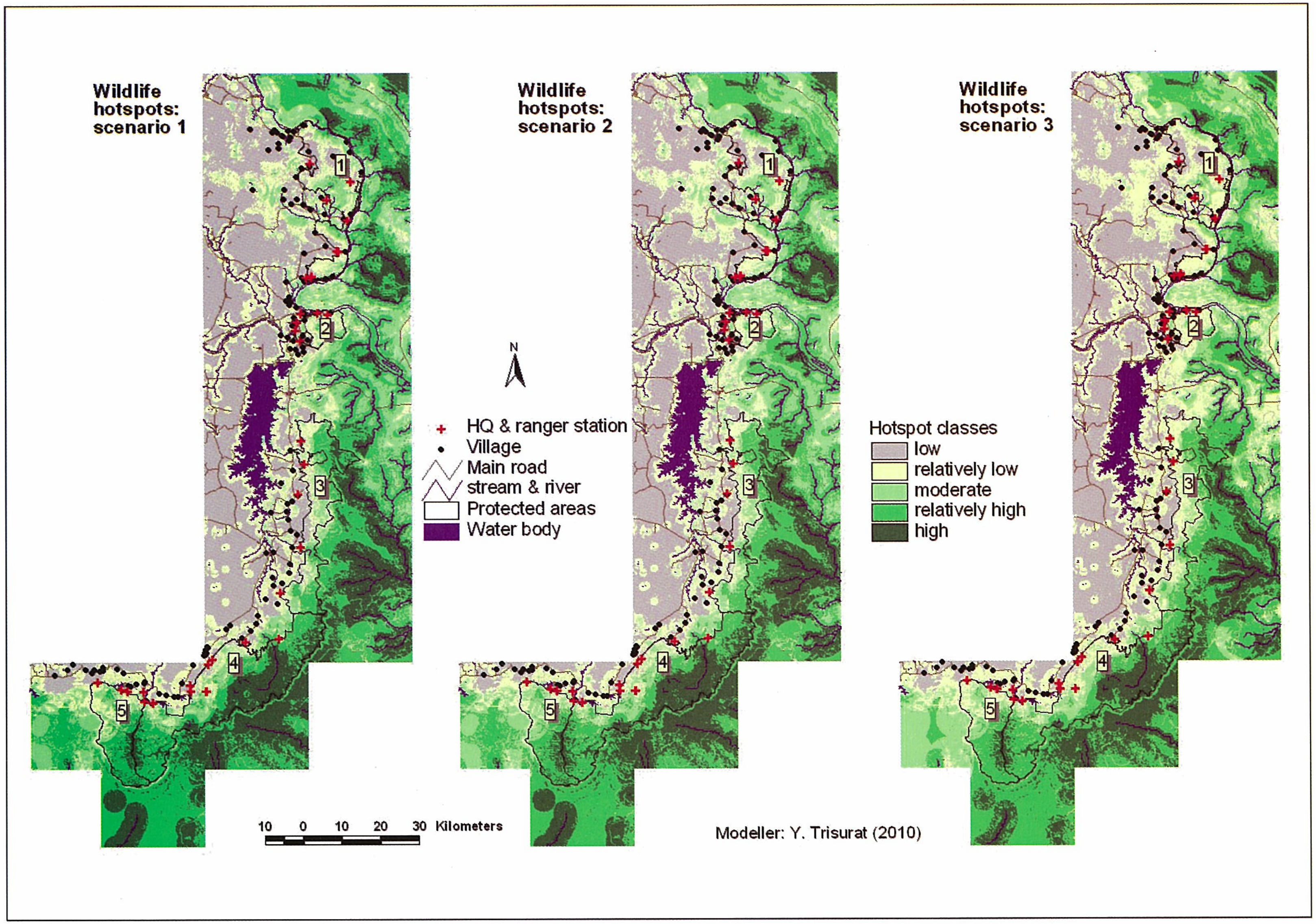


Figure 5.10 Predicted wildlife hotspots derived from different land demand scenarios in the PPFC landscape by 2030

5.4.2 Wildlife Hotspots

Predicted areas of low, relatively low, moderate, relatively high and high concentrations in 2030 under trend scenario are 21.79, 21.49, 17.26, 24.28 and 15.19% respectively. The results of other scenarios 2 and 3 are shown in Table 5.2 while wildlife hotspots in the PPFC are shown in Figure 5.10.

