



Brandenburgische Technische Universität Cottbus

Brandenburg University of Technology Cottbus

Faculty of Environmental Sciences and Process Engineering
International Course of Study: Environmental and Resource
Management (PhD)

Strategic Environmental Assessment of a Land-Use Programme in the Riviera Maya, Mexico

Analysis of alternatives, development of a monitoring concept and
GIS-monitoring assessment

Thesis approved by the Faculty of Environmental Sciences and Process
Engineering at the Brandenburg University of Technology Cottbus
for the academic degree of Ph.D.

presented by

Master of Engineering

Engelberth Soto-Estrada

from Mexico City, Mexico

Supervisor: Prof. Dr. Dr. h.c. Michael Schmidt

Supervisor: Prof. Dr. Eike Albrecht

Date of oral defence: 18.01.2008



Brandenburgische Technische Universität Cottbus

Brandenburgische Technische Universität Cottbus

Fakultät für Umweltwissenschaften und Verfahrenstechnik
International Course of Study: Environmental and Resource
Management (PhD)

Strategische Umweltprüfung eines Landnutzungsprogramms in der Riviera Maya, Mexico

Analyse von Alternativen, Aufbau eines Überwachungskonzeptes
und GIS-basierte Auswertung

Von der Fakultät für Umweltwissenschaften und Verfahrenstechnik der
Brandenburgischen Technischen Universität Cottbus zur Erlangung des
akademischen Grades eines Ph.D. genehmigte Dissertation

vorgelegt von

Diplom-Ingenieur

Engelberth Soto-Estrada

aus Mexiko Stadt, Mexiko

Gutachter: Prof. Dr. Dr. h.c. Michael Schmidt

Gutachter: Prof. Dr. Eike Albrecht

Tag der mündlichen Prüfung: 18.01.2008

Declaration

I declare that the work submitted is my own and that appropriate credit has been given where reference has been made to the work of others.

This dissertation has never been presented for a degree in this or any other university, neither published at national or international level.

M.-Ing. Engelberth Soto-Estrada
Cottbus, January 2008

Acknowledgements

The author would like to extend profound thanks to:

The National Council for Science and Technology of Mexico (CONACyT), the German Academic Exchange Service (DAAD), and the Ministry of Education of Mexico (SEP) for their support to this work.

Prof. Dr.-Ing. Dr. h. c. Michael Schmidt for giving me the opportunity to carry out my research work under his supervision.

Hendrike Helbron for her very helpful comments, suggestions, improvements and corrections, and for her tireless encouragement during the realization of this investigation.

Dra. Rina Aguirre-Saldivar from the National Autonomous University of Mexico (UNAM) for her guidance and support during my activities in Mexico.

Bernadett Hoppe and other members of the Chair of Environmental Planning who assisted my research activities at the BTU Cottbus.

Petra Fleischhammel and other members of the Chair of Hydrology and Water Resources Management for their support during my stay in Cottbus.

Ricardo Vega, Norma Oropeza and the Centro Ecologico Akumal for their assistance during the fieldwork.

All my friends who encouraged me during my stay in Germany.

Finally, very special thanks to my family: Adriana, Sofia, and my mother for their support, for helping me through the bad times, and for giving me inspiration and strength to complete this work.

Dedication

This thesis is dedicated to my wife, Adriana, our little daughter, Sofia, and to the rest of my family.

Abstract

Ecological Land-Use Planning (ELUP) is the central strategy implemented in Mexico to achieve sustainable development. However, even after more than a decade of experience there are no concrete evaluations to determine how the implemented ELUP-Programmes (ELUPP) have influenced regional development and thus what the consequences on the environment are. In this investigation, some of the key stages of the Strategic Environmental Assessment (SEA) are carried out on the ELUPP Cancun-Tulum, which is considered to be one of the most important land-use programmes in Mexico.

Aim of the study: To achieve the SEA key principles, i.e. to identify reasonable alternatives and to improve the ELUPP Cancun-Tulum. Special emphasis is dedicated to the selection of environmental indicators for monitoring and to the supervision of the programme implementation using a GIS-remote sensing approach.

Method of investigation: The baseline environment in the Riviera Maya and the ELUPP Cancun-Tulum's framework are first examined. Next, an identification of alternatives at regional level is effectuated using geographic information systems (GIS). A monitoring scheme is then proposed to supervise the implementation of the ELUPP Cancun-Tulum. The supervision mechanism is based on a pressure-state-response (PSR) indicator framework. Finally, six environmental indicators are examined using GIS-remote sensing techniques. The assessment encompasses the remote sensing interpretation of two Landsat Geocover Mosaics, and the determination of six landscape spatial indices to evaluate extend and pattern of fragmentation of vegetation.

Results and technical applicability: A reasonable alternative site location for the development of New Tulum (which is one of the cities included in the ELUPP Cancun-Tulum) was proposed. A monitoring mechanism was suggested to supervise the ELUP implementation, including the identification of 19 environmental indicators. The GIS-remote sensing analysis demonstrated that there has been a reduction in the total area of habitat available and that fragmentation of vegetation increased in the Riviera Maya. The results reported here can be used to improve the ELUPP Cancun-Tulum. In addition, this investigation may be useful to improve other ELUP-Programmes in Mexico.

Kurzfassung

Die Ökologische Flächennutzungsplanung (ELUP) wird in Mexiko als zentrale Strategie angewendet, um eine nachhaltige Entwicklung zu erreichen. Nach mehr als einem Jahrzehnt der Erfahrung gibt es jedoch noch keine konkreten Auswertungen darüber, wie die eingeführten ELUP-Programme (ELUPP) regionale Entwicklungen beeinflussen und welche Auswirkungen sie auf die Umwelt haben. In dieser Forschungsarbeit werden einige Schlüsselphasen der Strategischen Umweltprüfung (SUP) auf das ELUPP Cancun-Tulum, das eines der wichtigsten Flächennutzungsprogramme Mexicos ist, angewendet.

Ziel: Es sollen die Grundsätze der SUP, angebrachte Alternativen zu identifizieren und damit das ELUPP Cancun-Tulum zu verbessern, erreicht werden. Schwerpunkte sind dabei die Auswahl von Umweltindikatoren zur Beobachtung und die Überwachung der Programmimplementierung mit einer GIS-basierten Fernerkundungsmethode.

Untersuchungsmethode: Zuerst werden die Umweltbedingungen der Riviera Maya und der Rahmen des ELUPP Cancun-Tulum untersucht. Anschließend erfolgt mit Hilfe eines geographischen Informationssystems (GIS) eine Identifizierung von Alternativen für die regionale Entwicklung. Für die Überwachung/Verifizierung der Programmimplementierung wird ein Monitoringkonzept empfohlen. Dieses Konzept basiert auf einem Druck-Zustand-Antwort (DZA)-Modell. Schließlich wird der Effekt der ELUPP Cancun-Tulum Implementierung auf die Pflanzenbedeckung analysiert. Diese Untersuchung umfasst die Interpretation der Fernerkundung von zwei Landsat Geocover Mosaiken und die Berechnung von sechs landschaftsräumlichen Indices.

Ergebnisse und technische Anwendung: Für die Entwicklung der Neuen Tulum City (die eine der Städte des ELUPP Cancun-Tulum ist) wurde ein angemessener alternativer Standort vorgeschlagen. Zur Überwachung der Programmimplementierung wurde eine Methode vorgestellt, die die Identifizierung von 19 Umweltindikatoren einschließt. Die Analyse der GIS-basierten Fragmentierung für die Riviera Maya zeigte, dass der verfügbare Lebensraum verkleinert und die Fragmentierung der Vegetation wesentlich erhöht wurden. Die Ergebnisse der vorliegenden Arbeit können für die Verbesserung des ELUPP Cancun-Tulum verwendet werden. Darüber hinaus steht damit auch eine Methodik für ähnliche Umweltanalysen zur Verfügung.

Table of contents

| | |
|--|-----------|
| Declaration | i |
| Acknowledgements | ii |
| Dedication | ii |
| Abstract | iv |
| Kurzfassung | v |
| List of maps | ix |
| List of tables | x |
| List of figures | xi |
| List of boxes | xii |
| List of abbreviations | xiii |
| | |
| Chapter 1: Introduction, methodology and scope | 1 |
| 1.1 Methodology and objectives | 2 |
| 1.2 Scope | 5 |
| | |
| Chapter 2: Theoretical background | 7 |
| 2.1 Strategic Environmental Assessment | 7 |
| 2.1.1 Benefits | 9 |
| 2.1.2 Limitations | 10 |
| 2.2 Mexican Environmental Impact Assessment Framework | 10 |
| 2.3 Practice of SEA in Mexico | 14 |
| | |
| Chapter 3: Case study | 16 |
| 3.1 Assessment of the environmental situation: baseline data | 17 |
| 3.1.1 Description of the biophysical environment | 17 |
| 3.1.2 Environmental impacts | 19 |
| 3.2 Environmental and sustainable development objectives and targets | 22 |
| 3.3 ELUPP Cancun-Tulum management model | 27 |
| | |
| Chapter 4: Identification and comparison of alternatives | 48 |
| 4.1 ELUPP Cancun-Tulum's settlement structure | 49 |
| 4.2 Alternative identification | 49 |
| 4.2.1 Obviating development in the Riviera Maya? | 51 |
| 4.2.2 How should development be done? | 53 |
| 4.2.3 Where should it go? | 53 |

Table of contents

| | | |
|--|---|------------|
| 4.3 | Identification of alternatives for the New Tulum's urban area | 57 |
| 4.3.1 | Information for the assessment | 59 |
| 4.3.2 | Assessment of alternatives | 61 |
| 4.3.3 | Impact classification | 70 |
| 4.3.4 | New Tulum area of influence | 74 |
| 4.3.5 | Alternative site location proposal | 74 |
| 4.4 | Timing and detailed implementation | 78 |
| Chapter 5: ELUP-Environmental monitoring framework | | 80 |
| 5.1 | Scope of monitoring | 80 |
| 5.2 | Monitoring framework | 83 |
| 5.2.1 | Selection of environmental indicators | 84 |
| 5.2.2 | Relevance, data requirements and methodological description of environmental indicators | 89 |
| 5.3 | Identification of existing sources of information | 104 |
| 5.4 | Integration of monitoring into the planning system | 107 |
| Chapter 6: GIS-Environmental monitoring of the ELUPP Cancun-Tulum | | 109 |
| 6.1 | GIS-database | 111 |
| 6.1.1 | Digital image classification | 111 |
| 6.1.2 | Digitalization of landscape features | 112 |
| 6.2 | Fragmentation of ecosystems and habitats | 118 |
| 6.2.1 | What is being fragmented? | 121 |
| 6.2.2 | What is the scale of fragmentation? | 121 |
| 6.2.3 | What is the extent and pattern of fragmentation? | 122 |
| 6.2.3.1 | Area/edge metrics: minimum, mean and maximum patch area, patch perimeter | 123 |
| 6.2.3.2 | Shape metrics: second shape index (S2) and fractal dimension index (D) | 126 |
| 6.2.3.3 | Isolation/proximity metrics: Nearest Neighbour Distance (NND) | 127 |
| 6.2.3.4 | Health metrics: Normalized Difference Vegetative Index (NDVI) | 127 |
| 6.2.3.5 | Discussion | 130 |
| 6.3 | Coverage of protected areas | 131 |
| 6.4 | Area of urban formal and informal settlements | 132 |
| 6.5 | Transport infrastructure network | 134 |
| 6.6 | Coverage of forest areas | 134 |
| 6.7 | Area affected by extraction of raw materials and mining | 135 |
| 6.8 | What is the mechanism causing fragmentation? | 135 |
| 6.9 | Conclusions | 135 |

Table of contents

| | |
|---|------------|
| Chapter 7: Conclusions and proposals | 138 |
| Literature cited | 144 |
| Annex I: Identification of environmental indicators | 155 |
| Annex II: Environmental indicator datasheets | 162 |

List of maps

| | | |
|-----------|--|-----|
| Map 3.1: | Location of the ELUPP Cancun-Tulum | 18 |
| Map 3.2: | Projected development actions in the Riviera Maya | 28 |
| Map 3.3: | ELUPP Cancun Tulum's EMUs and predominant land-uses | 31 |
| Map 3.4: | Environmental Management Unit 4 (Playa del Carmen) | 43 |
| Map 4.1: | ELUPP Cancun Tulum's settlement structure | 50 |
| Map 4.2: | Main land covers in the ELUPP Cancun-Tulum region | 55 |
| Map 4.3: | Dense vegetation in the ELUPP Cancun-Tulum region | 56 |
| Map 4.4: | Proposed development area for the New Tulum City | 58 |
| Map 4.5: | Subterranean river systems and cenotes in the Tulum region | 60 |
| Map 4.6: | Traffic noise buffer zones according to roadway type | 65 |
| Map 4.7: | Airport impact zones according to aircraft type and road track length | 67 |
| Map 4.8: | Subterranean river systems, cenotes and protection buffer zones | 68 |
| Map 4.9: | Natural protected area (NPA) and conservation buffer zone (300m) | 69 |
| Map 4.10: | Determination of potential effects resulting from the development of New Tulum | 71 |
| Map 4.11: | Potential conflict areas resulting from the development of New Tulum according the ELUPP Cancun-Tulum's development strategy | 73 |
| Map 4.12: | Alternative site location proposal for the development of New Tulum | 76 |
| Map 4.13: | Likely environmental conflict areas resulting from the site location alternative | 77 |
| Map 6.1: | GIS-monitoring study region | 110 |
| Map 6.2: | Landsat band combination 3,2,1 RGB | 113 |
| Map 6.3: | Landsat band combination 4,3,2 RGB | 114 |
| Map 6.4: | Landsat band combination 7,4,2 RGB | 115 |
| Map 6.5: | Digital image classification 1988, according to the Minimum Distance-to-mean classifier | 116 |
| Map 6.6: | Digital image classification 2001, according to the Minimum Distance-to-mean classifier | 117 |
| Map 6.7: | Digitalization of land covers and linear components 1988 | 119 |
| Map 6.8: | Digitalization of land covers and linear components 2001 | 120 |
| Map 6.9: | Patch size distribution of rainforest and flooded vegetation (1988) | 124 |
| Map 6.10: | Patch size distribution of rainforest and flooded vegetation (2001) | 125 |
| Map 6.11: | Normalized Difference Vegetative Index (NDVI), April 1988 | 128 |
| Map 6.12: | Normalized Difference Vegetative Index (NDVI), April 2001 | 129 |
| Map 6.13: | Protected areas in the Riviera Maya | 133 |

List of tables

| | | |
|------------|---|-----|
| Table 3.1: | Endangered species in the ELUPP Cancun-Tulum | 21 |
| Table 3.2: | Environmental and sustainable development objectives and targets related to the ELUPP Cancun-Tulum | 23 |
| Table 3.3: | Strategies and indicators of Agenda 21 | 24 |
| Table 3.4: | Objectives, strategies and indicators of the Convention on Biological Diversity and the UN Millennium Development Goals | 26 |
| Table 3.5: | ELUPP Cancun-Tulum expected development actions | 29 |
| Table 3.6: | Allocation of predominant land-uses according to environmental policy | 30 |
| Table 3.7: | Allocation of environmental policies according to environmental sensitivity and environmental pressure | 32 |
| Table 3.8: | ELUPP Cancun-Tulum ecological criteria | 33 |
| Table 3.9: | Allocation of attributes for the Environmental Management Unit 4 | 44 |
| Table 4.1: | Selection criteria and buffer zones suggested to preserve environmental elements in the Riviera Maya | 63 |
| Table 4.2: | Potential area of influence of existing activities in the Tulum's region | 64 |
| Table 4.3: | Classification of likely conflict areas for urban development | 72 |
| Table 4.4: | Comparison between development alternatives considering likely conflict areas | 78 |
| Table 5.1: | Environmental impact prediction/identification matrix | 81 |
| Table 5.2: | Criteria for Indicator Selection | 85 |
| Table 5.3: | Indicators for the environmental theme landscape | 87 |
| Table 5.4: | Indicator framework to supervise the ELUPP Cancun-Tulum implementation | 89 |
| Table 5.5: | Indicator framework and main pressure-state-response issues in the Riviera Maya | 103 |
| Table 5.6: | Status of the identified sources and information needs | 106 |
| Table 6.1: | Information managed to build a GIS-database | 111 |
| Table 6.2: | Land-cover classes in the sample set for a supervised image classification | 112 |
| Table 6.3: | Patch size of vegetation in the Riviera Maya (1988-2001) | 123 |
| Table 6.4: | Patch perimeter of vegetation types in the Riviera Maya (1988-2001) | 123 |
| Table 6.5: | Second shape index (S2) in the Riviera Maya (1988-2001) | 126 |
| Table 6.6: | Landscape spatial indices 1988-2001 | 130 |
| Table 6.7: | Protected areas in the Riviera Maya | 132 |
| Table 6.8: | Road network in the Riviera Maya's north part | 134 |
| Table 6.9: | Coverage of forest areas in the Riviera Maya's north part | 134 |

List of figures

| | | |
|-------------|--|----|
| Figure 4.1: | Procedure for the assessment of alternatives | 61 |
| Figure 4.2: | Effect of individual development actions | 62 |
| Figure 4.3: | Cumulative effect of a development strategy | 62 |
| Figure 4.4: | Development of Tulum by 2003 | 74 |

List of boxes

| | | |
|----------|---|-----|
| Box 1.1: | Main and specific research objectives | 4 |
| Box 1.2: | Research methodology | 5 |
| Box 2.1: | The links between the different tiers of policy, plan, programme and project. | 8 |
| Box 4.1: | “Hierarchy” of alternatives: from obviation to detailed implementation | 51 |
| Box 5.1: | Pressure-State-Response framework for the environmental theme landscape in the Riviera Maya | 84 |
| Box 6.1: | Requisites to define habitat fragmentation | 121 |

List of abbreviations

| | |
|----------|---|
| BID | Inter-American Development Bank |
| BOD | Biological Oxygen Demand |
| BTU | Brandenburgische Technische Universität-Cottbus |
| CAPA | Quintana Roo Water and Sewer Commission |
| CBD | Convention on Biological Diversity |
| CEC | Commission of the European Communities |
| CONABIO | National Biodiversity Commission of Mexico |
| CSD | United Nations Commission on Sustainable Development |
| D | Fractal dimension index |
| EEA | European Environment Agency |
| EIA | Environmental Impact Assessment |
| ELUP | Ecological Land-Use Planning |
| ELUPP | Ecological Land-Use Planning Programme |
| EMU | Environmental Management Unit |
| ESC | Earth Satellite Corporation |
| FAA | USA-Federal Aviation Administration |
| FHA | USA-Federal Highway Administration |
| FONATUR | National Trust Fund for Tourism Development of Mexico |
| GCP | Ground Control Points |
| GDP | Gross Domestic Product |
| GIS | Geographic Information Systems |
| GM | Government of Mexico |
| GQR | Government of Quintana Roo |
| ILWIS | Integrated Land and Water Information System |
| INE | National Institute of Ecology of Mexico |
| INEGI | National Institute of Statistics, Geography and Data Processing of Mexico |
| LGEEPA | General Law on Ecology Equilibrium and Environmental Protection of Mexico |
| LGM | Landsat Geocover Mosaics |
| LUMA-GIS | Lund University Master's Program in Geographical Information Systems |
| MIA | Mexican Environmental Impact Statement |
| NACEC | North American Commission for Environmental Cooperation |
| NASA | USA-National Aeronautics and Space Administration |
| NDVI | Normalized Difference Vegetative Index |
| NIR | Near Infrared |
| NND | Nearest-Neighbour Distance |
| NOM | Mexican Official Standard |
| NPA | Natural Protected Area |
| OECD | Organisation for Economic Co-operation and Development |
| PBFRM | Planungsverband Ballungsraum Frankfurt Rhein-Main |
| PROFEPA | Federal Attorney for Environmental Protection of Mexico |

List of abbreviations

| | |
|---------------|--|
| PPP | Policies, Plans and Programmes |
| PSR | Pressure-State-Response Framework |
| RGB | Red Green Blue colour system |
| S2 | Second shape index |
| SEA | Strategic Environmental Assessment |
| SECTUR | Ministry of Tourism of Mexico |
| SEDESOL | Secretariat for Social Development of Mexico |
| SEGOB | Ministry of Interior of Mexico |
| SEMARNAP | Secretariat of Environment, Natural Resources and Fisheries of Mexico (now SEMARNAT) |
| SEMARNAT | Secretariat of Environment and Natural Resources of Mexico |
| SEMARNAT-QRoo | SEMARNAT office in Quintana Roo |
| SNIA | Mexico's National System of Environmental Indicators |
| UDP | Urban Development Programme |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USA | United States of America |
| USD | USA-Dollar |
| WHO | World Health Organization |

1

Introduction, methodology and scope

Strategic Environmental Assessment (SEA) is a process to ensure that significant environmental effects of policies, plans and programmes (PPP) implementation are identified, assessed, mitigated, communicated to decision-makers, monitored, and that opportunities for public involvement are provided. Although there are still many challenges to implement SEA even in developed countries, it has become an important instrument to achieve sustainable development in public planning and policy making, and has streamlined other processes such as Project-Environmental Impact Assessment (EIA) and environmental monitoring (based on Thérivel and Partidário, 2002:9).