Basically, high concentrations of the eight focal species were clustered in three places. The area with highest concentration is located along the western border of Phu Jong-Na Yoi, next to Laos. In this area, wildlife seasonally migrate between Thailand and Laos. The second region is in the Phuxiangthong NBCA in Laos and the third area extends along the western border of Bun Thrik-Yot Mon. The total areas of high concentration of eight wildlife species or wildlife hotspots cover approximately 40% of the PPFC landscape. For trans-boundary biodiversity conservation among the three countries, the first concentration patch is ranked as the most important for consideration.

5.4.3 Consequences of predicted land use change on wildlife distribution

The GIS Consultant replaced land use in 2002 with the predicted land use in 2030 under three demand scenarios: trend, integrated land use, and conservation-oriented land use derived from the dyna-CLUEs models as discussed in chapter 4. The likely presence area of each species and wildlife hotspots were compared for years 2002 and 2030. In addition, a paired samples correlation and a paired-samples T-test were used to test temporal difference in species distributions and wildlife hotspots under different land demand scenarios. The results are shown in Table 5.3.

Generally, the likely suitable habitats (relatively high and high suitability) and the extent of wildlife hotspots are greater in year 2002 than year 2030 for all selected species. However, there are no significant differences in mean suitable classes. The t-calculated values for all species and wildlife hotspots are lower than critical value of t at 0.05 level of significant for the two-tailed test (Table 5.3). There are three reasons to explain these statistic results. Firstly, the predicted deforestation areas obtained from the three land demand scenarios are mainly found in outside the protected areas where they are defined as of moderate or low suitability. Secondly, the GIS output products of habitat modeling are derived from the deductive approach, thus they only identify potential habitats, but do not imply that the species is actually present at a given location. Therefore, the analyses were done at landscape level and assumed that only land use is changes, while other variables (e.g. proximities to water, main roads and villages) are stable. In fact, at local scale or at a particular area, there might be more roads, and new village development. Nevertheless, the wildlife hotspots maps derived from the current situation and under the three land use scenarios clearly show that the suitable habitats between Kaeng Tana and Bun Thrik-Yot Mon are fragmented. The viability of trans-boundary biodiversity conservation, especially focal wildlife species depends to a high degree on the persistence of suitable habitats in Loas. In addition, the suitable habitats in Thailand's protected areas are not adequate to support viable population in this region. Thus, concrete cooperation among the three countries is very important.

Table 5.3 Paired-samples correlations and paired samples test of predicted wildlife distribution in 2002 and 2030

Species/pair	Paired samples correlation		Paired samples test		
	Correlation	Sig [1/]	Mean (±)	SD [2/]	Sig(2-tailed) [1/3/]
Leopard					
2002-Scn. 1	0.966	0.007	0.000	1.96	1.000
2002- Scn. 2	0.974	0.005	0.000	1.437	1.000
2002-Scn. 3	0.974	0.005	0.000	1.43	1.002
Elephant					
2002-Scn. 1	0.961	0.009	-0.008	3.05	0.993
2002- Scn. 2	0.997	0.000	0.000	1.98	1.000
2002-Scn. 3	0.997	0.000	0.000	1.98	1.000
Banteng					
2002-Scn. 1	0.927	0.023	0.0002	4.673	0.999
2002- Scn. 2	0.998	0.002	0.002	2.769	0.999
2002-Scn. 3	0.998	0.002	0.002	2.762	0.999
Sambar					
2002-Scn. 1	0.911	0.031	-0.002	2.863	0.999
2002- Scn. 2	1.000	0.000	0.000	0.007	1.000
2002-Scn. 3	1.000	0.000	0.000	0.173	1.000
Serow					
2002-Scn. 1	0.997	0.000	0.002	0.932	0.996
2002- Scn. 2	0.992	0.001	0.006	1.458	0.993
2002-Scn. 3	0.991	0.001	0.002	1.511	0.998
Macaque					
2002-Scn. 1	0.998	0.000	0.000	0.338	1.000
2002- Scn. 2	0.998	0.000	0.000	0.348	1.000
2002-Scn. 3	0.998	0.000	0.000	0.338	1.000
Pheasant					
2002-Scn. 1	1.000	0.000	0.000	0.248	1.000

Species/pair	Paired samples correlation		Paired samples test		
	Correlation	Sig [1/]	Mean (±)	SD [2/]	Sig(2-tailed) [1/ 3/]
2002- Scn. 2	1.000	0.000	-0.002	0.250	0.987
2002-Scn. 3	1.000	0.000	-0.002	0.250	0.987
Crocodile					
2002-Scn. 1	0.995	0.000	0.000	0.954	1.000
2002- Scn. 2	0.995	0.000	0.000	0.954	1.000
2002-Scn. 3	0.994	0.001	0.000	0.970	1.000
Hotspots					
2002-Scn. 1	0.886	0.058	-0.002	1.847	0.998
2002- Scn. 2	0.965	0.008	0.002	0.862	0.996
2002-Scn. 3	0.815	0.093	-0.002	4.177	0.989

1/ = Significant level at 0.05; SD = standard deviation; 3/ T-table for two-tailed level = 2.776

5.5 Conclusion

During the Project Phase I, the Wildlife Ecology Consultant selected eight wildlife species, namely the leopard *(Panthera pardus),* Asian elephant (*Elephas maximus*), banteng *(Bos javanicus),* sambar *(Cervus unicolor),* southern serow *(Naemorhedus sumatraensis*), pig-tailed macaque *(Macana nemestrina),* Siamese fireback pheasant *(Lophura diardi*), and Siamese crocodile *(Crocodylia siamensis).* In addition, a new Wildlife Ecology Consultant working in the Project Phase II conducted additional field observations in Bun Thrik-Yot Mon proposed wildlife sanctuary. However, there were not enough sample points to run sophisticated statistic analysis. Therefore the deductive approach was employed to predict habitat suitability of all focal species.

The GIS Consultant used the habitat requirements for each species and modeling techniques from the Project Phase 1 to generate wildlife suitability maps and wildlife hotspots. The habitat factors for the focal species were subdivided into two groups: biophysical habitat factors and human factors. The biophysical factors include forest type, accessibility to permanent water, elevation and slope while the human factors include distance to ranger station, distance to human settlement and distance to main road. The distribution of prey species was also added for the leopard. In addition, the predicted land use map years 2030 derived from different land demand scenarios were replaced with land use year maps year 2002 in order to generate new species distribution map. Finally, the impacts of land use changes on species distribution were assessed for individual species and wildlife hotspots.

The results revealed that the likely suitable habitats for leopard, Asian elephant, banteng, sambar, southern serow, pig-tailed macaque, Siamese fireback pheasant and Siamese crocodile covered 40.41, 37.96, 38.60, 49.26, 18.37, 46.56 and 46.02%, respectively. In addition, wildlife hotspots are mainly located in western Thailand's protected areas and extend to Laos and Cambodia. In Thailand, Phu Jong-Na Yoi and Yot Dom are determined as important high to high suitability areas for all wildlife species because they contain intact forest and the limited human disturbances. On the other hand, Pha Taem, Kaeng Tana and western Buntrik Yot Mon are classified as of moderate to low suitability.