SEA has demonstrated to have larger benefits in developing than in industrial countries (World Bank, 2002:30). It can contribute to improve transparency in decision-making, coordination among agencies and, over the long term, good governance (Dalal-Clayton and Sadler, 2005:22). Additionally, new approaches and areas of application of SEA are emerging rapidly, particularly in the fields of development cooperation and international trade. Dalal-Clayton and Sadler (2005:4) noted that “there is growing enthusiasm on the part of many EIA practitioners in developing countries to adopt this approach”.

So far, there is no legal requirement for SEA in Mexico. EIA as mandatory environmental instrument was introduced in the country in 1988. The implementation of EIA was an important step forward in Mexican environmental law. However, this decision aiding tool has had virtually no influence on the environmental performance of development activities in Mexico due to both methodological and procedural limitations (based on BID 2006:40). Most notably, the scope of analysis (which does not include strategic actions), and the lack of clear evaluation, supervision and decision making procedures to provide transparency and certainty in the assessment (based on Azuara-Monter 2006 and NACEC 2006).

This investigation aims to discuss the use of SEA to improve the environmental performance of strategic actions in Mexico. This research is based on the environmental assessment of the Ecological Land Use Planning-Programme (ELUPP) Cancun-Tulum.

Ecological Land Use Planning (*Ordenamiento Ecológico Territorial*) is the central strategy implemented in Mexico to achieve sustainable development. However, to date there are no concrete evaluations (as the environmental assessment of ELUPP implementation is not required by the Mexican legislation) to determine how the implemented programmes have influenced regional development and thus what the consequences on the environment are.

Considering the above, two research hypotheses were formulated to guide the focus of this investigation:

- A. Most of the significant environmental effects of the implementation of strategic actions (policies, plans and programmes) are currently not being considered during the preparation of such actions in Mexico.
- B. It is necessary to carry out the environmental assessment at the level at which the strategic decisions are taken.

In this investigation, special attention is given to the identification of alternatives and to the development of a monitoring concept to supervise the implementation of ELUP-Programmes in Mexico.

1.1 Methodology and objectives

This research was structured in two stages. The first part (chapter 2) contains the theoretical background for this work. In this chapter, the characteristics of SEA and the Mexican EIA procedure are introduced. In addition, the current practice and experience of applying SEA in Mexico is briefly reviewed. Chapter 2 concludes with a discussion about the effectiveness of the Mexican environmental assessment mechanism.

The second part (chapters 3 to 6) presents the results of the strategic environmental assessment effectuated to the case study: the ELUPP Cancun Tulum (*Programa de Ordenamiento Ecológico Territorial del Corredor Cancun-Tulum*).

The ELUPP Cancun-Tulum is located in the region known as *Riviera Maya* (182,000 ha along the Caribbean coast of Quintana Roo, Mexico; see map 3.1). It is considered to be one of the most important land-use programmes in the country. The ELUPP Cancun-Tulum is one of the first Mexican regional management schemes that incorporate ecological criteria and the concept of environmental sensitivity in its agenda.

Chapter 3 describes the ELUPP Cancun-Tulum management framework and the environmental baseline in the Riviera Maya. Additionally, the environmental and sustainable development objectives and targets that have to be satisfied through the programme implementation are summarized. In the last part of the chapter, the efficiency of the land-use management strategies and mitigation measures already implemented in the Cancun-Tulum region are discussed.

Following the SEA procedure, the identification of alternatives at strategic level is examined in chapter 4. The assessment presented in this chapter aims to identify alternative site locations for the development of New Tulum, which is one of the new urban settlements expected to be developed in the Riviera Maya. The analysis is based on the identification of feasible sites for urban development using geographic information systems (GIS). In this assessment, the classification of suitable, conflict and restricted areas for urban development assisted in the identification of likely environmental conflicts resulting from the programme implementation, and therefore to the identification of a reasonable development alternative.

SEA demands the supervision of the significant environmental effects of the programme implementation. A monitoring concept is proposed in chapter 5 to supervise the ELUPP Cancun-Tulum implementation. This innovative environmental monitoring mechanism, based on an indicator framework, represents the first supervision concept intended to monitor the implementation of a development action at strategic level in Mexico. In addition, this framework is conceived to serve as a model to supervise other ELUP-Programmes in the country.

In the first part of chapter 5, the identification, prediction and evaluation of the significant effects of the ELUP implementation are briefly discussed. Considering the programme's environmental objectives and the significant environmental effects of its implementation (scope of monitoring), a set of relevant indicators for monitoring is selected, discussed and information sources are identified. The supervision scheme reported here is founded on the pressure-state-response (PSR) framework of the Organisation for Economic Co-operation and Development (OECD).

Finally, the effect of the ELUP Cancun-Tulum implementation is supervised in chapter 6. Based on a GIS-remote sensing approach, six environmental indicators are evaluated: (i) fragmentation of ecosystems and habitats, (ii) transport infrastructure network; (iii) coverage of protected areas, (iv) area of urban formal and informal settlements; (iv) coverage of forest areas; and (v) area affected by extraction of raw materials and mining.

The assessment is based on the remote sensing interpretation of two Landsat Geocover Mosaics (LGMs) of 1988 and 2001. To determine extent and pattern of fragmentation both LGMs are classified using a supervised multi-spectral classification method. Six landscape indices are then calculated: (i) minimum, mean and maximum patch area; (ii) patch perimeter; (iii) the second shape index (S2); (iv) the fractal dimension index (D); (v) the Nearest Neighbour Distance (NND); and (vi) the Normalized Difference Vegetative Index (NDVI).

The final chapter contains the conclusions, experiences and proposals resulting from this investigation. The objectives of the research work are summarized in box 1.1. The general arrangement of the investigation is outlined in box 1.2.

Box 1.1: Main and specific research objectives

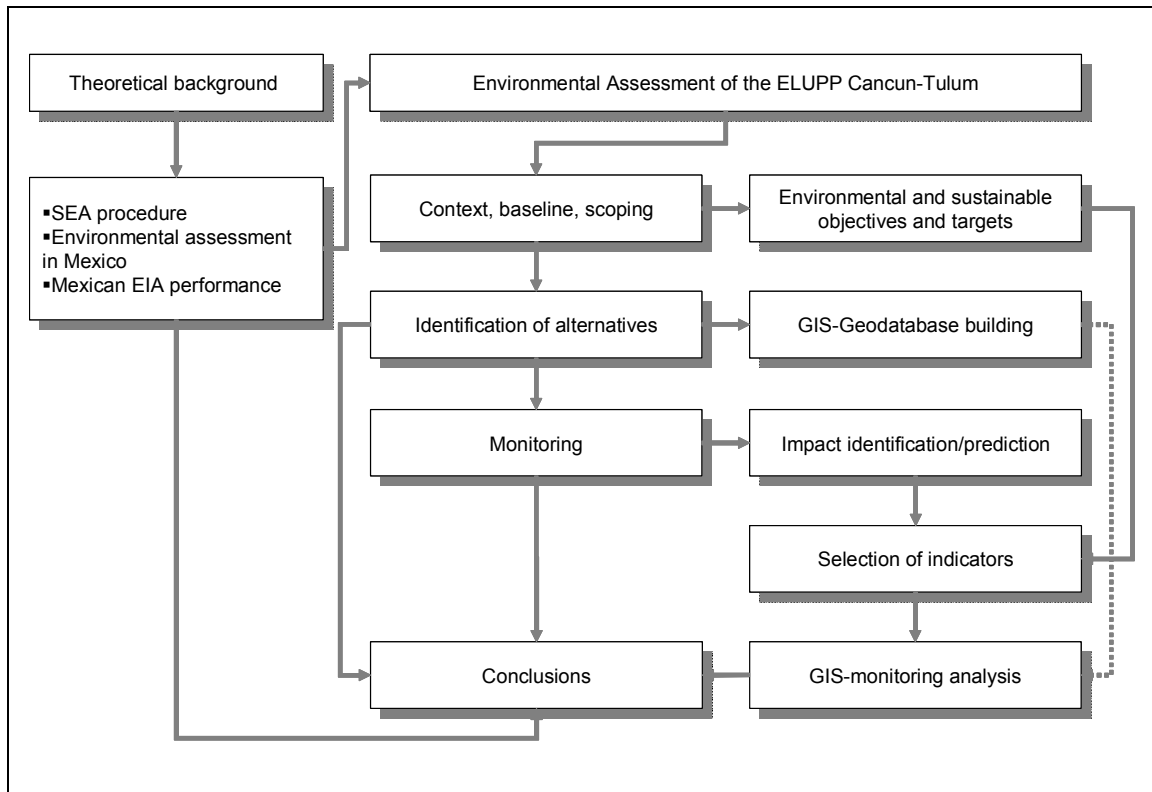
Main objective:

- To achieve the SEA key principles, i.e. to identify reasonable alternatives and to improve the ELUPP Cancun-Tulum. Special emphasis is dedicated to the identification of alternatives, selection of environmental indicators for monitoring and to the supervision of the programme implementation using a GIS-remote sensing approach.

Specific objectives:

- To introduce the concept of SEA and to discuss the characteristics and performance of the Mexican EIA.
- To examine the environmental baseline of the Cancun-Tulum region, identifying the significant environmental impacts.
- To identify the environmental and sustainable development objectives and targets that have to be satisfied through the ELUPP Cancun-Tulum implementation.
- To examine the effectiveness of the land-use management strategies and mitigation measures already implemented in the Riviera Maya.
- To identify reasonable development alternatives to the case study.
- To propose an environmental monitoring concept to supervise the ELUPP Cancun-Tulum implementation and other ELUP-Programmes in Mexico.
- To identify a set of environmental indicators for monitoring.
- To specify information needs for monitoring and to identify suitable data sources.
- To introduce a GIS-database to supervise the case study.
- To supervise some of the selected environmental indicators using GIS-remote sensing techniques.
- To present conclusions, experiences and proposals.

Box 1.2: Research methodology



1.2 Scope

As shown in box 1.1, the scope of this investigation covers most of the SEA key stages. However, as any practical research, the scope of this study was framed by several factors.

One limiting factor was the access to information. On the one hand, there is a lack of information at regional level in the Riviera Maya (for example land-use maps, vegetation cover maps, coverage of urban areas, etc.), whereas the available information is incomplete, imprecise or incompatible. On the other hand, the access to most of the digital information that the Government of Mexico has, particularly high resolution satellite images (that could be used to create the necessary information for the assessment), is restricted to the public.

Due to the lack of information, the analysis of alternatives (chapter 4) was limited to one of the development actions proposed by the ELUPP Cancun-Tulum: the urban development strategy, and within this activity to one of the

urban areas expected to be developed: New Tulum City (see map 4.1). The supervision of the ELUPP Cancun-Tulum implementation (chapter 6) was carried out to the programme's north part (94,190 ha; see map 6.1), as digital information for the entire region could not be obtained.

Regardless of these restrictions, the objectives of the investigation were achieved. A reasonable alternative for the development of New Tulum was identified, and the ELUPP Cancun-Tulum was improved through the development of a monitoring concept and the introduction of a GIS-database to manage environmental information. In addition, the identification of alternatives and the monitoring concept proposed in this research may serve as a model to improve the Mexican ELUP strategy. The strategic environmental assessment of the ELUPP Cancun-Tulum represents one of the first SEAs carried out in Mexico. The results and experience gained in this investigation can serve to identify strengths and weaknesses, opportunities and threats to adopt this decision aiding tool in the country.

2

Theoretical background

Strategic Environmental Assessment (SEA) focuses on the evaluation of policies, plans and programmes (PPPs) and its alternatives. The purposes of the assessment are: (i) to identify likely significant environmental effects of future actions, (ii) to ensure that these effects are considered during planning, designing and authorization of the action, and (iii) to influence how it is subsequently managed during its implementation.

To date, there is no legal requirement for SEA in Mexico. Environmental impact assessment at project level (EIA) is a mandatory instrument in the country since 1988. This chapter aims to introduce SEA and the characteristics of the Mexican EIA procedure, including an analysis of its performance. In the last section, the current status of the practice of SEA in Mexico is briefly discussed.

2.1 Strategic Environmental Assessment

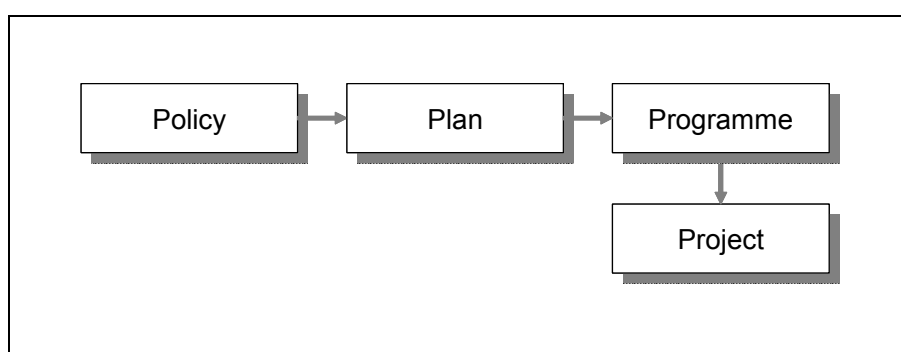
SEA can be defined as a systematic process for the evaluation of the environmental consequences of a proposed PPP initiative, in order to ensure that they are fully included and appropriately addressed at the earliest stage of decision making, together with economic and social considerations (based on Sadler and Verheem 1996:27).

A policy has been defined as “the inspiration and guidance for action, a plan as a set of coordinated and timed objectives for the implementation of the policy, and a programme as a set of projects in a particular area (Wood et al 1991:3; see box 2.1). However, in practice these distinctions and stages are not necessarily very clear-cut and the terminology is not consistently used (João 2004:4). What is important to notice is that one policy, plan or programme often sets the structure for another PPP (Thérivel et al, 1992).

For instance, the Ecological Land Use Planning (ELUP) strategy is currently implemented at national, state and regional level in Mexico. However, regardless of the level at which ELUP is implemented, all land-use management schemes are called ELUP-Programme.

According to the ELUP legislation (SEMARNAT 2003a), the General ELUP-Programme (*Programa de Ordenamiento Ecológico General del Territorio*, which covers the entire country) sets the framework for the State ELUP-Programmes. State-Programmes determine the structure for the regional ones. Furthermore, regional ELUP-Programmes establish the frame for other programmes such as the Urban Development Programmes (UDP).

Box 2.1: The links between the different tiers of policy, plan, programme and project.



Source: Based on João 2004:4

There are two fundamental principles to implement SEA. First, that SEA must clearly identify feasible PPP alternatives and compare them in an assessment context. Second, that SEA must improve, rather than just analyze the PPP (João 2004:3).

The typical steps in SEA process are: (i) screening, in which the decision of whether the PPP needs SEA is made; (ii) scoping, to determine what are the impacts that must be assessed with SEA; (iii) identification, prediction and evaluation of such impacts; (iv) mitigation; and (v) monitoring (World Bank 2005a:12).

SEA has been applied to three main types of actions: (i) sectoral PPPs, related to specific sectors (such as tourism, transport, forestry, energy, etc.); (ii) area based or comprehensive PPPs, which cover all activities in a given area (e.g. land-use programmes); and (iii) actions that do not set the framework for future development consent of projects but nevertheless have a significant environmental impact (for example agricultural practices, privatization; Thérivel and Partidário 2002:5).

The key actors involved in SEA are: the action-leading agent (proponent), the competent authority, the environmental authority and the public. The action leading agent is the organization responsible for developing the action. The competent authority is the institution responsible for deciding on the PPP (usually a government or quasi-government organization). The action-leading and the competent authority are frequently the same, public, organization. The environmental authority and the public contribute with information to, and must be consulted and considered as part of, the SEA process.

2.1.1 Benefits

SEA can overcome the limitations of the assessment conducted for individual projects and promote sustainable development. Some of the limitations of project-level environmental impact assessment are:

- EIA normally reacts to development proposals rather than proactively anticipating them.
- Because EIA takes place once many strategic decisions have already been made, it often addresses only a limited range of alternatives and mitigation measures.
- Consultation in EIA is limited, and its contribution to the final decision is not clear (CEC 1993).
- It is generally limited to the project's direct impacts and ignores: (i) the additive effect of small projects that do not require EIA (for example agricultural schemes); (ii) induced impacts, where one project stimulates other development (for instance a new tourist complex that requires other infrastructure); (iii) synergistic impacts, where the impact of several projects exceeds the sum of their individual impacts; and (iv) global impacts such as biodiversity loss and greenhouse gas emissions (Wood 1995).

SEA can deal with many of these difficulties. It can integrate environmental issues intrinsically into project planning by influencing the context within which project decisions are made (Thérivel and Partidário 2002:9). SEA provides a mechanism for public engagement in discussions relevant to sustainability at a strategic level (Dalal-Clayton and Sadler 2005:20). It promotes the identification of likely environmental consequences, alternatives, and mitigation measures that go beyond individual projects. SEA helps to define environmental targets for monitoring purposes. Moreover, it could simplify the process of environmental investigations at project-level, and thereby SEA can reduce or possibly avoid the need for EIA and also accelerate the process of decision-making (World Bank 2002:24).

SEA has the potential to allow the principle of sustainability to be carried down from policies to individual projects (Partidário 1999:7). It can produce a better balance between environmental, social, and economic aspects. It could anticipate whether the impacts of a strategic action are likely to be in accordance with sustainability objectives. SEA can help to create a more integrated system of planning by incorporating environmental and sustainability criteria into the objective of a PPP.

2.1.2 Limitations

SEA has both technical and procedural limitations. Data collection and analysis can be very complex as SEA can cover a large area and large number of alternatives. The analysis at strategic level may be subject to greater levels of uncertainty than project-EIA, since it has to cope with limited or incompatible information and long analysis periods. Additionally, SEA may disregard impacts that are important at a local level but that do not influence a strategic level decision (Thérivel and Partidário 2002:10).

Furthermore, policies, plans and programmes are generally non-linear, complex and iterative (World Bank 2005a:32). A PPP may have no formal authorization stage, but instead evolve in fits and starts through to implementation (Thérivel and Partidário 2002:9). Strategic actions may also change considerably from their original statements, which may limit the degree to which SEA results are integrated into decision-making. This makes it difficult to know when a SEA should be carried out, and what exactly the PPP is that is being assessed.

2.2 Mexican Environmental Impact Assessment Framework

Project-EIA as mandatory environmental instrument was introduced in Mexico under the General Law on Ecology Equilibrium and Environmental Protection (LGEEPA) in 1988. EIA is formally defined as “the process used by the Secretariat of Environment and Natural Resources (SEMARNAT) to determine the requirements that are necessary to approve development actions likely to cause an ecological imbalance... with the aim to avoid negative environmental consequences” (LGEEPA 2003:18).

Mexico's EIA process comprises: (i) sectoral projects (e.g. tourism, oil related activities, mineral extraction, cement industry); (ii) actions considered as a high risk (such as hazardous waste management); (iii) activities to be located in fragile ecosystems (for example coastal ecosystems); and (iv) actions that may be a threat to human health or ecosystem integrity (SEMARNAP 2000a:10-23). Activities that need an EIA must not proceed without an EIA permit.

There are two types of documents in the Mexican EIA, the main document called *Manifestación de impacto ambiental* (MIA) and the *Reporte preventivo* (RP).

The MIA can be *regional* or *particular*. The *regional* analysis is required when the project involves: (i) extensive actions (more than 500 ha), motor and railways, nuclear energy plants, dams, etc.; (ii) actions included in urban development programmes (UDP); (iii) a set of actions located in a specific ecological region (habitat); and (iv) actions likely to have cumulative, synergistic or residual impacts, which may lead to destruction, fragmentation or isolation of ecosystems (SEMARNAP 2000a:9-21). This approach includes an analysis of the regional environment that surrounds the project and the consequences it will likely cause, including a description of potential cumulative and residual impacts.