The results of the statistic analyses showed that the extent and patterns of wildlife distribution between year 2002 and 2030 (all scenarios) were not significantly different. However, the likely suitable areas for all species derived from the land use trend are relatively lesser than current situation and those derived from the integrated land use and the conservation-oriented land use scenarios. The results clearly show that long-term survival of biodiversity in this region depends on cooperation between the three countries and maintenance of suitable habitats in Laos and Cambodia.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

After completion of the PPFC Project Phase I, the RFD of Thailand and Forestry Administration (FA) of Cambodian jointly developed and implemented the Project entitled "*Management of the Emerald Triangle Protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos (Phase II)*". The Project Phase II (PD 289/04 Rev.1 (F) was for two years (2008-2009) and it built on the achievements of phase I of the Management of the Pha Taem Protected Forests Complex to Promote Conservation for Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Laos. The overall objective was to conserve trans-boundary biodiversity in the Emerald Triangle and its specific objectives were 1) to strengthen existing cooperation among the three countries, 2) to enhance protection of biological resources along the tri-national borders, and 3) to strengthen the involvement of local communities and stakeholders in sustainable use and management of natural resources in buffer zone.

The Royal Forest Department (RFD) invited the Forestry Research Center of the Faculty of Forestry, Kasetsart University to render professional services assigned to 1) GIS Consultant, 2) Botany Consultant and 3) Forest Ecology Consultant. Based on the contract agreed upon between the RFD and the Forestry Research Center, the GIS Consultant had an overall responsibility to plan and establish the information management system using GIS technology combining with other database systems. This system was to be used for management planning, implementation and monitoring of the biodiversity conservation activities at the Project and to be the model for Trans – boundary biodiversity conservation.

6.1.1 Duties of GIS Consultant and Outputs

Specific duties of the GIS Consultant outlined in the Term of Reference (TOR) and achievements are shown in Table 6.1

Table 6.1 Summary of achievements conducted by GIS Consultant based on assigned activities

Duties	Outputs	Corresponding PD's activities	Mean of validation
Work with the project team and other consultants to develop additional GIS database as required	Wildlife observation Land use 2008, 2030	A2.3.1	New data created and used
Continue updating the data	Indian 1975 – WGS 1984 Road, water body, road network	A2.2.2	Updated GIS database
Work with GIS Consultants in Cambodia and Laos to ensure that both countries develop GIS using standardized design	Disseminate GIS dictionary Map preparation	A2.1.1	Cambodia's GIS database & maps
Propose mechanism and guideline for data sharing among the three countries	Wildlife distribution and hotspots predicted	A2.3.1	Reports
Conduct GIS/GPS training for PA staff	3 training courses conducted 109 participants trained	A2.1.1, A2.2.1	Training program approved and conducted
Assist on the site demarcation of selected communities	Wildlife monitoring data Ban Pak La demarcated Sample plots established & monitored	A2.2.4	Photos PPFC report
Prepare and implement public information systems on PPFC	Maps were used in various PSC meetings and disseminated to PAs	A3.2.3	Meetings
Analyze results and prepare reports as specified in the designed schedule	Reports 1-4 submitted and approved Draft and final reports being prepared	A2.2.2	Letters from KUFF

The achievements are summarized as follows:

1) Develop additional GIS database

The GIS Consultant developed 16 new GIS layers to support the expected outputs of the Project Phase II and the needs of Superintendents of Thailand's protected areas. These layers included wildlife observation (derived from Wildlife Ecology Consultant), land use in 2008, three predicted land use maps (derived from dyna-CLUEs), eight predicted wildlife distribution maps in 2030 (derived from habitat models), and three wildlife hotspots corresponding to the land demand scenarios. These layers were added to the new GIS dataset for the Project Phase II.

2) Updating GIS database

All existing map layers (point, line polygon and grid), developed during the Project Phase I using the projected coordinate system of Indian 1975 UTM Zone 48N, were converted to the projected coordinate system of WGS 1984 UTM Zone 48N, which is commonly used by all government agencies nowadays. In addition, a new GIS database was also developed using the WGS 1984 UTM Zone 48N.