Any other project that does not need a regional assessment must have a *particular* MIA. The particular approach encompasses only the local ecosystem where the action will take place.

Finally, a *Preventive Report* can be requested if the likely impacts of the proposed action are impacts already addressed by other Mexican environmental instruments, for example by Mexican Official Standards (NOMs), or when the proposed actions are included in activities that have already an EIA permit.

EIA performance

EIA was an important step forward in Mexican environmental law. It clarified what projects need an environmental assessment and the information required for it (INE 2000a:25). The Mexican EIA overcame initial limitations such as the lack of experience of authorities and proponents, and has been refined to improve its performance. However, it still has both technical and procedural

limitations, most notably “the federal government’s centralization of a broad range of decision-making, ambiguity as to the types of actions to which EIA applies, and the lack of clear administrative procedures and citizen participation mechanisms to provide transparency and certainty in the decision-making process” (NACEC 2006).

Centralization

According to LGEEPA, federal, state and municipal governments should participate in EIA. The federal government is responsible to evaluate the actions included in LGEEPA (Article 28) and, when required, the expedition of authorizations. State governments are accountable for the assessment of actions that are not reserved for the federation. The municipalities are involved in the assessment of actions of state competence, when the actions are located within the municipal circumscription (LGEEPA 2003:5-9). However, in practice most of the environmental decisions are taken at federal level.

It was recognized (years ago) that the federation did not have the capacity to act and react as stipulated in LGEEPA (INE 2006a, BID 2006:41). A decentralization process was initiated in 1996 to extend the functions and competencies of local governments (SEMARNAT 2002a:37). Nevertheless, the process faced several difficulties that to date have not been satisfactorily resolved.

According to SEMARNAT (2002a:37), difficulties arise from the facts that: (i) the functions to be decentralized were chosen by the federal government, they were not attractive to local governments as only few of them offered the possibility to create revenues; (ii) the transference of authority acts (decision-making) was not included; (iii) there were obstacles to relocate technical, financial and human resources due to the centralized management structure; (iv) political interests; and (v) incipient institutional development of local governments.

Gaps and ambiguities in the environmental legislation

The Mexican EIA legislation still has ambiguities and gaps concerning the competence of authorities at different levels (INE 2006b), the types of actions to which EIA applies (NACEC 2006, INE 2006c), and the procedures for assessing the likely environmental consequences of proposed actions.

The practice of EIA in Mexico showed that “it was difficult to decide what actions had to be assessed at federal and local levels, especially when dealing with public-work projects” (INE 2000a:32). This problem was related, in the early-stages of the Mexican EIA, to the lack of experience of authorities, and to the way in which the projects that had to be assessed at federal level were defined in the legislation.

Additionally, there are no mandatory methodologies for impact identification and assessment in the Mexican EIA (BID 2006:39). In general, environmental impact statements (MIAs) do not contain a clear identification of impacts and the methodologies used in the assessments are not verifiable (Azuara-Monter 2006). These reports can be considered, consequently, limited and uncertain. Procedural ambiguities have facilitated a discretionary use of the EIA, principally when the government participates as proponent or when economic interests exist.

Transparency and public participation

The Mexican EIA provides the public the opportunity to express its opinion. SEMARNAT must notify about all MIAs received by publishing a notice in the Ecological Gazette (*Gaceta Ecológica*). Any citizen can request the start of a public participation procedure. Comments received must also be incorporated into the project's record.

This public participation procedure has been criticized, inter alia, because SEMARNAT does not have to engage in public outreach activities if the public does not request it (and even if there is a request SEMARNAT is not obligated to carry out a public participation process). Consequently, the public is responsible for finding the information and requesting the start of a formal public participation process. The procedure takes place after the MIAs have been submitted, which hinders public's opportunity to get involved in the actual preparation of the documents. In addition, the forms for public process must be filed at the SEMARNAT office, which might be far from the place where the citizens live. This difficulty might provide a disincentive, especially for low-income citizens who do not have the money or time to travel to the corresponding office (based on Maldonado 2005:15).

The “2006 Evaluation of the Mexican EIA”, effectuated by the Inter-American Development Bank (IDB 2006:40), concluded that “yet public participation mechanisms are not widely practised in the Mexican EIA, the procedures are still little known and their benefits are rarely used by the affected communities”. According to this report, only 0.4% of the MIAs submitted during the period 1990-2000 (6,978 environmental impact statements) carried out a public participation procedure.

A second aspect limiting transparency is monitoring. It can be considered as one of the weakest phases for most EIAs in Mexico. In fact, the supervision of the impacts reported in the MIAs is not demanded by the EIA legislation (SEMARNAP 2000a). SEMARNAT, through the Federal Attorney for Environmental Protection (PROFEPA), verify the observance of the mitigation measures required as a condition of getting the EIA permit. However, so far there are no concrete evaluations about environmental changes, positive or negative, produced by the implementation of EIA and its global effects (IDB 2006:40). Once the approval process is complete, MIAs are filed and never reviewed or used thereafter.

Since there is no regular post-EIA phase, it is not possible to determine project impacts that could represent a guide for future projects. Any knowledge that results from the study remains within the staff that carried it out. It seems that every EIA is an individual activity, which has no relevance to similar projects either before or after. Experience suggests that “the Mexican EIA procedure, as it is currently practiced, does not represent a useful tool for environmental management, it is simply a document that is necessary to clear a project” (Tortajada 2002:3).

2.3 Practice of SEA in Mexico

As it was previously mentioned, so far there is no legal requirement for SEA in Mexico. Nevertheless, according to the EIA legislation (SEMARNAP 2000a:23-28), for certain actions at strategic level, such as UDP or ELUP, a regional EIA (which can be considered as a para-SEA procedure) can be required. In those cases, however, the assessment has to include all the programme’s activities (but not the programme itself) that are listed by LGEEPA (Article 28). Similarly, the ELUP legislation (SEMARNAT 2003a:43-50) requires the consideration of the existing environmental impacts to determine the strategies of an ELUP-Programme, but it does not demand the consideration of the effects of the programme implementation.

Some environmental assessments at regional or national level, nevertheless, have been done in Mexico, most of them in the context of programmes and plans financed by international aid. For example, in 2003 the World Bank financed the environmental assessment of the “Water-sector Modernization Programme”, which covered the entire country and focused on the determination of the likely environmental effects (primarily on aquifers, natural protected areas, and key forestry zones) of the rehabilitation of irrigation infrastructure (Pisanty 2004). In the same way, in 2005 the World Bank promoted the “Strategic Environmental Assessment of the Tourism Sector in Mexico”, evaluating the actual Mexican tourism development model (World Bank 2005b).

Considering the aforementioned, probably to this point the arising question is: should the Mexican authorities consider the implementation of SEA, even though there are still some performance and legislative gaps in the Mexican project-EIA? This question will be examined, considering the theoretical discussion presented here and the outcomes of the investigation, in the last chapter of this research work.

As mentioned in chapter 1, in this investigation the strategic environmental assessment of the ELUPP Cancun-Tulum is carried out. The analysis starts in Chapter 3 with the introduction of the ELUPP Cancun-Tulum framework, the identification of the programme’s environmental objectives and targets, and the description of the baseline environment in the Cancun-Tulum region. Additionally, Chapter 3 discusses the environmental consequences of the ELUPP Cancun-Tulum implementation so far.

3

Case study

Ecological Land Use Planning (ELUP) is the management scheme used to control or induce land-use and productive activities in Mexico. ELUP as environmental instrument was introduced in Mexico under LGEEPA in 1988. It is implemented at federal, regional and local levels. ELUP establishes land-uses and densities of space use, as well as the areas that have to be protected or recovered (LGEEPA 2003:3).

By 2000, nineteen ELUP-programmes (ELUPPs) had been implemented (decreed) in Mexico, covering 9.3 percent of the Mexican territory (18,401,235 ha), and fifty eight new ELUPPs were in process of elaboration or implementation (SEMARNAP 2000b).

ELUP main objectives are to protect the environment and to promote sustainable use of resources. This strategy was intended to increase investor confidence to support long-term development. Public participation is essential during ELUP preparation and implementation, the reason why it also had to be an instrument for the prevention and solution of land-use controversies (SEMARNAP 2000b:9-31). Nevertheless, until present there is not enough evidence to determine how the implemented ELUPPs have influenced regional development and thus what the consequences on the environment are. Reports published by SEMARNAT (2006a, SEMARNAP 2000b) suggest that, in the implementation of ELUPPs, most regional departments have not made serious efforts to analyze the performance of the implemented programmes.

In this chapter, the Ecological Land-Use Planning Programme (ELUPP) Cancun-Tulum is presented. Located in the region known as the *Riviera Maya*, this programme is one of the most complex and important management schemes of Mexico. The Riviera Maya's expected growth has placed great demands on the planning and construction of new tourist facilities (around thirty five percent of the Mexican tourism revenues are generated in this region), residential housing (during the last thirty years, the Cancun-Tulum region has had an average population increase of eight percent annually, the fastest growing region of Latin America) as well as infrastructure. The Riviera Maya is of decisive significance for the entire regional economic development.

Following the SEA procedure, in the first part of this chapter the state of the environment in the area under study is described. In the second section, the environmental and sustainable development objectives, targets and priorities in the Riviera Maya are summarized. Next, the ELUPP Cancun-Tulum's framework is presented, and finally, the performance of the implemented land-use management strategies is discussed.

3.1 Assessment of the environmental situation: baseline data

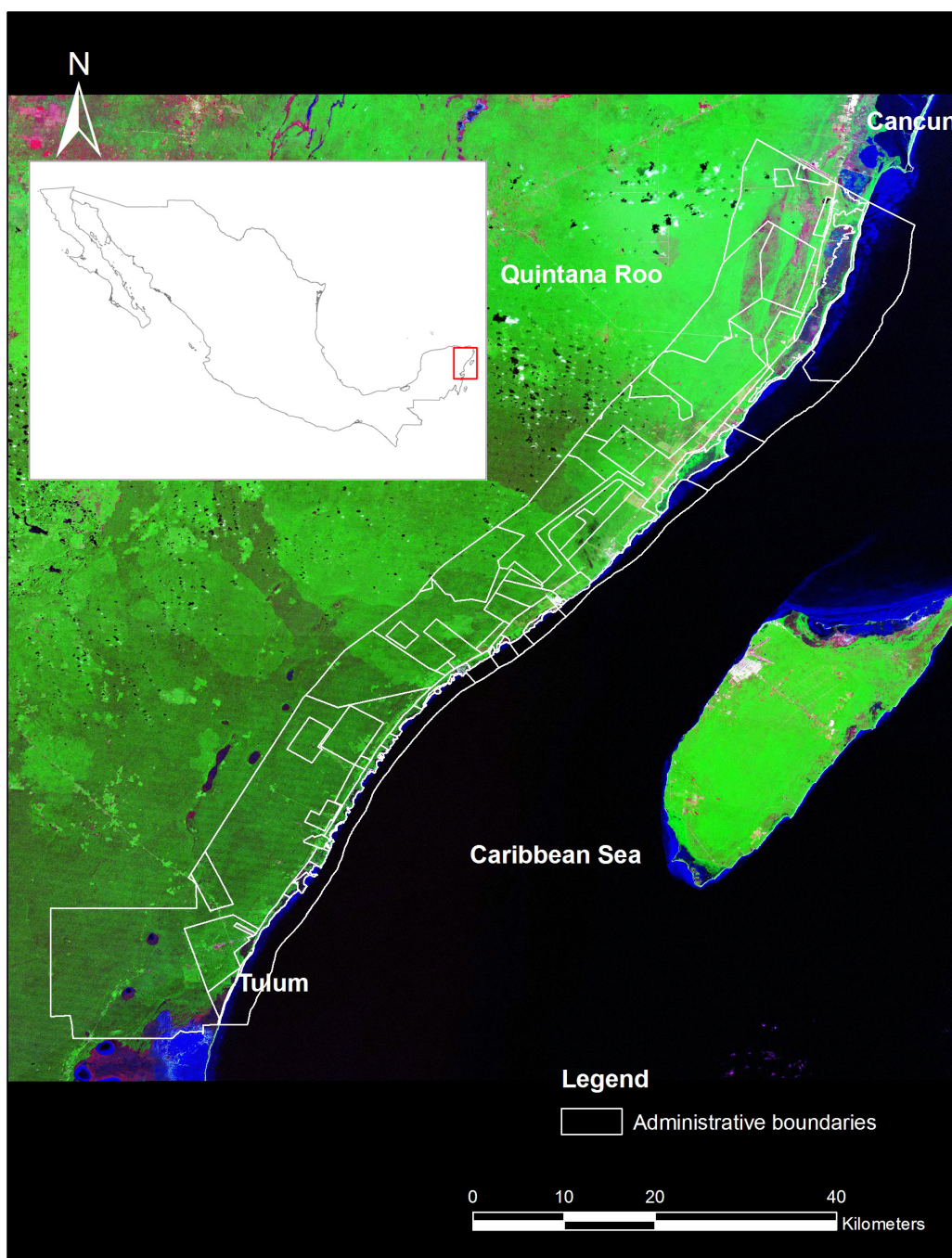
The Cancun-Tulum Corridor is located in the State of Quintana Roo on the Caribbean coast of Mexico (see map 3.1). It covers 182,000 ha between the parallels 20°20'24" and 21°10'48" of north latitude, and the meridians 86°44'24" and 87°28'12" of west longitude. The predominant climate is warm sub-humid with rains in summer. The annual average temperature is 26 degrees Celsius and the annual average precipitation of 1,500 mm (CONABIO 2006).

The Riviera Maya is characterized by its biological diversity and cultural richness and in the last decades by the accelerated tourism development. Tourism is the main economic activity in the Riviera Maya. It represents more than 90 percent of the Quintana Roo's GDP (GQR 2000). In 2004, tourism in the Cancun-Tulum region generated more than 4.3 billion United States dollars (USD), which corresponded approximately to thirty five percent of the Mexican tourism revenues (SEDETUR 2005). The main settlements in the region are: Cancun, Playa del Carmen, Puerto Morelos, Tulum, and Xel-ha (see map 3.2).

3.1.1 Description of the biophysical environment

The Riviera Maya is remarkably rich in biological diversity. Vegetation types: medium (*subperennifolia*) and low (*perennifolia*) rainforest, low flooded rainforest, mangroves, savannah, flooded palm groves, and coastal dune vegetation. Habitats: estuaries, wetlands, coastal dunes, coves, cenotes¹ and beaches. In addition, the coastal line is composed by coral reefs, which are considered the second longest barrier reef in the world (more than 500 km long), and marine grasses (CONABIO 2006).

¹ From the Mayan word "d'zonot", meaning sacred well. A cenote can be described as a deep sinkhole in limestone with a pool at the bottom that is found especially in the Yucatan Peninsula (SEMARNAT, 2001a:3).



Map 3.1: Location of the ELUPP Cancun-Tulum

Source: Based on vector data (SEMARNAT 2001c) and a Landsat GeoCover 1984 Mosaic (ESC 2004)

It has been estimated that 1,252 species of plants, 60 families of coral reef fish, 16 species of amphibians, 79 of reptiles, 340 species of birds, 43 of terrestrial mammals, 39 of flying mammals and 8 of marine mammals occur in Quintana Roo (CECADESU 2006:7). The Riviera Maya is considered to have a high ecological significance due to the existence of rare, vulnerable and endangered species. A minimum of 246 species of vertebrates are found in the ELUPP's area (INE 1999:2). In addition, there are several vestiges of the Maya culture along the coastal line, i.e. Tulum, Xel Há, and Xcaret. Currently, around 45,000 Maya speakers live in the region (CDI 2006).

The protection schemes implemented so far in the Riviera Maya are: (i) "Tulum" National Park (664 ha); (ii) "Reefs of Puerto Morelos" Marine Natural Park (9,067 ha); and (iii) "Sea Turtle Sanctuary Xcacel-Xcacelito" Ecological Conservation Zone (362 ha). Additionally, the ELUPP southern area is adjacent to the Sian Ka'an Biosphere Reserve, which was inscribed on the World Heritage List in 1987.

3.1.2 Environmental impacts

The rapid population growth and economic development in the Riviera Maya resulted in a non-sustainable tourism and urban development. During the last thirty years, local tourism industry grew from 1,300 rooms in 1975 to 26,500 in 2004 (FONATUR 2004a). At the same time, population grew up to 30 percent annually, which is considered one of the highest growth rates in Latin America (SEGOB 2004:1). The population in the Riviera Maya is currently estimated around 150,000 inhabitants (INEGI 2006a). However, building of basic urban services (environmental structure) has not occurred at a corresponding rate.

The socioeconomic development in Quintana Roo during the last three decades can be summarized as follows:

- *Asymmetric development.* The most populated areas are located in the most fragile ecosystems, i.e. coastal ecosystems, whereas the central part of the State remains undeveloped. Approximately 59 percent of the population is located in urban areas.
- *Non-sustainable tourism development.* It has been recognized that most tourist facilities do not have suitable infrastructure for managing wastewater and solid-waste, nor eco-friendly management policies. In addition, highly impacting activities such as massive tourism and fishing, and wild animal trade are common in Quintana Roo (SEMARNAT 2002b).

- *Lack of basic water and sanitation services.* The Riviera Maya is undersupplied with basic urban services. In 2002, SEMARNAT (2002b) estimated a deficit of 50 million USD in basic infrastructure in urban settlements (water, sanitation and solid-waste management) in the Riviera Maya. In contrast, extra-official sources have estimated this deficit up to 500 million USD (La Jornada 2002).
- *Non-diversified economic model,* which generates poverty conditions to the population segment that does not have access to the main economic activity (tourism).
- *Non-sustainable livestock farming, agriculture and forestry practices* (World Bank 2001:9).
- *Limited participation of the local communities* in natural resource management, planning and decision-making (World Bank 2001:9).

All these factors press the natural and cultural environments causing: deforestation, biodiversity loss, overexploitation of aquatic resources, water and soil pollution by inadequate wastewater treatment and urban solid-waste disposal, and cultural impacts.

Deforestation

Quintana Roo has one of the highest deforestation rates in America (World Bank 2001:15, SEMARNAP 2000c:24). According to SEMARNAT (2003b), between 2000 and 2002 tropical forest in Quintana Roo diminished by 11.42 percent (from 3.37 to 2.98 million ha). Clearing for tourism and urban development, and the introduction of African species of grass for livestock grazing are the main causes of deforestation (INE 1999:4). During the same period, grasslands grew by 220 percent (from 103 to 332 thousand ha) and urban areas grew from 9.2 to 14.5 thousand ha (57.4 percent) (SEMARNAT 2003b).

Biodiversity loss

Illegal hunting and fishing, and wild animal trade are common in the Riviera Maya. In addition, the expansion of human activities is leading to biodiversity losses (due to destruction or modification of habitats, pollution, etc.). Table 3.1 shows some of the endangered species in the programme's area.

Overexploitation of aquatic resources

Due to the geology of the Yucatan Peninsula (limestone bedrock which is honeycombed with caves and cenotes, known as karst topography), marine ecosystems, i.e. lagoons, estuaries, wetlands, etc., aquifers and cenotes are highly affected by overexploitation, infrastructure construction, agriculture, forestry, and tourism. Today, some areas such as Akumal and Puerto Aventuras are subject to saline water intrusion.