3) Extend lessons learned from Project Phase I to neighboring countries

At the beginning of the Project Phase II (1st PSC meeting held in Bangkok), the That GIS Consultants gave the GIS Database Dictionary to the Cambodian counterpart. The GIS dictionary describes all GIS layers, tables, columns and relationships of all datasets including their implementation. In addition, it also contains the database object names (e.g. administration, elevation), description, data type, length, etc. The Cambodian GIS Consultant used this document as a guideline to prepare a GIS database using the same standardized design. In addition, the GIS Consultant and PPFC staff also assisted Cambodian counterparts to generate map layouts.

4) Propose mechanism and guideline for data sharing among the three countries

The GIS Consultant developed updated land use maps and predicted land use maps for 2030, as well as predicted wildlife distributions and wildlife hotspots under different land demand scenarios. These derived maps are of importance and should be used as a common platform for trans-boundary biodiversity conservation in the Emerald Triangle Protected Forests Complex because the derived maps clearly show that long-term viability of biodiversity, especially of focal landscape species depends to a high degree on concrete cooperation between the three countries to protect and maintain good habitats for wildlife. Further encroachment and poaching across the national boundaries would jeopardize biodiversity in the region.

5) GIS/GPS training

The GIS Consultant worked closely with the Project Manager of PPFC to arrange three courses aiming at developing human resources with the skills and technical knowledge necessary to effectively and efficiently obtain, exchange and use core datasets. These training courses were conducted at the PPFC Project area, namely *1) Introduction to GIS and Map Reading, 2) GIS and MIST: Smart Patrolling Technique,* and *3) Dyna-CLUEs: Land Use Modeling Technique.* The number of participants in each training course was 52, 29 and 28 persons. It is noted that participants were both protected area staff and local multi-stakeholders. For instance, 50% of the participants in the first training were local people from seven Tambons situated in the buffer zone of PPFC.

6) Participatory demarcation

A number of post-GIS training activities were conducted. For example, the rangers of Pha Taem National Park worked with local people at Ban Pak La, Na Pho Klang sub-district and Khong Jium district to demarcate existing land occupancy in the village. This activity was not only inline with the project but also the policy of Department of National Park, Wildlife and Plant Conservation. Other activities were wildlife monitoring at Bun Thrik-Yot Mon wildlife sanctuary and mapping of *Dipterocarpus alatus*. The staff of Bun Thrik-Yot Mon wildlife sanctuary, who were trained in GIS and map reading assisted the Wildlife Ecology Consultant in monitoring key wildlife species in the sanctuary using GPS. Later, the geo-referenced coordinates of wildlife observations and signs were transferred to the GIS database. In addition, PPFC staff trained teachers and students from Srimuang Wittayakan at Ban Chat, Nam Taeng sub-district, Si Muang Mai district in using GPS to map *Dipterocarpus alatus* trees around the village. These three activities clearly revealed that trained participants are able to use knowledge gained from the training for real practices.

7) Prepare and implement a public information system for PPFC

The GIS Consultant produced a lot of maps and power point presentations during November 2008 - January 2010. The hard copy maps were disseminated to the PPFC Project office and the five protected areas in the PPFC for day-to-day activities and extension programs. In addition, the PPFC project also borrowed digital files (map layouts and presentations) for many meetings such as PSC meeting, mid-term report meeting, etc.

8) Analyze results and prepare reports

Most activities outputs were documented in the reports and submitted to the RFD. The GIS Consultant submitted 6 reports (including this report) to the RFD as specified in the contract agreed upon between KUFF and RFD. They were inception report, 1st progress report, 2nd progress report (mid-term progress report), 3rd progress report, draft final technical report, and final technical report. The structure and format of all reports followed the ITTO guidelines. It is noted that the main text of the final technical report was written in English, while the executive summary was available both in Thai and English.