Table 3.1: Endangered species in the ELUPP Cancun-Tulum

| Common name (<i>Scientific name</i>) | Common name (<i>Scientific name</i>) |
|---|--|
| Ocellated Turkey (<i>Agriocharis ocellata</i>) | Spyder monkey (<i>Ateles geoffroyi</i>) |
| Yellow-lored Parrot (<i>Amazona xantholora</i>) | Grison (<i>Galictis vittata</i>) |
| Blue-winged Teal (<i>Anas discors</i>) | Northern tamandua (<i>Tamandua mexicana</i>) |
| Limpkin (<i>Aramus guarana</i>) | Manatee (<i>Trichechus manatus</i>) |
| Common Black-Hawk (<i>Buteogallus anthracinus</i>) | Loggerhead sea turtle (<i>Caretta caretta</i>) |
| Hocofaisán (<i>Crax rubra</i>) | Green sea turtle (<i>Chelonia mydas</i>) |
| Tawny-winged Woodcreeper (<i>Dendrocincla anabatina</i>) | Leather-back (<i>Dermochelis coriacea</i>) |
| Reddish Egret (<i>Egretta rufescens</i>) | Scorpion mud turtle (<i>Kinosternon scorpioides</i>) |
| Merlin (<i>Falco columbarius</i>) | Furrowed wood turtle (<i>Rhinoclemmys areolata</i>) |
| Crane Hawk (<i>Geranospiza caerulescens</i>) | Common slider (<i>Trachemys scripta</i>) |
| Orange Oriole (<i>Icterus auratus</i>) | Horseshoe crab (<i>Limulus polyphemus</i>) |
| Hooded Oriole (<i>Icterus cucullatus</i>) | Boa constrictor (<i>Boa constrictor</i>) |
| King Vulture (<i>Sarcoramphus papa</i>) | Cozumel whiptail (<i>Cnemidophorus cozumela</i>) |
| Least Tern (<i>Sterna antillarum</i> , <i>Strix nigrolineata</i>) | Spiny-tailed iguana (<i>Ctenosaura similes</i>) |
| Howler monkey (<i>Alouatta pigra</i>) | Green iguana (<i>Iguana iguana</i>) |

Source: CONABIO 2006

Pollution by inadequate wastewater treatment and urban solid-waste disposal

It was recognized that the lack of environmental infrastructure (water, sanitation and solid-waste management) and suitable management programmes are the main environmental threats in the Riviera Maya due to the likely contamination of aquifers, cenotes and coastal ecosystems (SEMARNAT 2002b, GQR 2000 and 2001:4).

The rapid population growth has not been met by the construction of basic urban services of sufficient magnitude. Sewer systems, for instance, are officially believed to cover 80 percent of the population in urban areas in the Riviera Maya (INEGI 2000a). However, these systems have been also estimated to cover only 35 percent of the inhabitants in the region (SEMARNAT 2004). In any case, the environmental impacts originated by the lack of basic urban services are notorious.

In the Nichupte Lagoon (about 3,000 ha), which is surrounded by the city and tourist complex of Cancun, more than 50 percent of the mangroves have been lost during the last thirty years. The environmental impacts are related to the construction of tourism facilities and urban settlements, as well as to pollution by leachate from the old municipal rubbish dump, to inadequate wastewater management (it is estimated that two-thirds of the inhabitants in Cancun still use septic tanks for wastewater disposal), and to inappropriate fuel and lubricant disposal from recreational uses (SEMARNAT 2004). Other indicator could be the incidence of water-related diseases in Quintana Roo. The incidence of these diseases, considering data on gastrointestinal diseases and amoebiasis, grew from 8,100 cases per 100,000 inhabitants in 1998, to 11,200 cases in 2005 (INEGI 2006b).

Cultural impacts

Cultural impacts in the Riviera Maya are the result of cultural clashes between locals, tourists, and immigrants coming from different regions of Mexico. The Government of Quintana Roo (2000) has recognized that immigration “generates impacts upon the Maya communities, transforming their habits and customs”.

3.2 Environmental and sustainable development objectives and targets

The establishment of environmental and sustainable development objectives, targets and priorities can assist in choosing between alternatives and in assessing the environmental performance of the strategic action (CEC 2003:22). This section presents the environmental objectives that the local governments in the Riviera Maya should achieve through the ELUPP Cancun-Tulum, and the objectives at federal and international level that can be supported with the programme implementation (see table 3.2).

Table 3.2 shows that federal and local governments have two clear priorities: environmental protection and the implementation of the strategy proposed by Agenda 21 (table 3.3 presents the objectives and strategies of Agenda 21 that can be related to the implementation of the ELUPP Cancun-Tulum). Table 3.2 also reveals that, in general, there is a lack of clear environmental objectives and targets, as well as specific environmental indicators to investigate the effectiveness of applied strategies. Finally, table 3.4 includes the objectives and strategies of the relevant international agreements that have been ratified by the Mexican Government: the Convention on Biological Diversity and the UN Millennium Development Goals.

Table 3.2: Environmental and sustainable development objectives and targets related to the ELUPP Cancun-Tulum

| According to: | Objectives | Strategies | Proposed indicators |
|---|---|---|---|
| National Development Plan of Mexico (2001-2006) (a) | To create the conditions for sustainable development | <ul style="list-style-type: none"> ▪ To protect key species and ecosystems. ▪ To promote sustainable use of resources, especially water and energy. ▪ To continue the design and implementation of the national strategy for sustainable development (Agenda 21). ▪ To reduce greenhouse gas emissions. ▪ To stop and revert water, air and soil pollution. | <ul style="list-style-type: none"> ▪ Atmosphere damage ▪ Energy consumption ▪ Loss of forest cover ▪ Rate of aquifer conservation |
| SEMARNAT's environmental objectives (2001-2006) (b) | <ul style="list-style-type: none"> ▪ To provide 78 percent of the population with sewage systems. ▪ To treat 65 percent of the wastewater produced in urban and industrial areas. | - | - |
| National Tourism Plan of Mexico 2001-2006's objectives, strategies and indicators (c) | To promote sustainable development of tourism | <ul style="list-style-type: none"> ▪ To implement Agenda 21 ▪ To implement tourism sustainable indicators | WTO sustainable indicators |
| Quintana Roo's environmental and sustainable development strategies (d) | - | <ul style="list-style-type: none"> ▪ To stop and revert water, air and soil pollution. ▪ To stop and revert the loss of natural capital. ▪ To conserve ecosystems and biodiversity. ▪ To promote sustainable development. ▪ To promote a sustainable use of forest resources. ▪ To promote the efficient use of water. ▪ To support a sustainable development of the tourism activity (implementation of Agenda 21). | - |

Source: (a) GM 2001:124-125
 (b) SEMARNAT 2006b
 (c) SECTUR 2001:140
 (d) GQR 2006:46-47

Table 3.3: Strategies and indicators of Agenda 21

| | Objectives | Strategies | Proposed indicators |
|--|--|--|--|
| Strategies and indicators of Agenda 21 (e) | 7. Promoting sustainable human settlement development | <ul style="list-style-type: none"> ▪ Providing adequate shelter for all. ▪ Improving human settlement management. ▪ Promoting sustainable land-use planning and management. ▪ Promoting the integrated provision of environmental infrastructure: water, sanitation, drainage and solid-waste management. ▪ Promoting sustainable energy and transport systems in human settlements. ▪ Promoting sustainable construction industry activities. ▪ Promoting human resource development and capacity-building for human settlement development. | CSD Indicators for Sustainable Development |
| | 8. Integrating environment and development in decision-making | <ul style="list-style-type: none"> ▪ Integrating environment and development at the policy, planning and management levels. | |
| | 9. Protection of the atmosphere | <ul style="list-style-type: none"> ▪ Promoting sustainable development: <ul style="list-style-type: none"> a. Energy development, efficiency and consumption b. Transportation c. Industrial development d. Terrestrial and marine resource development and land use ▪ Preventing stratospheric ozone depletion. | |
| | 10. Integrated approach to the planning and management of land resources | <ul style="list-style-type: none"> ▪ To review and develop policies to support the best possible use of land and the sustainable management of land resources. ▪ To improve and strengthen planning, management and evaluation systems for land and land resources. ▪ To strengthen institutions and coordinating mechanisms for land and land resources. ▪ To create mechanisms to facilitate the active involvement and participation of all concerned, particularly communities and people at the local level, in decision-making on land use and management. | |

Source: UNDSA 2006

Table 3.3: Strategies and indicators of Agenda 21 (continuation)

| | Objectives | Strategies | Proposed indicators |
|--|--|--|--|
| Strategies and indicators of Agenda 21 (e) | 11. Combating deforestation | <ul style="list-style-type: none"> ▪ To effectively ensure the sustainable utilization and production of forests' goods and services. | CSD Indicators for Sustainable Development |
| | 14. Promoting sustainable agriculture and rural development | <ul style="list-style-type: none"> ▪ Land conservation and rehabilitation. ▪ Water for sustainable food production and sustainable rural development. ▪ Integrated pest management and control in agriculture. | |
| | 15. Conservation of biological diversity | <ul style="list-style-type: none"> ▪ Integrate strategies for the conservation of biological diversity and the sustainable use of biological resources into national development strategies and/or plans. ▪ Recognize and foster the traditional methods and the knowledge of indigenous people and their communities. | |
| | 17. Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources | <ul style="list-style-type: none"> ▪ Integrated management and sustainable development of coastal areas, including exclusive economic zones. Marine environmental protection. | |
| | 18. Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources | <ul style="list-style-type: none"> ▪ Integrated water resources development and management. ▪ Water resources assessment. ▪ Protection of water resources, water quality and aquatic ecosystems. ▪ Drinking-water supply and sanitation. ▪ Water and sustainable urban development. ▪ Water for sustainable food production and rural development. | |
| | 21. Environmentally sound management of solid wastes and sewage-related issues | <ul style="list-style-type: none"> ▪ Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources. ▪ Promoting sustainable human settlement development. Protecting and promoting human health conditions. | |

Source: UNDSA 2006

Table 3.4: Objectives, strategies and indicators of the Convention on Biological Diversity and the UN Millennium Development Goals

| | Objectives | Strategies | Proposed indicators |
|--|---|--|---|
| Convention on Biological Diversity goals and indicators (f) | Protect the components of biodiversity | <ul style="list-style-type: none"> ▪ Promote the conservation of the biological diversity of ecosystems, habitats and biomes. ▪ Promote the conservation of species diversity. ▪ Promote the conservation of genetic diversity. | Indicators for Assessing Progress towards the 2010 Biodiversity Target |
| | Promote sustainable use of biodiversity | <ul style="list-style-type: none"> ▪ Promote sustainable use and consumption. | |
| | Address threats to biodiversity | <ul style="list-style-type: none"> ▪ Pressures from habitat loss, land use change and degradation, and unsustainable water use, reduced. ▪ Control threats from invasive alien species ▪ Address challenges to biodiversity from climate change, and pollution. | |
| | Maintain goods and services from biodiversity | <ul style="list-style-type: none"> ▪ Maintain capacity of ecosystems to deliver goods and services and support livelihoods. | |
| | Protect traditional knowledge, innovations and practices | <ul style="list-style-type: none"> ▪ Maintain socio-cultural diversity of indigenous and local communities. | |
| | Ensure the fair and equitable sharing of benefits arising out of the use of genetic resources | Ensure the fair and equitable sharing of benefits arising out of the use of genetic resources. | |
| Strategies and indicators of the UN Millennium Development Goals (g) | Ensure environmental sustainability | Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources | <ul style="list-style-type: none"> ▪ Proportion of land area covered by forests ▪ Ratio of area protected to maintain biological diversity to surface area ▪ Energy use per GDP (kilojoules/peso) ▪ Carbon dioxide emissions per capita and consumption of ozone-depleting chlorofluorocarbons (ODP tons) ▪ Proportion of the population using solid fuels |
| | | Reduce by half the proportion of people without sustainable access to safe drinking water | <ul style="list-style-type: none"> ▪ Proportion of population with sustainable access to an improved water source, urban and rural ▪ Proportion of population with access to improved sanitation, urban and rural |
| | | Achieve significant improvement in lives of at least 100 million slm dwellers, by 2020 | <ul style="list-style-type: none"> ▪ Proportion of households with access to secure tenure |

Source: UN 2003

3.3 ELUPP Cancun-Tulum management model

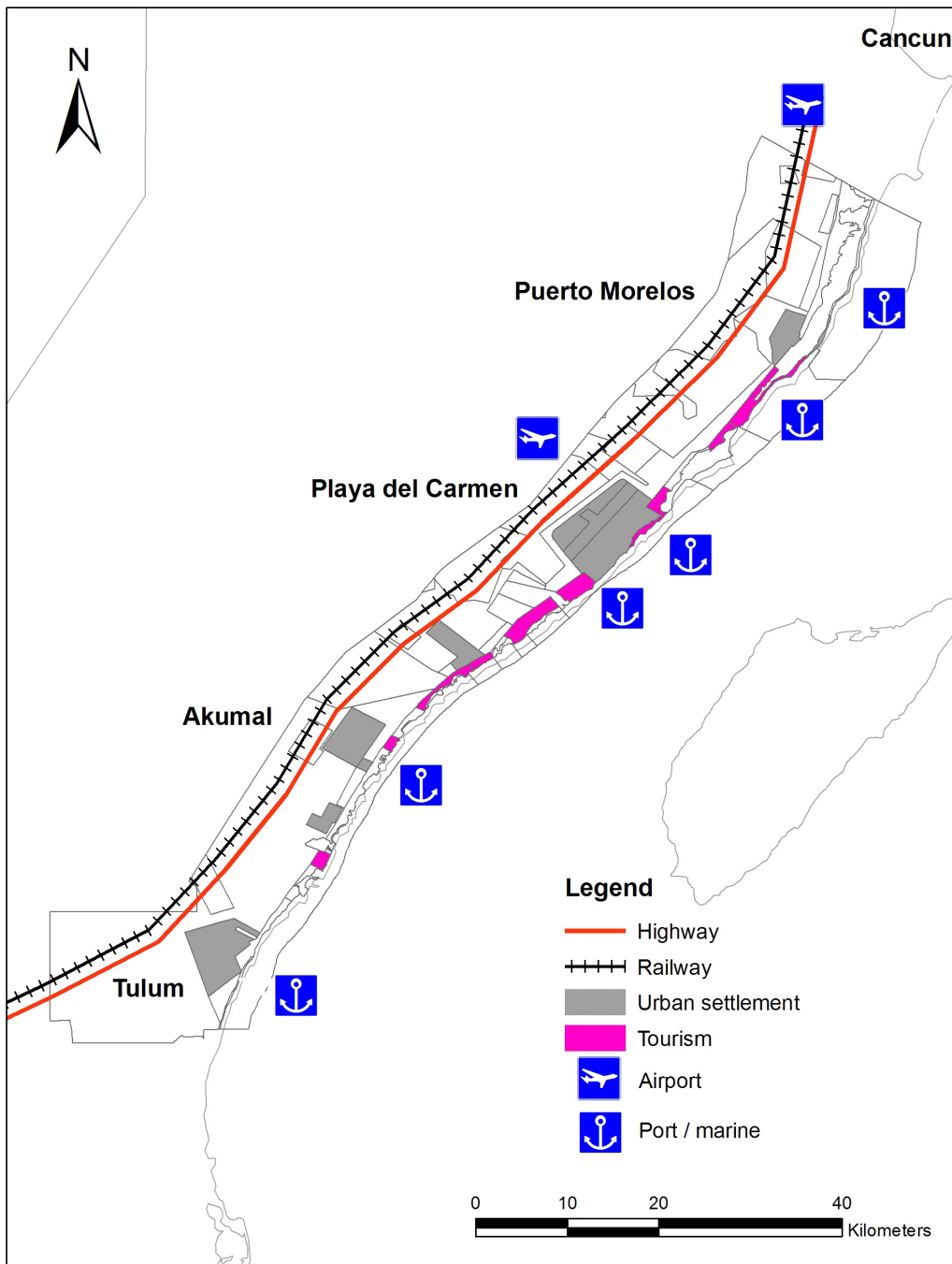
The Riviera Maya's expected tourism and urban development, and the obligation to preserve its ecological patrimony, created a need for planning with a long-term perspective.

The ELUPP Cancun-Tulum was adopted in 1996 as a strategic instrument to integrate continuing growth with long-term sustainable development. The programme entered into force as law on November 15th, 2001. During this several-year-long process, development strategies, objectives and goals in the Riviera Maya were redefined together with the ELUPP framework. According to the last programme's amendment (2000) and the Quintana Roo's Strategic Development Plan 2002-2025 (GQR 2000) the regional development goals by 2025 are:

- To increase lodging capacity in the Cancun-Tulum corridor to 80,000 rooms (currently, around 40,000 rooms are located in the region);
- To create urban areas for 650,000 inhabitants (predicted scenario for population growth in the Riviera Maya during the period 2000-2025);
- To construct a second highway and a high-speed train between the cities of Cancun and Tulum;
- To expand airport infrastructure: enlargement of the Cancun International Airport (2nd track) and construction of the Playa del Carmen Regional Airport;
- To construct or to enlarge port and harbour infrastructures; and
- To develop golf courses to promote low-impact tourism.

Through the implementation of this development strategy, it is expected to reach 11 million tourists annually and to triple tourism revenues to 10 billion USD per year by 2025 (GQR 2000 and FONATUR 2004b). The general arrangement of the projected actions is shown in map 3.2. The programme's development actions are summarized in table 3.5.

The ELUPP Cancun-Tulum was formulated on the basis of an adaptive management approach. This model of policy formulation promotes the use of quasi-experiments that take place as an ongoing part of the policy process (Jacobs and Westcoat 2002). It involves taking action while there is still considerable uncertainty about outcomes, but designing actions so that they can be monitored and adjusted as their effects become more clearly understood. "Management policies are designed to be flexible and are subject to adjustment in an iterative social learning process" (Lee 1999:3).



Map 3.2: Projected development actions in the Riviera Maya
 Source: Based on sketches from FONATUR (2001) and a Landsat GeoCover 1984 Mosaic (ESC 2004)

Table 3.5: ELUPP Cancun-Tulum expected development actions

| |
|--|
| Development action (area expected for this use in the programme) |
| <i>Urban development</i> Urban areas for 650,000 inhabitants (16,211 ha) |
| <i>Tourism development</i> 80,000 rooms (4,507 ha) |
| <i>Infrastructure</i> Highway and high-speed train Cancun-Tulum, Playa del Carmen Regional Airport, port and harbour infrastructure (98 ha) |
| <i>Forestry</i> (41,317 ha) |
| <i>Natural protected areas (NPA)</i> 2 NPAs (1,067 ha) |
| <i>Natural corridor</i> (8,341 ha) |
| <i>Flora and fauna management</i> (77,627 ha) |
| <i>Mining</i> (1,145 ha) |
| <i>Marine activities</i> (31,853 ha) |

While there is no formula for adaptive management, elements generally include (World Bank 2005a:35): (i) management objectives that are regularly revised; (ii) a model of the system being managed; (iii) a range of management choices; (iv) monitoring and evaluation of outcomes; (v) a mechanism for incorporating learning into future decisions; and (vi) a collaborative structure for stakeholder participation and learning.

Management objectives

The programme is to contribute to the achievement of four basic objectives (INE 1999:1-4):

- To promote sustainable development in the Riviera Maya, harmonising socioeconomic growth and environmental protection;
- To regulate land-use;
- To establish strategies for preservation, protection and control of resources to protect the environment; and
- To determine maximum urban growth thresholds to protect aquifer recharge areas.

Management model

The ELUPP Cancun-Tulum was subdivided into 31 Environmental Management Units (EMUs) (see map 3.3). The EMUs are spatial units in which the biophysical and the socioeconomic characteristics are considered to be homogeneous (SEMARNAT 2001a:6).

Each EMU has an individual management scheme based on the allocation of the following attributes:

A. Environmental sensitivity, which indicates the ecosystem susceptibility to impacts and modifications. The environmental sensitivity was divided into five levels: 1 minimum, 5 maximum.

B. Predominant land-use, which is consistent with the traditional land-use and the ELUPP strategy. The predominant land-uses were determined according to the EMU's environmental policy (see table 3.6). In the ELUPP Cancun-Tulum the environmental policies are protection, conservation, exploitation and restoration.

Table 3.6: Allocation of predominant land-uses according to environmental policy

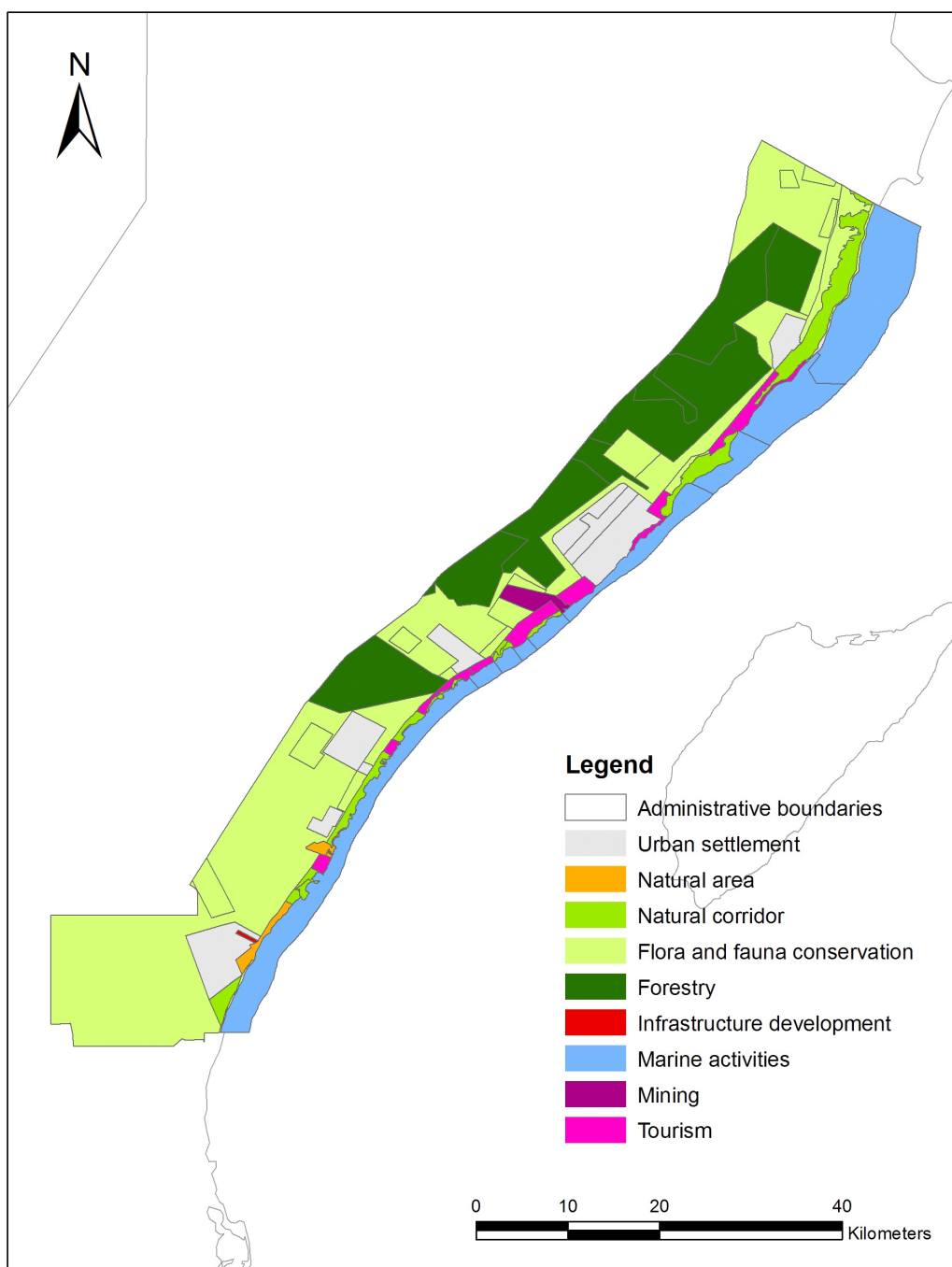
| EMU's Environmental Policies in the Riviera Maya | Predominant land-uses according to environmental policies |
|--|--|
| Exploitation | Urban settlement, infrastructure, mining, tourism |
| Conservation | Urban settlement, natural corridor, flora and fauna, tourism |
| Restoration | Natural corridor, flora and fauna |
| Protection | Natural area, natural corridor |

Source: SEMARNAT 2001a

C. Compatible land-use. It represents a sustainable alternative which does not compete directly with the predominant land-use.

D. Conditional land-use. Due to their likely environmental consequences, conditional land-uses must be subject to strict regulations in order to avoid competition for the same resources with the predominant and compatible uses.

E. Incompatible land-use. Because of its likely environmental impacts and social unacceptance, incompatible land-uses are considered unsuitable for the EMU core vocation and the ELUPP strategy.



Map 3.3: ELUPP Cancun–Tulum’s EMUs and predominant land-uses
 Source: Based on vector data (SEMARNAT 2001c)

F. Environmental policy, which determines the EMU core vocation and the maximum use space densities. The environmental policies were established according to the EMU's environmental sensitivity and environmental pressure (1 minimum, 5 maximum; see table 3.7).

Table 3.7: Allocation of environmental policies according to environmental sensitivity and environmental pressure

| Level | | Environmental pressure | | | | |
|---------------------------|---|------------------------|--------------|--------------|--------------|--------------|
| | | 1 | 2 | 3 | 4 | 5 |
| Environmental sensitivity | 1 | Restoration | Restoration | Exploitation | Exploitation | Exploitation |
| | 2 | Conservation | Restoration | Restoration | Exploitation | Exploitation |
| | 3 | Protection | Conservation | Conservation | Restoration | Exploitation |
| | 4 | Protection | Protection | Conservation | Restoration | Restoration |
| | 5 | Protection | Protection | Protection | Conservation | Conservation |

Source: SEMARNAT 2001a

According to table 3.7, areas having high environmental sensitivities (for example primary rainforest or wetlands) and low environmental pressures (e.g. unaffected primary rainforest) should be protected. On the contrary, areas having low environmental sensitivity (for instance grassland, areas already affected) and high environmental pressures (such as areas close to urban/tourism developments) can be exploited.

G. Ecological criteria, which are compulsory regulations generally at project level, which specify technical and procedural conditions for the development of activities in the Riviera Maya. Ecological criteria are allocated in each EMU according to core vocation and permitted land-uses. In the ELUPP Cancun-Tulum 282 ecological criteria were developed (see table 3.8).

To exemplify the ELUPP management model, the attributes given to an EMU are examined. In map 3.4, the EMU 4, designated to promote urban development in Playa del Carmen, is shown.

Table 3.8: ELUPP Cancun-Tulum ecological criteria*

| Code | | Ecological criteria |
|------|----|--|
| | | Urban |
| AH | 1 | In developing urban areas, the policy of “consolidation” will be applied. |
| AH | 2 | In developing urban areas, the policy of “control” must be applied to minimize urban expansion. |
| AH | 3 | A policy of “development” will be applied to the main urban areas in the corridor: Playa del Carmen, Tulum, and N.C.P Akumal. |
| AH | 4 | Only rural villages from local materials are allowed. Density permitted: 4.3 inhabitants/ha. |
| AH | 5 | Expected urban areas shall maintain vegetation cover until the establishment of an urban development programme (UDP). |
| AH | 6 | The use of expected urban areas without an UDP is not allowed. |
| AH | 7 | New urban developments without an UDP are not allowed. |
| AH | 8 | In the ejidos of Akumal, Puerto Aventuras, Chemuyil and Puerto Morelos, a population density of 40 inhabitants/ha will be authorized. |
| AH | 9 | For settlements up to 50,000 inhabitants, 1.0 m ² /inhabitant of green spaces with public access (neighbourhood garden) and 1.1 m ² /inhabitant of green spaces with public access (district park) shall be considered. |
| AH | 10 | Settlements with more than 50,000 inhabitants shall consider: 1.0 m ² /inhabitant of green areas with public access (neighbourhood garden) 1.1 m ² /inhabitant of green areas with public access (district park) 2.0 m ² /inhabitant of green areas with public access (city park) |
| AH | 11 | Urban areas adjacent to natural protected areas must consider appropriate buffer zones. |
| AH | 12 | Municipalities should assess urban projects to avoid unnecessary clearing. |
| AH | 13 | Population density authorized: 60 inh/ha. |
| AH | 14 | Population density authorized: 70 inh/ha. |
| AH | 15 | Population density authorized: 100 inh/ha. |
| AH | 16 | At least 50% of the vegetation cover must be preserved in properties up to 300 m ² . |
| AH | 17 | At least 70% of the vegetation cover must be preserved in properties with traditional land tenure (<i>ejido</i>). |
| AH | 18 | UDP must identify and protect key ecosystems such as: aquifer recharge areas, <i>dolinas</i> , cenotes, and endangered species of flora and fauna. |
| AH | 19 | Urban development in <i>reholladas</i> , caves, cenotes, cracks and natural wells is not allowed. |
| AH | 20 | In suburban areas with traditional land tenure (<i>ejido</i>), single-family properties must have a minimum area of 1,250 m ² . Subsequent subdivision is prohibited. |
| AH | 21 | Development of suburban or rural settlements can be carried out only in the areas approved by the UDPs, except the area between the EMU 1 and the urban area of Puerto Morelos. |
| AH | 22 | Land-use and density of space use of areas not included in UDP must be determined through a partial urban development programme (PUDP) which evaluates: <ul style="list-style-type: none"> ▪ The capacity of the area to provide drinking water. ▪ The environmental impacts on ecosystems. ▪ The best technology for the solid and liquid waste management and additional equipment. |
| AH | 23 | The UDP of Playa del Carmen shall: <ul style="list-style-type: none"> ▪ Promote the gradual and progressive development of the urban area. ▪ Force the saturation of the first polygon of 5,500 ha. ▪ Avoid the development of projects that affect the rational use of the available infrastructure. ▪ Avoid the use of the west reserve area (3,000 ha) until the first polygon is completely developed. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|---|
| | | Construction |
| C | 1 | Only the area for the construction project can be cleared. |
| C | 2 | Flora and fauna likely to be relocated must be preserved before preparation and construction activities. |
| C | 3 | Construction camps must be located in zones already disturbed within the project area such as stables or young <i>acahuales</i> . They can not be located in wetlands, federal zones or native vegetation. |
| C | 4 | Construction camps must have <i>in-situ</i> systems for sanitary waste management. |
| C | 5 | Construction camps must have comprehensive systems (minimization, separation, collection and elimination) for solid waste management. |
| C | 6 | During dredged and canalization activities, geomembranes and other techniques for avoiding suspension and dispersion of sediment must be used. |
| C | 7 | Construction camp infrastructure must be totally removed at the end of the construction activities. |
| C | 8 | Activity changes or abandonment must comprise a programme for site restoration. |
| C | 9 | The use of explosives is subject to environmental impact assessment and the regulations of the Ministry of Defence. |
| C | 10 | The use of explosives, whit the exception of domestic well construction, is not allowed. In such cases a preventive environmental report that met the regulations of the Ministry of Defence is required. |
| C | 11 | Material disposal from construction activities on vegetation is forbidden. |
| C | 12 | Solid and liquid construction waste must be disposed in areas approved by the municipals. A comprehensive waste management programme is required. |
| C | 13 | Measures for hydrocarbons disposal and reduction of air emissions and noise must be undertaken. |
| C | 14 | The use of <i>Trinax radiata</i> , <i>Pseudophoenix sargentii</i> , and <i>Cocotrinax readii</i> (chit, cuca and nakás) for construction is only allowed when they come from units for the conservation, management and sustainable exploitation of wild life (UMAS) or authorized nurseries. |
| C | 15 | Dust dispersion during storage and handling of materials shall be avoided. |
| C | 16 | All calcareous material, vegetal soil (<i>tierra negra</i>), clearing soil, marine sand, "muca" stone, and vegetal residues must come from authorized sites. |
| C | 17 | Construction camps of projects outside urban areas must be located up to 4 km from the nearest settlement. |
| C | 18 | Underground water flow must not be interrupted by foundations. |
| C | 19 | Energy and communication infrastructure shall be installed subterraneous to avoid visual landscape effects. |
| C | 20 | Energy substations and fuel tanks must be located at least at 5 km of the maximum limit of urban areas. |
| | | Equipment and Infrastructure |
| EI | 1 | Infrastructure construction/installation is not allowed. |
| EI | 2 | Temporal infrastructure is permitted. |
| EI | 3 | Infrastructure construction requires an environmental impact assessment permit. |
| EI | 4 | Infrastructure construction is subject to the management programme. |
| EI | 5 | Tourism/urban development must have a comprehensive solid-waste management programme. |
| EI | 6 | Solid waste management infrastructure is not allowed, except municipal and particular sites already approved. |
| EI | 7 | UDPs must encompass guidelines for solid waste management in urban or semi-urban areas. |
| EI | 8 | The use of organic waste as compost shall be promoted. |
| EI | 9 | The use of dry toilets in sub-urban and rural areas should be promoted to minimize soil contamination. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|---|
| | | Equipment and Infrastructure |
| EI | 10 | Tourism developments and urban areas provided with medical centres should have comprehensive management programmes for biological and infectious waste. |
| EI | 11 | Tourism developments and urban areas must have infrastructure for solid and liquid waste management. |
| EI | 12 | Tourism developments and urban areas must have comprehensive management systems to minimize, treat and dispose wastewater "in situ", according to the applicable legislation. |
| EI | 13 | Discharge of pluvial water to the sea and water bodies is prohibited. The construction of absorption wells must have the consent of the SEMARNAT and the National Water Commission (CNA). |
| EI | 14 | Separate pluvial and wastewater drainage systems have to be considered when designing streets and avenues. |
| EI | 15 | Wastewater from urban areas, if possible, must be send to wastewater treatment systems. |
| EI | 16 | Reusing treated wastewater will be promoted. |
| EI | 17 | Wastewater treatment plants must minimize sludge production and implement programmes for its final disposal. |
| EI | 18 | Treated wastewater shall be reused for gardens and golf courses irrigation. Irrigation systems shall be connected to wastewater treatment systems. |
| EI | 19 | Wastewater discharge to the soil is prohibited. |
| EI | 20 | Wastewater discharge to mangroves is not allowed. |
| EI | 21 | Burning of solid-waste and vegetation, and the use of defoliant products and heavy machinery in maintaining the right-of-way is prohibited. |
| EI | 22 | Consolidation of road slopes shall be performed with native vegetation. |
| EI | 23 | Road sides must be protected with native trees and bushes. |
| EI | 24 | Cutting down of trees and bushes on road sides is not allowed. |
| EI | 25 | Access roads must have speed reducers and signalling for fauna protection. |
| EI | 26 | Road construction on mangroves is prohibited. |
| EI | 27 | Road construction on wetlands has to be based on piles or bridges, avoiding the use of sewers, in order to preserve hydrodynamic flows and biological corridors. |
| EI | 28 | Solid-waste management infrastructure construction is not allowed. |
| EI | 29 | Airport infrastructure shall have systems for grease, oil and fuels recovery. |
| EI | 30 | Marina construction needs an EIA permit. |
| EI | 31 | Marina construction shall guarantee the preservation of the coastal transport processes and water quality. |
| EI | 32 | Marina constructions must be subject to batimetric, topographic, mechanic, and geologic studies. |
| EI | 33 | Dock construction must be subject to geo-hydrologic studies and international regulations. |
| EI | 34 | Construction of permanent docks shall guarantee the coastal transport processes and water quality. |
| EI | 35 | Only the construction of wood quays is allowed with the exception of EMUs with protection, restoration environmental policies or NPA. |
| EI | 36 | Dock construction is not allowed. |
| EI | 37 | Quays construction is prohibited. |
| EI | 38 | Alternative energy programmes will be promoted. |
| EI | 39 | In golf courses, only biodegradable fertilizers and pesticides are allowed. |
| EI | 40 | Clearing area for golf courses should preserve native vegetation as demanded in the EMU. |
| EI | 41 | Golf course construction needs a regional EIA permit. |
| EI | 42 | In golf course roads and the proximities of "fairway", "tees" and "greens" native vegetation must be preserved or recovered. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|---|
| | | Equipment and Infrastructure |
| EI | 43 | Golf courses are prohibited. |
| EI | 44 | Only infrastructure for the conservation and rescue of archaeological sites is allowed. |
| EI | 45 | Urban areas in the right-of-way of high tension electric power lines are prohibited. |
| EI | 46 | Urban development around golf courses is prohibited. |
| EI | 47 | Golf courses in tourism zones must preserve at least 65% of the native vegetation. |
| EI | 48 | Tourism development projects must consider public access to the coastal zone. Obstruction of public access already established is not allowed. Relocation of public access is in certain cases possible. |
| EI | 49 | Construction of communication infrastructure (such as posts, towers, structures, equipment, buildings, lines and antennas) in vulnerable ecosystems, high scenic, cultural or historical sites is prohibited. |
| EI | 50 | The use of burned oil and other toxic substances for wood treatment during construction activities on water bodies is prohibited. |
| EI | 51 | Road construction (perpendicular to the coastal line) is prohibited. |
| EI | 52 | Road construction (parallel to the coastal line) must be carried out in the limit between the last sand-dune and the wetland, considering corridors for fauna mobility. |
| EI | 53 | Roads already constructed on wetlands must be adapted with bridges to guarantee water flow and fauna mobility. |
| EI | 54 | Septic tank construction or operation close to drinking-water wells is not allowed. These systems shall be changed to alternative waste management systems. |
| EI | 55 | The construction of absorption fields for wastewater management is prohibited. |
| | | Flora and Fauna |
| FF | 1 | The use of firewood for tourism and commercial purposes is prohibited. |
| FF | 2 | Tourism and urban development must minimize the impacts on fauna (mammals, reptiles and birds, specially the spider monkey). |
| FF | 3 | Capture of marine mammals is prohibited. |
| FF | 4 | Affectations to the coastal line and mangroves, marine grass elimination, and water quality alteration are not allowed. |
| FF | 5 | Land-use in areas close to marine turtle nesting sites needs an EIA permit. |
| FF | 6 | Infrastructure installation in marine turtle nesting beaches must be carried out not less than 50m from the high tide line, or as determined by ecological studies. |
| FF | 7 | During nesting season, locals and authorities shall work together to protect marine turtle. |
| FF | 8 | Activities in marine turtle nesting beaches are subject to the management programme. |
| FF | 9 | Alteration of dunes in marine turtle nesting beaches is prohibited. |
| FF | 10 | In marine turtle nesting beaches direct illumination is prohibited. |
| FF | 11 | Artificial illumination (when needed) in areas adjacent to marine turtle nesting beaches must be amber to guarantee turtle arrivals. |
| FF | 12 | Vehicular transit is prohibited, except authorized monitoring and maintenance activities. |
| FF | 13 | During the nesting season, signalling for marine turtle areas must be carried out. |
| FF | 14 | In marine turtle nesting beaches the access to cattle (pig, equine, and ovine), dogs, cats or any other type of exotic animals, and the disposal of animal faecal waste is not allowed. |
| FF | 15 | Green spaces should conserve the most developed trees of the original vegetation. |
| FF | 16 | Flora and fauna removal, capture and commercialization are not allowed, except to the mentioned by the General Wildlife Law. |
| FF | 17 | Nurseries and greenhouses are allowed. |
| FF | 18 | The use of chemical products for weed and plague control is prohibited. Mechanical or biological procedures should be promoted. |
| FF | 19 | It is allowed to construct Wild Life Management and Conservation Units (UMAS for its name in Spanish). |
| FF | 20 | Extraction of flora and fauna from cenotes is not allowed. Only those activities authorized by SEMARNAT are allowed. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|--|
| | | Flora and Fauna |
| FF | 21 | The use of the species: <i>Thrinax radiata</i> , <i>Pseudophoenix sargentii</i> , <i>Chamaedorea seifrizii</i> , <i>Coccothrinax readii</i> and <i>Beaucarnea ameliae</i> (chit, cuca, xiat, nakás and despeinada or tsipil) and all species of orchids is prohibited, with the exception of those produced in UMAS. |
| FF | 22 | The introduction of invasive exotic species of flora and fauna is prohibited. |
| FF | 23 | Eradication of detrimental exotic plants will be promoted, especially Sea Pine (<i>Casuarina equisetifolia</i>). Native flora must be recovered. |
| FF | 24 | Native plants must be used in gardens; other species have to be restricted. |
| FF | 25 | Removal or alteration of marine grass is prohibited. |
| FF | 26 | The use of explosives, dredging, and construction activities near coral reefs and mangroves is not allowed. |
| FF | 27 | Location and construction of anchorage points must be subject to specific studies. |
| FF | 28 | Boat anchorage must be located not less than 35 m from coral reefs. |
| FF | 29 | Boat anchorage in sandy and “ceibadales” areas is allowed. |
| FF | 30 | Recollecting, removing, or transplanting of alive, died organisms and natural materials in coral reefs is prohibited. |
| FF | 31 | Construction of artificial reefs with peak shape (to promote beach) is prohibited. |
| FF | 32 | Dredging, channel construction or any other activity that affect coralline communities is prohibited. |
| FF | 33 | Existing and new developments must guarantee the permanence of crocodile populations. |
| FF | 34 | Studies to minimize negative impacts must be carried out, in areas with presence of species included in NOM-059-ECOL-1994. |
| FF | 35 | Construction of structures to promote beach formation is prohibited. |
| FF | 36 | Dredging and the use of explosives in mangrove areas are not allowed. |
| FF | 37 | In roads, the connectivity of the top of the trees must be preserved to allow fauna mobility. |
| | | Ecosystem Management |
| MAE | 1 | Only temporary structures on beaches such as “palapas” of wood are allowed. |
| MAE | 2 | Activities to control erosion in coastal zone require an EIA permit. |
| MAE | 3 | Modifications to the coastline are prohibited. |
| MAE | 4 | Bonfires in beaches are not allowed. |
| MAE | 5 | Extraction of sand from beaches, dunes or lagoons is prohibited. |
| MAE | 6 | Disposal of hydrocarbons and non-biodegradable products is prohibited. |
| MAE | 7 | Recreational and service infrastructure in the frontal dune cord is not allowed. |
| MAE | 8 | Buildings can be constructed after dune cord, not close than 40 m to the federal zone and a max height of 6 m. |
| MAE | 9 | New roads on dunes are prohibited. |
| MAE | 10 | Only pedestrian crossing over dunes is allowed. |
| MAE | 11 | Removal of dune vegetation or dune modifications is prohibited. |
| MAE | 12 | The use of wetlands must be subject to an EIA permit. The preservation of the geo-hydrological processes, water quality, nutrients flow, and biological diversity must be guaranteed. |
| MAE | 13 | Drying, dredging and filling of water bodies, cenotes, lagoons, “rejolladas”, and mangroves is prohibited. |
| MAE | 14 | Additionally to the drinking-water systems, all constructions shall be provided with a system for rain-water reuse. |
| MAE | 15 | The use of groundwater is subject to geo-hydrological studies to avoid saline intrusion. It must be approved by the National Water Commission. |
| MAE | 16 | Green spaces in urban areas must preserve native vegetation cover. |
| MAE | 17 | Native vegetation in federal zones and water bodies shall be maintained or restored. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|---|
| | | Ecosystem Management |
| MAE | 18 | Vegetation around water bodies shall be maintained or restored. |
| MAE | 19 | Only 35% of a property can be cleared. |
| MAE | 20 | Only 25% of a property can be cleared. |
| MAE | 21 | Only 15% of a property can be cleared. |
| MAE | 22 | Clearing is prohibited, except investigation or archaeological preservation activities approved by the National Institute for Anthropology and History. |
| MAE | 23 | Reforestation must be based on native vegetation. |
| MAE | 24 | Modifications to dolinas, cenotes, and caverns are prohibited. |
| MAE | 25 | Dredging, filling, excavation or expansion of cenotes and vegetation removal is not allowed. Except rescue activities with an EIA permit. |
| MAE | 26 | Clearing and topographical modifications in a 50 m buffer zone around cenotes, dolinas and caverns are prohibited. |
| MAE | 27 | The use of caverns and cenotes needs an EIA permit, which includes a strategy to preserve biodiversity. The National Water Commission must approve these activities. |
| MAE | 28 | Only 5% of the vegetation can be cleared. |
| MAE | 29 | Projects shall guarantee vegetation connectivity between adjacent properties for fauna mobility. |
| MAE | 30 | The alteration of the main drainages of flooded areas is not allowed. |
| MAE | 31 | Projects on mangroves must guarantee flow regimes with a geo-hydrological study. |
| MAE | 32 | Obstruction or modification of runoff drainages is not allowed. |
| MAE | 33 | A comprehensive system for the control of plagues, technologies, space and final disposal of pesticide packages will be promoted. |
| MAE | 34 | To restore material banks native vegetation must be used. |
| MAE | 35 | Restoration of material banks should consider a minimum of 500 trees/ha. |
| MAE | 36 | Vegetation cleared in tourism developments can be used to restore material banks. |
| MAE | 37 | In restoring material banks, the reproduction of the vegetation planted must be ensured, replacing the units that do not survive. |
| MAE | 38 | Material banks must guarantee the non-infiltration of leachade, solid or liquid waste to aquifers. |
| MAE | 39 | Clearing is prohibited. |
| MAE | 40 | Only the area for restoration and maintenance of archaeological sites can be cleared. |
| MAE | 41 | The use of material banks for compost and solid-waste separation purposes must guarantee the non-infiltration of leachade. The use of sites where groundwater level is visible is not allowed. |
| MAE | 42 | Houses in rural or semi-urban areas, where no sewer system exist, must have a system for wastewater treatment. Treated water should be used for green areas. |
| MAE | 43 | The original coastal structure must be restored. |
| MAE | 44 | Areas designated to environmental compensation and mangroves can not be used to productive activities. |
| MAE | 45 | The use, clearing and fill of mangroves can not exceed 10% of the total area. The continuity and quality of hydrodynamic processes, species populations must be guaranteed, as well as the permanence of the remaining 90%. |
| MAE | 46 | Construction of golf courses are allowed in areas (not recently) already impacted such as material banks, deforested areas that only have secondary vegetation. |
| MAE | 47 | Geohydrological studies approved by the National Water Commission are required to use water bodies. |
| MAE | 48 | Only biodegradable fertilizers, herbicides and pesticides are allowed. |
| MAE | 49 | Only native vegetation in green areas is allowed. |
| MAE | 50 | Only recreational, scientific, or ecological activities included in a management programme are allowed in ecological protection units. |
| MAE | 51 | Reforestation programmes must be implemented to recover affected or cleared areas close to urban areas. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|-----------------------------|----|--|
| Ecosystem Management | | |
| MAE | 52 | Reforestation in urban and tourism areas must be carried out with native or compatible vegetation that do not affect native species, urban development and local landscape. |
| MAE | 53 | The use of fire or chemical products for clearing is prohibited. Vegetation waste burning is not allowed. |
| MAE | 54 | Areas affected by fire, soil movements, products or activities that eliminate or modify vegetation can not be used for urban or tourism development within a 10 year time period. These areas must be reforested with native vegetation. |
| MAE | 55 | Aquaculture in natural water bodies is prohibited. |
| MAE | 56 | Recreational marine activities during the sea turtle nesting period (sunset to dawn) are prohibited. |
| MAE | 57 | Excavation under the water table in material banks are not allowed, except when an authorization of the National Water Commission exists. |
| MAE | 58 | Approved golf courses must be environmentally certified. They can have associated urban developments, but these settlements shall be auto sufficient and environmentally certified. |
| MAE | 59 | The area between the tourist development of X'cachel and X'cachelito remains indefinite. |
| Mining | | |
| MI | 1 | The extraction of calcareous material is only possible if the activity has a comprehensive site restoration programme. |
| MI | 2 | The exploitation of new material banks requires an environmental impact and risk assessment approved by the competent authority. |
| MI | 3 | The location of new material banks must be defined by studies approved by the competent authority. |
| MI | 4 | Location of material banks west of this road, and not less than 200 meters to the way of right is not allowed. |
| MI | 5 | During exploitation of material banks, areas already exhausted must be restored. A maximum of 20% of the area can remain without vegetation for transit purposes. The competent authority must be periodically informed to supervise and approve the activities. |
| MI | 6 | Material banks already exploited must be totally restored. Native vegetation shall be used and the use of compost material must be promoted. The competent authority must supervise and approve the activities. |
| MI | 7 | In order to prevent erosion and destabilization of slopes, containment structures have to be constructed. Slope angle must be $\leq 45\%$. |
| Tourism | | |
| TU | 1 | A density of space use of 60 rooms/ha, in the approved clearing area, is allowed. |
| TU | 2 | A density of space use of 40 rooms/ha, in the approved clearing area, is allowed. |
| TU | 3 | A density of space use of 30 rooms/ha, in the approved clearing area, is allowed. |
| TU | 4 | Ecotourism development based on rustic cabins (made from local materials) for four people is permitted. Density of space use: 5 cabins in 5 ha. |
| TU | 5 | Hotel room development is prohibited. |
| TU | 6 | Coral reefs tours are subject to specific studies. |
| TU | 7 | The use of motorized boats in creeks and cenotes is prohibited. |
| TU | 8 | Nautical activities must have environmental regulations for impact mitigation. |
| TU | 9 | Landing on water of hydroplanes is prohibited. |
| TU | 10 | Recreational activities must have a comprehensive programme for solid and liquid waste management. |
| TU | 11 | Recreational activities must have regulations to minimize impacts on flora, fauna, and geological formations. |
| TU | 12 | During cave diving, it is prohibited to disturb, capture or hurt native fauna, and to modify or contaminate the cavern environment. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|---|
| | | Tourism |
| TU | 13 | The use of mangroves and wetlands is allowed under the modalities of: nature contemplation, trekking, camping, and photographic walks. |
| TU | 14 | The practice of camping, observation of flora and fauna and photographic walks are allowed. |
| TU | 15 | Buildings must not exceed the average height of arboreal vegetation (12 m). |
| TU | 16 | The construction of hotels and associate infrastructure can occupy up to 30% of the beach front of the property. |
| TU | 17 | The construction of hotels and associate infrastructure can occupy up to 10% of the beach front of the property. |
| TU | 18 | Tourism/recreational activities are subject to special ecological studies to determine areas, schedules, and carrying capacity, according to the current legislation. |
| TU | 19 | The practice of motorized aquatic sports less than 100 m from coral reefs is not allowed. |
| TU | 20 | The use of platforms or boats for massive diving and snorkelling is prohibited. |
| TU | 21 | When tourism areas are located close to natural protected areas (NPA), buffer zones shall be established from the limit of the NPA to the tourism area. |
| TU | 22 | Tourism development must preserve key ecosystems such as coral reefs, <i>subperennifolia</i> rainforest, mangroves, cenotes, coves, among others, as well as the species included in the Mexican Official Standard 059 (NOM-059-ECOL-2001, List of endangered species). |
| TU | 23 | With exception to the mentioned in the criterion TU-22, in tourism developments the non-cleared area must be distributed around the property and between buildings and infrastructure. |
| TU | 24 | Preservation and maintenance of non-cleared vegetation is responsibility of the owners of the tourism development or the person in charge. |
| TU | 25 | The practice of any motorized aquatic sport must have an official authorization and guarantee the security of swimmers. Entrances and exits of boats have to be determined. |
| TU | 26 | The navigation of boats in transit, according to the established routes, is allowed. |
| TU | 27 | The practice of recreational activities that require motorized aquatic equipment, such as jet sky, parachute, and speedboats, in coastal lagoons and coral reefs areas is prohibited. |
| TU | 28 | The use of coastal and coral reef lagoons for landing of hydroplanes, for inspection, monitoring, investigation and emergency purposes, is allowed |
| TU | 29 | It is prohibited to touch, stand up, damage, alter or hold coral reefs. |
| TU | 30 | The use of gloves and knives for diving and swimming is prohibited. |
| TU | 31 | Fishing of any type is prohibited. |
| TU | 32 | In access channels to lagoons, only transit boats are allowed. |
| TU | 33 | In access channels to lagoons recreational or cultural, diurnal or nocturnal, surface of submarine activities are prohibited. |
| TU | 34 | Service providers should provide security conditions to users according to the applicable legislation. |
| TU | 35 | Nautical motorized surface or submarine tournaments or competitions in coral reef lagoons are not allowed. |
| TU | 36 | Access channels to lagoons shall be signalized. |
| TU | 37 | Maintenance, clearing, fuel supply, discharge of liquids or boat repair is prohibited, with exception of emergency cases in which the security of human lives is involved. |
| TU | 38 | The navigation of motorized boats with more than 1.5 m of draught in lagoons is not allowed. |
| TU | 39 | To maintain in stationary stage motorized boats or to navigate without defined destiny in lagoons is prohibited. |
| TU | 40 | To feed wild fauna is prohibited. |
| TU | 41 | The use of two-time motors for marine tourism activities is prohibited. |
| TU | 42 | The use of marine platforms or similar devices is not allowed. |