6.1.2 Land use maps and land use changes

The major land use map year 2008 was interpreted from Landsat imageries using visual interpretation. The derived map was used to update the land use map year 2002 to derive 10 general land-use/land-cover types, namely Dry Evergreen Forest, Mixed Deciduous Forest, Deciduous Dipterocarp Forest, Scrub, eucalyptus plantation, para rubber plantation, agriculture, settlement, bare soil and water body. Meanwhile, land-use changes between 2002 and 2008 were investigated using GIS overlay technique. The results indicated that forest cover declined from 66.05% to 62.23%. High loss was found in the buffer zone. On the other hand, rubber plantations have increased rapidly in the last six years.

It is expected that deforestation in Thailand will continue, especially outside protected areas unless strict protection measures are seriously undertaken. Therefore, the GIS Consultant used the Dyna-CLUEs model to simulate land use change based on the three land demand scenarios in 2030: trend scenario, integrated land use scenario and conservation-oriented land use scenario. The simulation was done only in Thailand. The results indicated that the existing forest cover of 46% of the region in 2008 is expected to decrease to 37% by 2030 under the trend scenario. The remaining forest cover will be found mainly in Pha Taem National Park, Phu Jong Na Yoi National Park and Yot Dom Wildlife Sanctuary as accessibility to these areas is difficult and land there is not suitable for agriculture. Forest cover in Kaeng Tana National Park, Bunthrik Yot Mon Wildlife Sanctuary and buffer zone will decline significantly from year 2002.

The integrated land use scenario aims to maintain 40% natural forest cover and accommodate 34,500 ha of para rubber plantation in suitable areas. The results of the simulation also reveal that all protected areas contain high forest cover and the lowest is found in Bunthrik Yot Mon where land conversion for agriculture and human settlement is allowed. The conservation-oriented scenario produces similar results as the scenario 2. The difference is that higher percentage of forest cover is found in the Bunthrik Yot Mon due to restriction policies in all protected areas. It is noted that the predicted forest cover in all protected areas in 2030 is nearly the same as year 2008. Besides forest losses, the landscape indices clearly indicate that scenario 1 will result in more forest fragmentation than scenarios 2 and 3.

6.1.3 Consequences of land use change on trans-boundary biodiversity

The GIS Consultant simulated the distribution of eight wildlife species, namely the leopard *(Panthera pardus)*, Asian elephant (*Elephas maximus*), banteng *(Bos javanicus)*, sambar *(Cervus unicolor)*, southern serow *(Naemorhedus sumatraensis*), pig-tailed macaque *(Macana nemestrina)*, Siamese fireback pheasant *(Lophura diardi*), and Siamese crocodile *(Crocodylia siamensis)* using the same wildlife habitat models derived from the project phase I and compared distribution patterns between the two periods.

The results revealed that the likely suitable habitats for all wildlife species are predicted to be less in 2030 than in year 2002. However, the results are not significantly different (P=0.05). Suitable habitats and wildlife hotspots for both periods are mainly located in western Thailand's protected areas and extend to Laos and Cambodia. In Thailand, Phu

Jong-Na Yoi and Yot Dom are determined as important with high to high suitability for all wildlife species, because they contain intact forest and have limited human disturbances. On the other hand, Pha Taem, Kaeng Tana and western Buntrik Yot Mon are classified as of moderate to low suitability. The results also imply that the long-term survival of biodiversity in this region depends on cooperation between the three countries to protect intact forest and remaining suitable habitats, especially in Laos and Cambodia. Even though, Thailand's protected areas are more effective by protected than those in Laos and Cambodia, they are not large enough to accommodate viable populations and ecological processes of target species in the Emerald Triangle.

6.2 Recommendations

6.2.1 Human resource capacities

During the Project Phase II, 109 participants were trained in three training sessions. In general, most participants gained additional knowledge and skill on GIS & GPS, spatial data, GIS ArcView 3.2, data display and query. However, some participants had limited capacity to obtain advanced knowledge in spatial analysis and to apply this technique for effective trans-boundary biodiversity conservation in the Emerald Triangle protected forest complex. This is because they did not have a good command of English and rarely practiced the exercises in these topics after the training session. Nevertheless, they are competent to use GPS for data gathering, demarcation and patrolling which are important inputs for protected area management.