Source: SEMARNAT 2001b

* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|------|----|--|
| | | Tourism |
| TU | 43 | In archaeological zones, only the construction of the infrastructure approved by the National Institute of Anthropology and History is allowed. |
| TU | 44 | Before the start of any development action an archaeological exploration is needed. The National Institute of Anthropology and History must be notified. |
| TU | 45 | It is considered equivalent: <ul style="list-style-type: none"> ▪ 1 two-room house with two hotel rooms. ▪ 1 hostel with 5 hotel rooms. ▪ 1 bungalow, cabin or villa with 3 hotel rooms. ▪ 1 department or study with 3 hotel rooms. ▪ 1 camper with two hotel rooms. ▪ 1 hospital room with 1.7 hotel rooms. ▪ 1 motel room with 1.3 hotel rooms. ▪ 1 junior suite with 1.7 hotel rooms. ▪ 1 palafito with 0.7 hotel rooms. ▪ 1 suite with 2 hotel rooms. <p>Hotel room is defined as the tourist infrastructure destined to lodge two persons with the maximum of one bath. The quantification of the total tourist rooms shall include the necessary rooms for the personnel.</p> |
| | | Forestry |
| AF | 1 | Collecting of fruits, seeds, wood rests for subsistence purposes is allowed. |
| AF | 2 | Tourism activities in forestry zones require the approbation of SAGARPA and SEMARNAT. |
| AF | 3 | Forestry exploitation requires a management programme approved by SAGARPA. |
| AF | 4 | Nurseries have to have a SAGARPA registry and the approbation of the Federal Vegetation Health. |
| AF | 5 | The use of fire is prohibited. |
| AF | 6 | Agriculture and cattle farming are allowed. |
| AF | 7 | The location of areas for productive activities, which include services and infrastructure, shall be determined by a Partial Urban Development Programmes. |
| AF | 8 | The application of intermediate forestry treatments may be permitted if it is demonstrated that it is technically and biologically viable. Specific studies to determine that the forests are in a succession advanced stage shall be conducted. |
| AF | 9 | Vegetation around drinking water sources/recharge areas must be conserved. Reforestation programmes shall be implemented when needed. |
| AF | 10 | The protection of drinking water sources/recharge areas is a priority. |
| AF | 11 | Capture or exploitation of fauna is subject to the applicable regulations. |
| AF | 12 | Ecotourism in restoration areas is allowed. It must be carried out in accordance with the applicable environmental regulations. |
| AF | 13 | The use of non-wood products under the scheme of Conservation, Management and Sustainable Exploitation of the Wild Life Units (UMAS) is allowed. |
| AF | 14 | Construction of access roads shall consider the applicable environmental regulations. Impacts on restoration zones shall be minimized. |
| AF | 15 | Activities that promote sustainable forestry use are allowed. |
| AF | 16 | Agriculture, cattle farming and other activities which require land-use change are prohibited. In special cases, according to the applicable regulations, land-use changes may be authorized. |
| AF | 17 | Forestry projects must consider: the Forest Law and its regulations, the Wild Life Law, LGEEPA and the applicable Mexican Standards and Norms. |
| | | Cattle farming |
| APC | 1 | Only intensive cattle farming practice is allowed. |
| APC | 2 | Only biodegradable products shall be used to weed control. |
| APC | 3 | Cattle farming close to tourism and urban areas is not allowed. |

Source: SEMARNAT 2001b

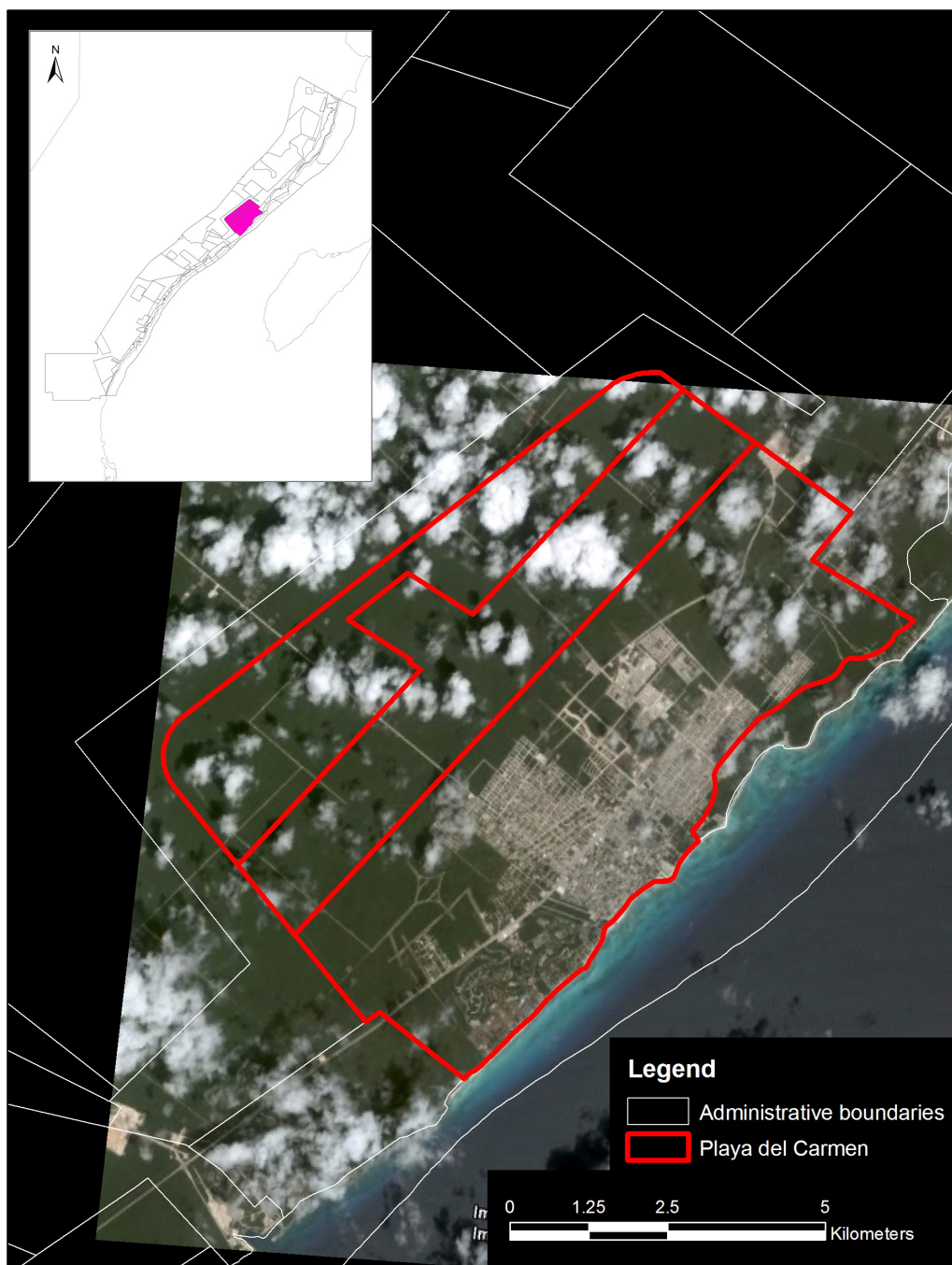
* Author's translation from Spanish

Table 3.8: ELUPP Cancun-Tulum ecological criteria* (*continuation*)

| Code | | Ecological criteria |
|-----------------------|---|---|
| Cattle farming | | |
| APC | 4 | The use of chemical products for cattle-disease control has to be made in adapted sites according to the regulations of SAGARPA. |
| APC | 5 | Construction of cattle farming facilities is possible only in sites with already altered vegetation. |
| APC | 6 | Excrements shall be confined in sites with impermeable mesh to avoid soil contamination. |
| APC | 7 | Only cattle farming for auto-consume purposes is allowed. |
| APC | 8 | Cattle farming excrements shall be treated (compost or bio digesters) to avoid the contamination of groundwater and the proliferation of undesirable fauna. |
| Agriculture | | |
| AA | 1 | An agricultural activity in sites with already impacted vegetation is allowed. |
| AA | 2 | Only the use of biodegradable herbicides and pesticides is allowed. |
| AA | 3 | Only irrigation systems approved by SAGARPA are allowed. |
| AA | 4 | Extensive agriculture is prohibited. |
| AA | 5 | In the preparation of agricultural activities the method of roza-tumba-limpia can be used. The use of fire is conditioned to the requirements established in the NOM-EM-SEMARNAP/SAGAR 1996. |
| Fishing | | |
| APS | 1 | Boats used for commercial fishing shall have the colours and distinguishing codes assigned by SEMARNAT, as well as the permission of fishing. |
| APS | 2 | The use of chemical products, electronic and mechanical devices for the capture of marine fauna is prohibited. |
| Industry | | |
| I | 1 | Under the following regulations, the establishment of agro-industries is allowed: Type of industry: fishing and agriculture Intensity of land use: intensive Type of location: industrial parks and ports Location: concentrated Location with respect to the urban area: outside of the urban area Other compatible land uses: zones with ecological policy, use or conservation. |
| I | 2 | Handicraft industry, which has the following characteristics: low impact, does not generate smoke, elevated noise level, chemical waste, dusts or odours, has low water consumption, and low energy consumption is allowed. It has the following restrictions: Type of industry: Handicraft Intensity of land use: intensive Type of location: industrial park, urban zone Location: concentrated Location with respect to the urban area: inside or in the periphery Other compatible land uses: zones with ecological policy, use or conservation. |
| I | 3 | The establishment of light industry activity is allowed. The industry must not generate smoke, high levels of noise, chemical waste, dusts and odours, and shall have low water consumption, highly energy efficiency. The following restrictions are applicable: Type of industry: low impact and low risk industry such as: smaller manufactures, clothes, warehouses, specialized services. Intensity of land use: intensive Type of location: industrial park Location: concentrated Location with respect to the urban area: in the periphery Other compatible land uses: zones with ecological policy of use. |
| I | 4 | Industrial zones and factories located within the urban zones shall have buffer zones delimited by natural or artificial barriers, which diminish the effects of noise and environmental contamination, including visual contamination. |

Source: SEMARNAT 2001b

* Author's translation from Spanish



Map 3.4: Environmental Management Unit 4 (Playa del Carmen)

Source: Based on vector data (SEMARNAT 2001c) and a satellite image from Google Earth (2006)

The environmental policy of EMU 4 is exploitation, which means that “the current land-use will be promoted and/or significant landscape changes will be permitted. It is allowed, in addition, higher exploitation rates due to the minimum environmental sensitivity” (SEMARNAT 2001a:1).

In map 3.4, the EMU 4 is superimposed on a satellite image that shows the city of Playa del Carmen in 2005 (Google Earth 2006). In Playa del Carmen, urban settlement is the predominant land-use. Compatible land-uses are conservation of flora and fauna, infrastructure and tourism development. Industry is considered as conditional land-use. Finally, aquaculture, agriculture, natural area, natural corridor, forestry, mining, livestock, and fishing are categorized as incompatible land-uses (see table 3.9).

Table 3.9: Allocation of attributes for the Environmental Management Unit 4

| EMU | Policy / Environmental Fragility | Predominant land-use | Compatible land-use | Conditional land-use | Incompatible land-use | Ecological criteria allocated to EMU 4* |
|-----|--|----------------------|--|----------------------|---|--|
| 4 | Exploitation | Urban settlements | Flora and Fauna, Infrastructure, Tourism | Industry | Aquaculture, Agriculture, Natural Area, Natural Corridor, Forestry, Mining, Cattle, Fishing | Ah 3, 5, 6, 7, 10, 11, 12, 15, 16, 17, 18, 20, 21, 22, 23 |
| | Urban settlements Tulum, Playa del Carmen and new urban areas. | | | | | C 1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 19, 20 |
| | | | | | | EI 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 30, 31, 32, 33, 34, 38, 39, 40, 41, 42, 45, 47, 48, 49, 50, 53, 54, 55 |
| | | | | | | FF 1, 2, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 34 |
| | | | | | | MAE 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 42, 43, 46, 47, 48, 49, 51, 52, 53, 54, 55 |
| | | | | | | Tu 4, 10, 11, 12, 15, 16, 21, 22, 23, 24, 34, 43, 44, 45 |
| | | | | | | AF 7, 10 |
| | | | | | | I 2, 3, 4 |

Key:

Ah = Urban settlements

FF = Flora and Fauna

AF = Forestry

C = Construction

MAE = Ecosystem management

I = Industry

EI = Equipment and Infrastructure

Tu = Tourism

* See definition of ecological criteria in table 3.8

Source: SEMARNAT 2001b

145 ecological criteria were allocated to EMU 4 according to its environmental policy and designated land-uses (see table 3.9). Two examples of ecological criteria formulation are the criteria Ah-7 (urban settlement) and MAE-13 (ecosystem management; see table 3.8).

The criterion Ah-7 establishes that “the development of new settlements without an urban development programme is not allowed” (SEMARNAT 2001b). The objective of this criterion is to obligate the establishment of regional development programmes and, at the same time, to ensure their observance. The criterion MAE-13 states that “it is prohibited to drain or to fill water bodies, cenotes, lagoons, and mangroves” (SEMARNAT 2001b). This criterion aims to protect vulnerable ecosystems.

The ELUPP Cancun-Tulum is legally binding. Actions to be realized in the programme’s area have to implement its provisions.

Stakeholder participation

Federal, state and municipal governments and a large number of local players participate in the programme. The federal government is involved through the agencies SEMARNAT, SEDESOL (Secretariat for Social Development) and SECTUR (Ministry of Tourism). However, the responsibility of each federal agency and local governments is not clearly established.

All authorities are responsible for: (i) updating of the programme; (ii) carrying out the required studies; (iii) coordinating the participation of other institutions and individuals; (iv) regulating urban development plans and programmes in the area; and (v) ensuring that all the concessions, permissions, licenses, authorizations, resolutions, and decision-making in general are in accordance with the programme provisions (GM 2003:10-12).

Implementation and monitoring

As it was previously mentioned, the ELUPP Cancun-Tulum implementation was initiated more than a decade ago. However, so far no monitoring mechanism was implemented to analyze the effectiveness of applied strategies. Without a mechanism for incorporating learning into future decision, how were development goals and ecological criteria updated, and above all, are the environmental and sustainable development objectives, targets and priorities of section 3.2 being achieved?

Currently, the number of projects that met the ELUPP Cancun-Tulum's provisions (considering the MIAs submitted and approved in the Riviera Maya annually) is used as a performance indicator. According to the last report (SEMARNAT 2002c), twenty MIAs were submitted in 2002 and seven of them were approved (which means that 35 percent of the proposed projects in the Riviera Maya met the ELUPP's provisions). However, there are no additional data to determine compliance trends and thus the efficiency of the programme implementation. If it is considered, in addition, the Riviera Maya's growth rate it could be said that this monitoring procedure is neither representative nor efficient. To have an idea, in the same year (2002) around 20,000 new inhabitants arrived in the region² and 58 new hotels (equivalent to 1,610 rooms) were constructed (SEDETUR 2004). It is easy to realize that the development actions in the Riviera Maya were not totally enclosed by the MIAs.

Due to the lack of monitoring, there is not enough evidence to demonstrate how ELUPP's strategies are influencing anthropogenic activities in the Riviera Maya. To mention one example, the ecological criterion MAE-29 allocated to EMU 4 (see table 3.8 and 3.9) demands that "development projects should guarantee vegetation connectivity for fauna mobility" (SEMARNAT 2001b), however, it is not evident to which extent this criterion is being satisfied or how it is being monitored.

It is possible to affirm that the second management objective (see page 30) has been achieved: land-use was regulated (at least on paper) in the region. On the contrary, it is uncertain if economic development and environmental protection have been harmonized, as well as the result of the implemented strategies.

It has been recognized (SEMARNAT 2006a), however, that the environmental objectives of the ELUPP Cancun-Tulum have not been achieved as its provisions have not been observed. In the Riviera Maya, programme's authorities and investor have been frequently criticized for the non-compliance with the programmes requirements. Some of the most common deficiencies in the observance of ELUPP Cancun-Tulum's provisions were summarized by SEMARNAT (2006a) recently:

- The proponents submit intentionally the location of development actions erroneously (normally new hotel facilities), to favour densities of space-use and clearing.

² Considering the population growth rates over the last thirty years

- The sanctions imposed by PROFEPA have had a negligible effect on development in the Riviera Maya. Until now, there was no demolition (partial or total) of activities executed illegally, only economic sanctions have been applied.
- Uncontrolled urban development which has not met the ELUP's provisions. The new urban areas (for example in Playa del Carmen) are also undersupplied with basic urban services.
- Illegal authorizations which have been promoted by economic interest, ambiguities and gaps in the environmental legislation and the programme's framework, and the absence of an oversight authority.
- Absence of public participation in decision-making due to the lack of clear public participation mechanisms.

SEMARNAT (2006a) has recognized that these deficiencies are related to the absence of an oversight body and clear environmental goals and objectives, as well as to the lack of commitment by authorities and investors.

Considering the above, the main concern of this investigation is to improve the ELUPP Cancun-Tulum by identifying reasonable alternatives to achieve its environmental objectives, and by developing a monitoring concept to supervise the ELUP implementation adequately. Chapter 4 discusses the identification of alternatives at strategic level. As an example, the identification of alternative site locations for the development of New Tulum (see map 3.2) is presented.

4

Identification and comparison of alternatives

Identification of alternatives is one of the key principles of SEA. There are different types of alternatives at strategic level such as (based on Thérivel and Partidário 1996):

- “Do nothing” or “continue with present trends” option.
- Demand reduction, e.g. reduce the demand for water through water metering.
- Different locational approaches, for example build new houses in existing towns versus in new towns.
- Different types of development that achieve the same objective, such as produce energy by coal or wind instead of fuel oil.
- Fiscal measures, e.g. toll roads or congestion charges.
- Different forms of management, like recycling as an alternative of incineration.

SEA demands the consideration of the reasonable alternatives that contribute to the programme’s objectives (CEC 2001:25). The first consideration in deciding on possible alternatives should thus be to take into account the objectives and the geographical scope of the ELUPP Cancun-Tulum.

Authorities in the Riviera Maya affirmed that the strategy implemented by the ELUPP Cancun-Tulum represents the best development alternative. However, there is no indication that other alternatives were considered before or during the preparation of the programme. In this chapter, the identification of alternatives for the settlement structure of the ELUPP Cancun-Tulum is discussed.

The outline of the chapter is as follows. First, the urban structure proposed in the ELUPP Cancun-Tulum is described. Next, the identification of alternatives is carried out according to the hierarchy of alternatives suggested in the draft guidance on implementing the SEA Directive (ODPM 2002). In order to identify feasible sites for urban development, the ELUPP Cancun-Tulum’s selection criteria for urban land-use are summarized and a GIS-database is introduced. The chapter concludes with the identification of alternative site locations for one of the urban areas proposed in the programme: the New Tulum City.

4.1 ELUPP Cancun-Tulum's settlement structure

The population growth forecast by 2025 (650,000 inhabitants; FONATUR 2004b) was based on the expected tourism development in the Riviera Maya. However, growth thresholds have been modified frequently. Until now, there is no consensus on the long-term tourism and urban development of the Cancun-Tulum region.

The settlement structure in the Riviera Maya is composed of six cities located along the coastal line (see map 4.1). Since the implementation of this strategy, in the middle of the 1990's, some of these settlements have grown exponentially such as Playa del Carmen (up to 30 percent yearly) and Tulum (up to 16 percent annually). Others, in contrast, remain less developed like New Akumal, an entirely new city for 150,000 inhabitants, currently inhabited by about 600 permanent residents.

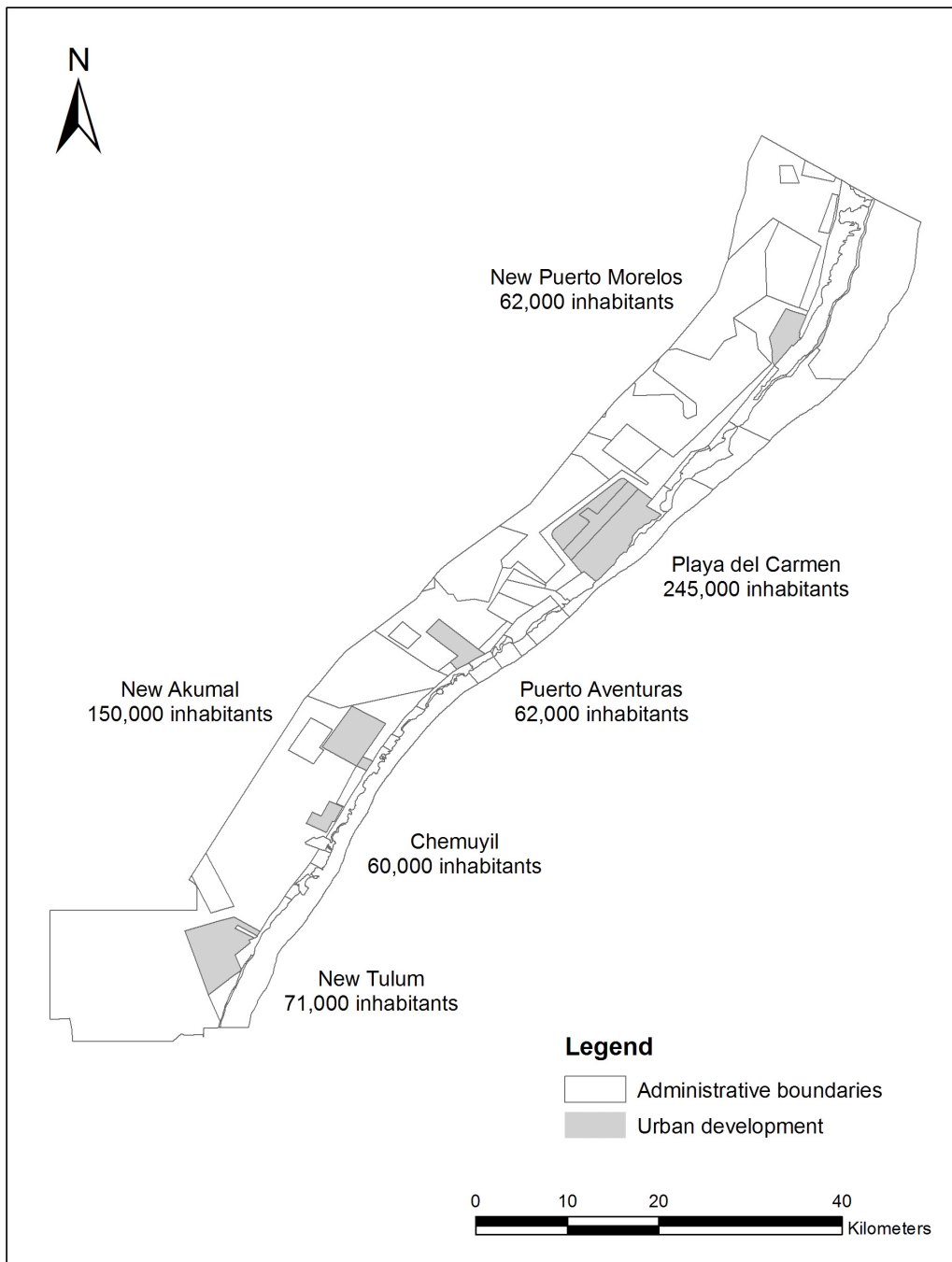
Local governments conducted competitions for the planning of the new urban areas. At present, all Urban Development Programmes (UDPs) in the ELUPP Cancun-Tulum area are being developed and are under implementation.

4.2 Alternative identification

For land-use planning a clear alternative is the different use of areas designated for an activity or purpose, as well as the use of alternative areas for such an activity. In addition, for programmes covering long time frames alternative scenario development is a way of exploring alternatives and their effects (CEC 2003:26). It is important to notice, however, that alternatives at strategic level are not just about different types of development which achieve the same objective (such as development of urban areas in one place or another), they are also about *obviating development*, e.g. making new tourism development or urban areas unnecessary (based on João 2005:7).

The draft guidance on implementing the SEA Directive (ODPM 2002) addresses obviation of development:

“It is not longer enough just to consider different possible locations for development. The shift from predict and provide to plan, monitor, manage means that alternative ways to meet need or respond to development demands should also be considered, including different types of development, and ways of obviating development, e.g. better local amenities or services might make some journeys unnecessary.

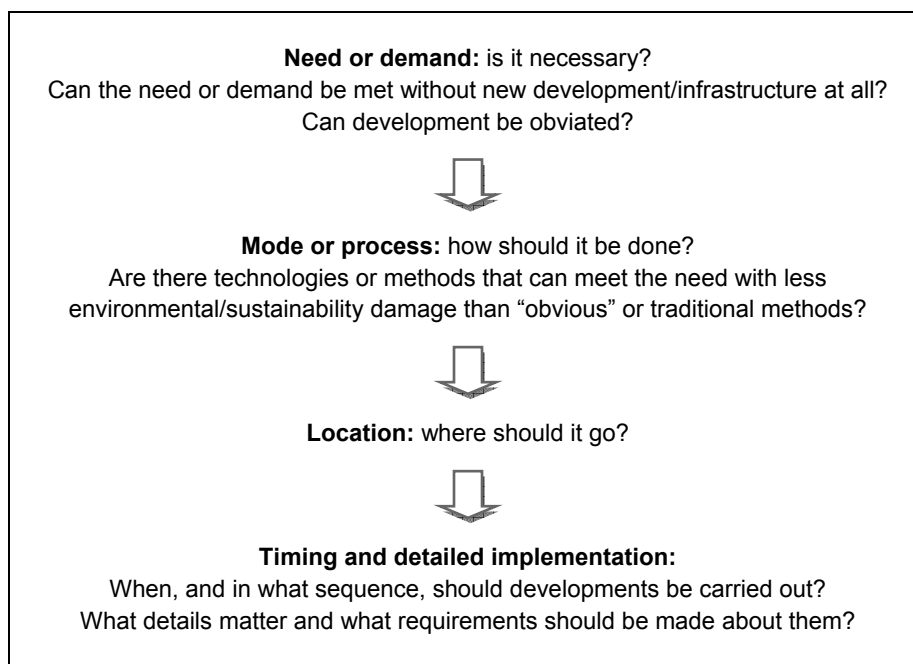


Map 4.1: ELUPP Cancun Tulum's settlement structure
Source: Based on vector data (SEMARNAT 2001c); expected population growth from FONATUR (2004b)

Obviation is not the same thing as restricting or thwarting demands. It should be seen as looking for different, more sustainable means to, achieve human quality of life ends. For example, obviating journeys should be seen as providing people with access to the things they want with less need for mobility.”

The guidance includes a useful diagram that stages the design of different alternatives (see box 4.1).

Box 4.1: “Hierarchy” of alternatives: from obviation to detailed implementation
Source: ODPM 2002



The hierarchy of alternatives of box 4.1 starts by deciding if development can be obviated, if not, then it considers how should it be done in a more environmentally or sustainable way, only after this stage it considers alternatives of where should the development go and decides about timing and detailed implementation (João 2005:8).

4.2.1 Obviating development in the Riviera Maya?

Tourism is one of Mexico’s most important industries. In 2002, tourism accounted for 8.2% of Mexico’s GDP (8,858 million USD) and was therefore considered a primary economic activity (SECTUR 2003:7). According to the

World Tourism Organization (SECTUR 2003:15), by 2020 Mexico will maintain the eighth place in the share of world arrivals with approximately 50 million tourists annually. However, the country will face growing competition at global and regional level, especially in the sectors where Mexico traditionally has had competitive advantages such as the destinations of sun and beach. Tourism development is considered thus a national priority.

The projected tourism development at federal and state levels in Quintana Roo is in line with the average growth rate over the last decades in the region. The settlement structure in the Riviera Maya was planned according to the expected tourism development over the next 30 years (see development goals in section 3.2). The population increase (650,000 inhabitants) was calculated considering 15 new inhabitants per hotel room constructed (SEMARNAT 2002b), which is equivalent to the construction of approximately 45,000 new hotel rooms in the Riviera Maya by 2025.

This trend growth scenario, however, does not seem to have a connection with the objectives of section 3.2, it is rather a logical linear way to achieve an economic goal. Unfortunately, until now it has not been demonstrated that the “continue with present trends” option has promoted a sustainable development in the Riviera Maya or in any other place of Mexico.

Can the need or demand be met without new development/infrastructure at all?

The Riviera Maya’s demand can not be met without new development. In fact, as mentioned in section 3.1.2, the region is currently undersupplied with basic urban services and infrastructure.

Can development be obviated?

According to the federal and local development policies, tourism and urban development can not be obviated in the Riviera Maya. However, it is considered that the current development strategy should be redefined as long as authorities fail to sort out current deficiencies and errors (see section 3.3.1). Why should the Mexican Government continue promoting a non-sustainable development model?

Moreover, development was already obviated in the Cancun-Tulum region. Tourism growth by 2025 was reduced in the “2000 ELUPP’s amendment”, from 230,000 to 80,000 hotel rooms (SEMARNAT-QRoo 2001).