Recently, the Regional Protected Area Management and Administration Office located in Ubon Ratchani established a GIS Center. Cable staff and equipments were provided for the center. It is strongly recommended that the GIS Center should host and maintain the GIS database of the PPFC and works as GIS mentors for protected area staff. This is to ensure that the GIS database will be kept in good shape for future uses. In addition, regional and protected area staff will work hand in hand and provide valuable and analyzed information to park Superintendents.

6.2.2 GIS Maintenance and Updating

Updating involves more than the simple editing of features. Updating implies the resurvey and processing of new information. The updating function is of great importance during GIS implementation. The life-span of most digital data can range anywhere from 1 to 10 years but the normal validation is 5 to 10 years (http://www.innovativesgis.com/education/primer/organization.html).

It is recommended the Regional Office worked closely with protected area staff to maintain and update the GIS database. The GIS Consultant proposes the schedule for updating 10 important core datasets as shown in Table 6.2.

Table 6.2 Proposed schedule for maintenance and updating key GIS layers

Core dataset	Spatial layer	Data custodian	Responsible agency	Schedule	Tools
1. Administration	Sub-district	Dept. of Local Administration	PPFC Project	Whenever changed	Map digitizing
	Village	Dept. of Local Administration	Protected areas	Whenever changed	Map/GPS mapping
2. Biodiversity	Ecological zone [1]/	PPFC Project	PPFC Project	3-5 years	GIS modeling
	Land use types	Regional office	PPFC Project	2-3 years	Remote sensing
	Wildlife observation	Protected areas	Protected areas	Yearly	Patrolling/GPS mapping
	Wildlife habitat suitability [1]/	PPFC Project	PPFC Project	2-3 years	GIS modeling
3. Infrastructure	Roads	Royal Survey Dept./ Highway Dept.	PPFC Project	Yearly	Map digitizing/GPS mapping
4. Meteorology	Rainfall	Meteorological Dept.	PPFC Project	5 Years	GPS mapping/data input
	Temperature	Meteorological Dept.	PPFC Project	5 Years	Interpolation
5. Protect	Protected area	Protected areas	Protected areas	Whenever changed	Map digitizing
	Locations of HQ and ranger station	Protected areas	Protected areas	Whenever changed	Map digitizing
	Attraction location	Protected areas	Protected areas	Whenever changed	Map digitizing
6. Soil	Soil	Land Development Dept.	PPFC Project	When new map is available	Map digitizing
7. Threats	Illegal case	Protected areas	Protected area	Yearly	Data input
	Proposed development project	PPFC Project	PPFC project	Yearly	Map digitizing
8. Topography	Contour	Royal Survey Dept.	PPFC Project	When new topographic map is available	Map digitizing & interpolation
	Spot height elevation	Royal Survey Dept.	PPFC Project		
	Elevation/DEM [2]/	Royal Survey Dept.	PPFC Project		
	Slope [2]/	Royal Survey Dept.	PPFC Project		
	Aspect [2]/	Royal Survey Dept.	PPFC Project		
9. Water	River and stream network	Royal Survey Dept.	PPFC Project	2-3 years	Map digitizing/remote sensing
	Water body (e.g. reservoir)	Irrigation Dept., EGAT	PPFC Project	2-3 years	Map digitizing
10. Images	Satellite image	GISTDA	DNP/PPFC Project	2-3 years	

Note: PPFC Project or DNP (if no second phase). [1]/ To be modified if variable factors change. [2]/ Derived from topographic data.

6.3 Implication for Practices

The GIS Consultant has produced land use, wildlife distribution and wildlife hotspots predictions for 2030. These data are useful not only for individual protected area management but also for trans-boundary biodiversity conservation in the long term. Park Superintendents can use these data for effective protection by allocating limited resources to patrol in risk areas as patrolling should be conducted more regularly in these areas. In addition, the predicted wildlife hotspots show that the main concentrations of focal species are located along the western boundaries of Bun Thrik-Yot Mon proposed wildlife sanctuary and Phu Jong-Na Yoi national park and extend to forested areas in Laos and Cambodia. The results clearly confirm the project assumption that long-term survival of key wildlife species depends on cooperation between the three countries. Thailand alone cannot ensure viability of trans-boundary biodiversity conservation.

It is noted that wildlife distribution and wildlife hotspots are dynamics. They change through times and whenever habitat factors change. In this technical report, the GIS Consultant defines important wildlife habitat factors and used deductive wildlife habitat models to determine suitable habitats for key wildlife species. It is strongly recommended that the dynamic habitat factors such as land use and human pressures should be updated 3-5 years and run the models again in order to obtain up-to-date results. These outputs are essential information to be used as a cooperative framework between the three countries for trans-boundary biodiversity conservation in the Emerald Triangle Protected Forests Complex.

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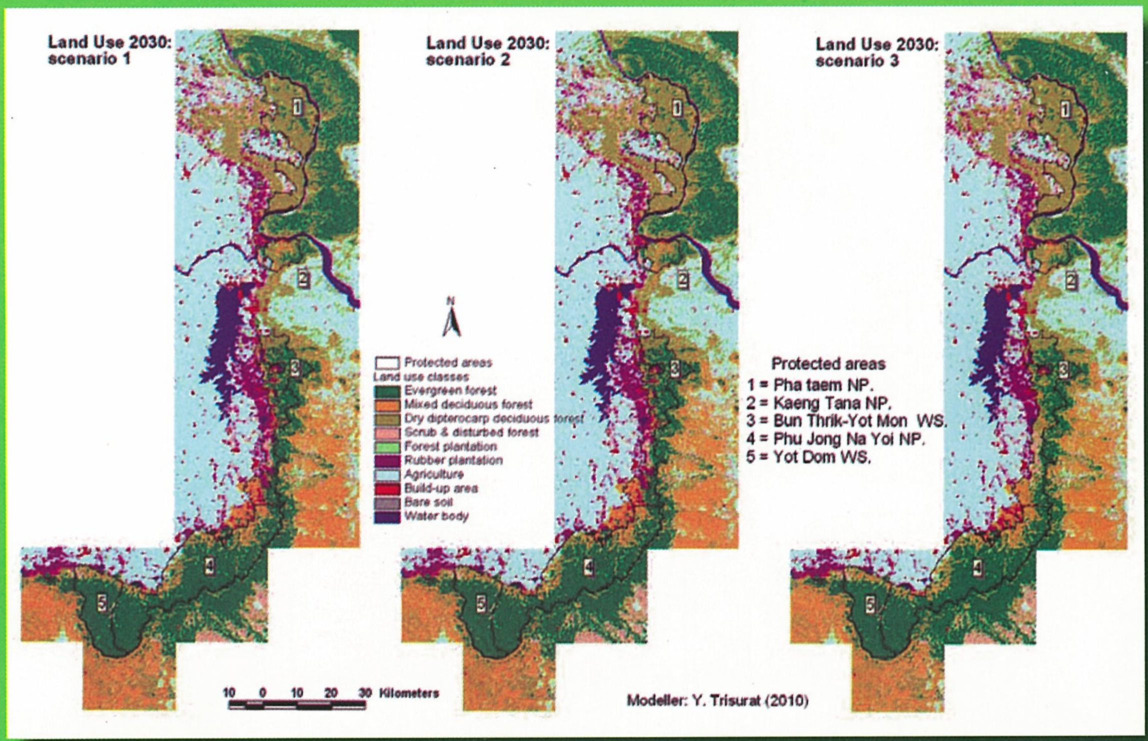

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