4.2.2 How should development be done?

Urban development should be done according to the environmental and sustainable development objectives and targets of section 3.2, the programme's ecological criteria (see table 3.8), the applicable Mexican official standards (NOMs), and the relevant international and national principles (such as the UN goals for sustainable development or the National Strategy for Climate Change of Mexico).

The objectives of section 3.2 demand, inter alia: (i) to promote sustainable human settlement development, which encompasses the provision of environmental infrastructure (water, sanitation, drainage and solid-waste management), the promotion of sustainable energy and transport systems, and construction of industrial activities; (ii) to protect biodiversity (key ecosystems, species and genes); (iii) to protect water resources, water quality and aquatic ecosystems; and (iv) to maintain socio-cultural diversity of indigenous and local communities (see tables 3.2 to 3.4).

The programme ecological criteria specify, among others: (i) land-use densities of space use (criteria AH-14, AH-13, AH-15, etc.); (ii) percentages of green spaces required in new urban settlements (criteria AH-9, AH-10); (iii) construction specifications, such as maximum construction height (criterion TU-15) or maximum clearing area for new projects (criterion C-1); and demand the protection of key ecosystems (criteria AH-18, AH-19, TU-22, etc.) (see table 3.8).

Are there technologies or methods that can meet the need with less environmental/sustainability damage than “obvious” or traditional methods?

The ELUPP requirements do not demand the use of a specific method or technology, but rather represent an inspiration and guidance for action. Evidently, in developing new urban areas the methods or technologies that improve the programme's provisions should be preferred.

4.2.3 Where should it go?

Due to the importance of the biological diversity in the Cancun-Tulum region, a key issue in urban/tourism development is the protection of the Riviera Maya's key ecosystems. The ELUPP Cancun-Tulum identifies as key ecosystems: “coral reefs, *subperennifolia* rainforest, mangroves, cenotes, coves, among

others, as well as the habitats of species included in the Mexican official standard 059 (NOM-059-ECOL-2001, List of endangered species)” (criterion TU-22, see table 3.8). In addition, the aquifer recharge areas were also recognized as high-priority areas.

According to the criteria used to design the programme’s strategy, the six urban areas that are expected to be developed in the Riviera Maya were selected by their low environmental sensitivity and the high environmental pressure (see section 3.3). In practice, it was decided to develop or to consolidate the existing urban/semi-urban areas. Nevertheless, it has not been evident how this strategy satisfies the programme’s environmental goals and objectives, promoting a sustainable long-term urban development.

In order to determine how the ELUPP Cancun-Tulum’s selection criteria for urban development (i.e. protection of key ecosystems, protection of aquifer recharge areas, etc.) were considered during the preparation of the programme a GIS-database was built. The main objective was to identify feasible sites for urban development. Nevertheless, many problems were faced. On the one hand, there is a lack of spatial information on key ecosystems, aquifer recharge areas, and in general, land cover in the Riviera Maya (whereas the available data is incomplete, imprecise or incompatible). On the other hand, the access to most of the digital information that the Government of Mexico has, particularly high resolution images, is restricted to the public.

The information presented here provides therefore a broad overview of the land cover in the Cancun-Tulum region. Map 4.2 shows the classification of the main vegetation covers scale 1:250,000 according to the National Institute of Statistics, Geography and Data Processing of Mexico (INEGI 1997). Map 4.3 presents the areas with dense vegetation scale 1:1’000,000 (INEGI 2000b), which could be used as an indicator of primary rainforest distribution.

Considering the lack of information for the entire Cancun-Tulum region, to improve the quality of the assessment the identification of alternatives (as an example) was restricted to one of the projected urban areas: the New Tulum City (see Map 4.1). The analysis was divided into two phases. In the first phase, all available digital information on key ecosystems, land covers and aquifer recharge areas in the Tulum region was collected. In addition, some detailed information about key ecosystem was digitised and georeferenced. In the second part, the criteria for the selection of feasible sites were summarized. According to these criteria, the current site location for the development of the city was evaluated. Finally, an alternative site location for New Tulum was proposed, evaluated, and the results compared and discussed.



Map 4.2: Main land covers in the ELUPP Cancun-Tulum region
Source: Based on vector data 1:250,000 (INEGI 1997) and 1:750,000 (SEMARNAT 2001c)



Map 4.3: Dense vegetation in the ELUPP Cancun-Tulum region
Source: Based on vector data 1:1'000,000 (INEGI 2000b)

4.3 Identification of alternatives for the New Tulum's urban area

According to the Urban Development Programme of Solidaridad (MS 2006), the New Tulum City is intended to provide space for 131,107 inhabitants and 9,934 hotel rooms by 2030. The Tulum's current population (2006) is approximately 18,000 inhabitants (CMDA 2006). In map 4.4 the EMU proposed for the development of New Tulum is overlaid with the Riviera Maya's vegetation cover.

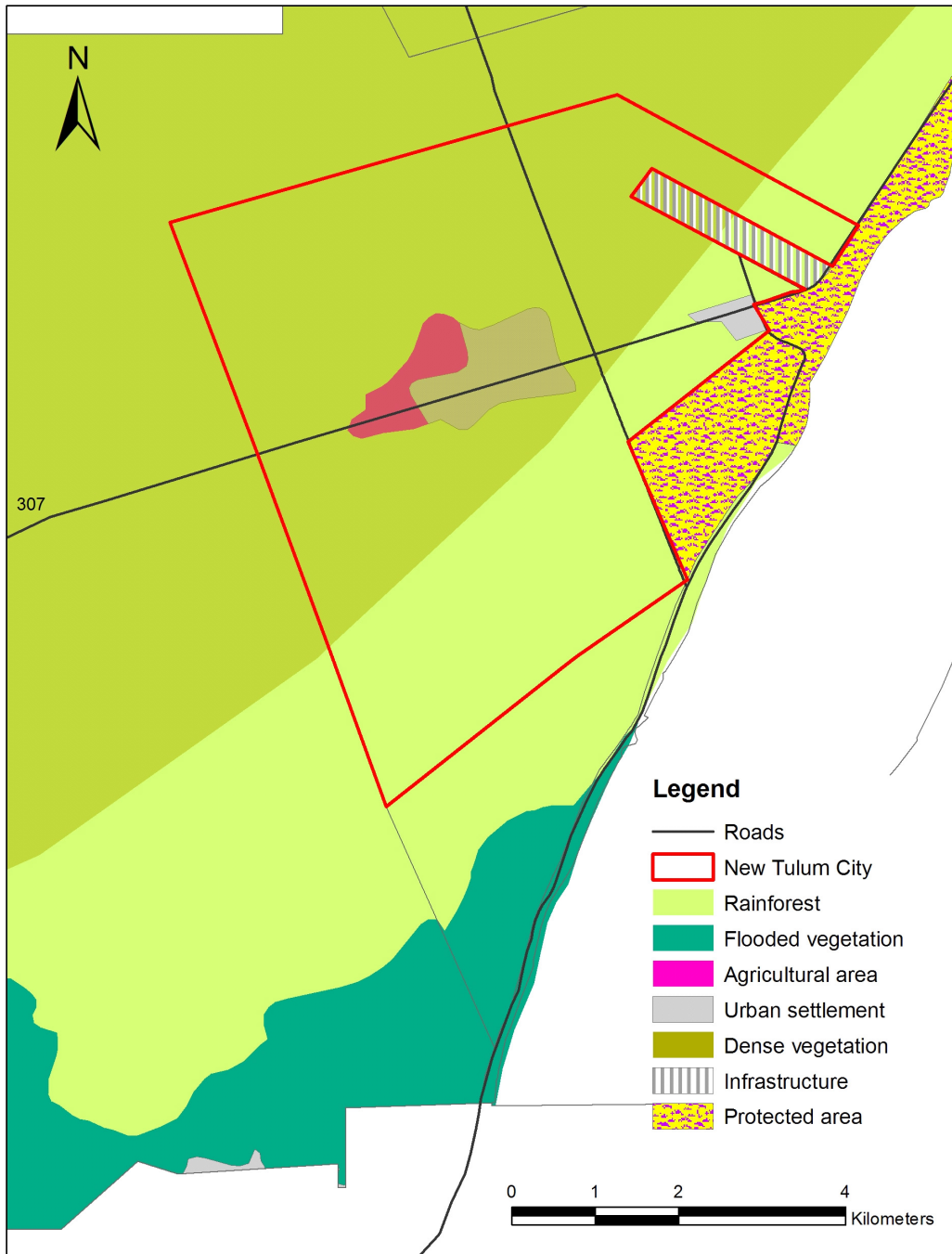
The city structure was based on two axes: the Federal Highway 307 and the Tulum-Coba Highway (see map 4.4). According to the last ELUPP Cancun-Tulum's amendment (2000), New Tulum is planned to have an extension of 3,597 ha. Local governments (different administrations) however have proposed different urban areas and population densities during the last years. Recently, the expected area of New Tulum was increased up to 14,000 ha in the "2006 UDP-Tulum modification". The assessment presented in this chapter was based on the information included so far in the ELUPP, namely, 3,597 ha.

As shown in map 4.4, New Tulum is expected to be adjacent to the protected area "National Park Tulum". In addition, this arrangement borders the EMU 6 (infrastructure development), which is currently used for aircraft operations.

Map 4.4 suggests that the urban area considered in the ELUPP does not correspond to the vegetation mosaic in the Riviera Maya as mentioned in section 3.2.2 (definition of environmental management units in the Cancun-Tulum region). Environmental effects of different magnitude (according to the affected environmental element) may result consequently from the development of the city. Additionally, the proposal to construct residential areas near the regional airport (currently expected less than 200 meters away from the road track) does not seem to be the best alternative. Potential effects of this activity, such as aircraft noise or emissions, and issues related to flight safety can lead to conflicts with the urban development.

Tulum's key ecosystems

The key ecosystems mentioned in section 4.2.3 can be found in Tulum. The Tulum's region is a landmark in the Riviera Maya. Two of the longest subterranean river systems on the planet run in the region: the Sac Actun and



Map 4.4: Proposed development area for the New Tulum City
Source: Based on vector data 1:250,000 (INEGI 1997), 1:750,000 (SEMARNAT 2001c) and 1:1'000,000 (INEGI 2000b)

the Ox Bel Ha, more than 80 and 145 km long respectively (QRSS 2006). They flow through the biggest underwater cave of Mexico (located in the Sac Actun System). These rivers are assumed to have a connection to six others nearby, including the systems of the Sian Ka'an Biosphere Reserve (which is included on UNESCO's world heritage list). In addition, 230 cenotes (see definition in section 3.1.1), which are interconnected by the subterranean systems, have been registered in the zone (CMDA 2006).

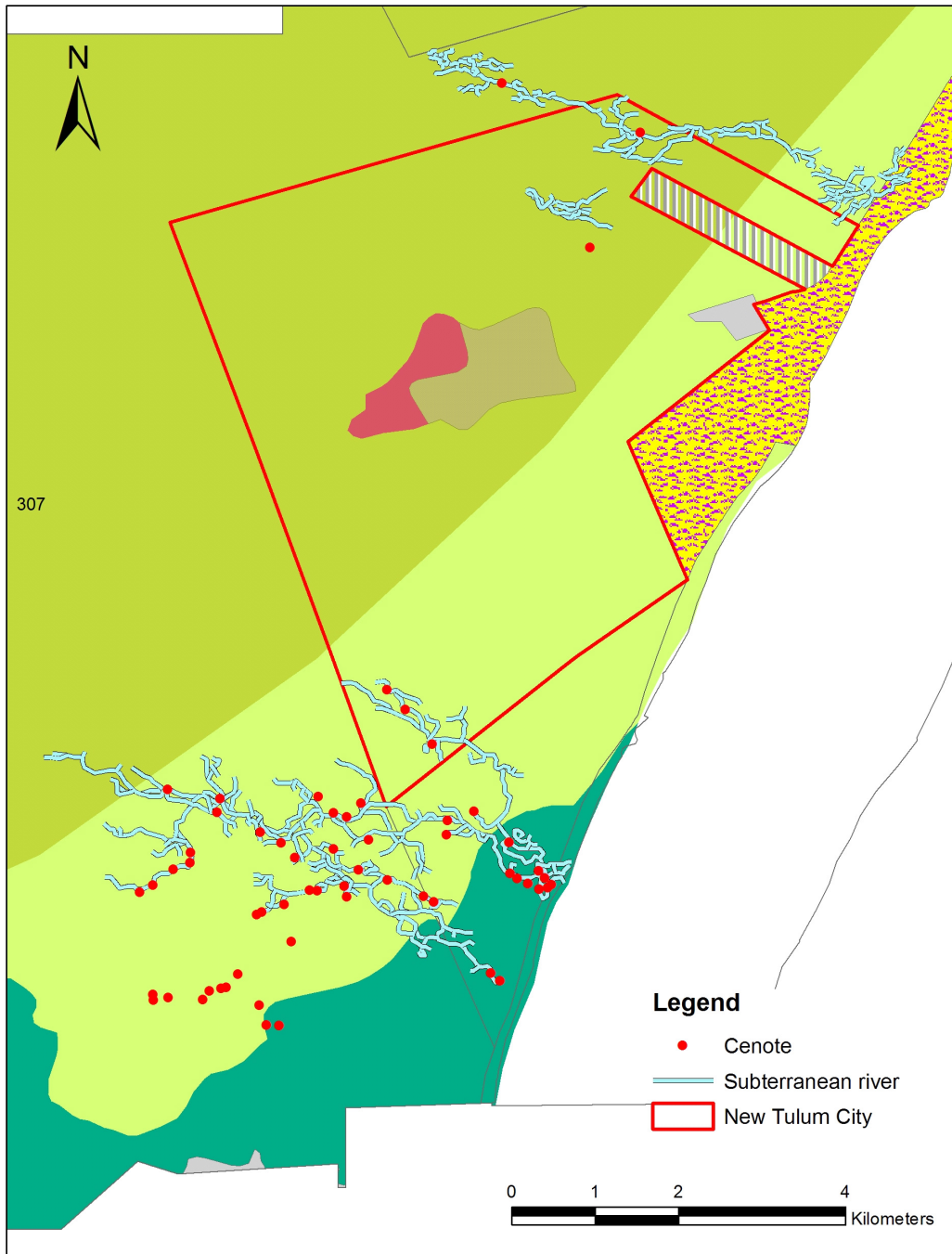
4.3.1 Information for the assessment

To date, the subterranean systems of Tulum have been explored and mapped partially by non-governmental organizations (NGOs). Although the objective of these investigations is to gather data and to create new information about key ecosystems to support decision-making, usually the information is not accessible neither to authorities nor the public. Information on the Sac Actun and Ox Bel Ha systems was unsuccessfully requested by the author (with a proposal to pay for the information) to two NGOs operating in the region. In spite of that, to illustrate the importance of considering these ecosystems in the identification of alternatives, both subterranean river systems were digitized and incorporated into the GIS-database using sketches and photos available in Internet.

Digitalization and georeferencing of subterranean systems

The subterranean river systems and cenotes of Tulum were digitised and georeferenced based on sketches and photos available in Internet (see map 4.5). To align the sketches to the existing spatial data, common features in both spatial data and target data (for example roads, water bodies, shoreline, etc.) were used. To determine ground control points (GCPs) Landsat GeoCover Mosaics provided by ESC (2004), satellite images from Goggle Earth (2006), and the road network vector data supplied by SEMARNAT (2001c) were considered.

Map 4.5 shows the location of the subterranean systems Sac Actun (on the top) and Ox Bel Ha (bottom). Map 4.5 must be considered as a first approximation to the location of the subterranean river systems and cenotes in Tulum, which will have to be verified in future more detailed investigations.



Map 4.5: Subterranean river systems and cenotes in the Tulum region
Source: Based on sketches from www.therebreathersite.nl and QRSS 2006

4.3.2 Assessment of alternatives

In order to compare alternatives, from an environmental point of view, the likely environmental consequences of their implementation must be determined. A general procedure to determine the environmental effect of proposed actions is shown in figure 4.1.

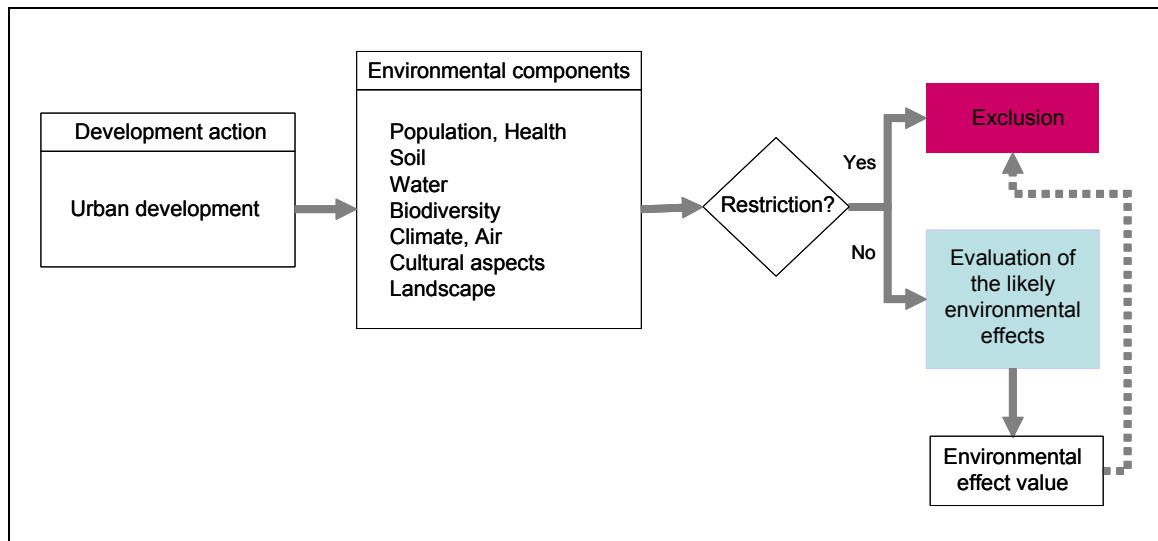


Figure 4.1: Procedure for the assessment of alternatives
Source: Based on Stock and Gründler 2004:6

The procedure of figure 4.1 initiates by deciding if the development action can be carried out, if no restrictions are found then it considers the assessment of the proposed alternative in order to calculate a final “environmental effect value”. The final value has to be compared with the values obtained for other suitable alternatives.

The assessment of environmental effects should include: (i) the direct effect (impact) of the development action on the environmental components (e.g. land consumption to urban development); (ii) potential effects in the development action’s area of influence (for example the area affected by noise, water or air pollution); (iii) induced effects (such as the construction of new connections between urban areas); (iv) synergistic effects; and (v) cumulative effects (sum of effects of a development strategy on a particular area). Stock and Gründler (2004:7) have illustrated the effect of development actions on the environmental components (see figures 4.2 and 4.3).

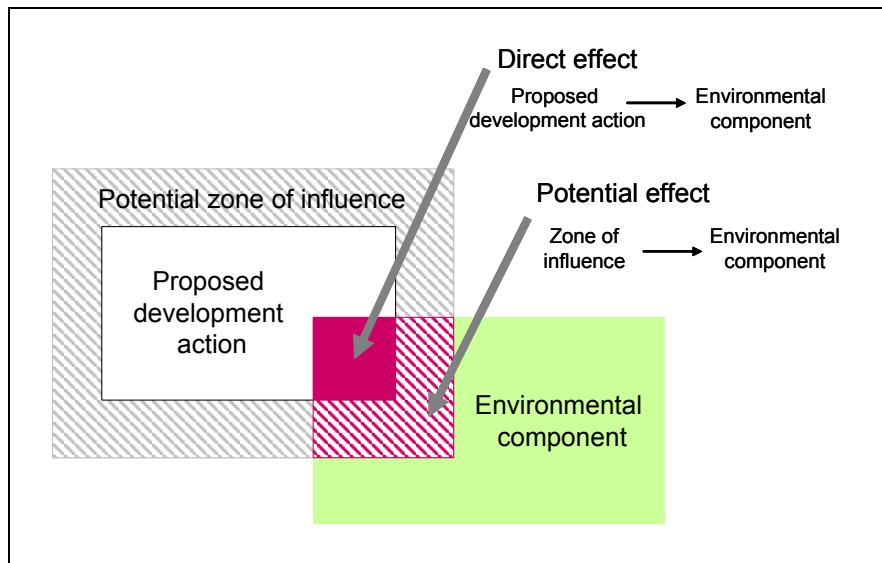


Figure 4.2: Effect of individual development actions
Source: Stock and Gründler 2004:7

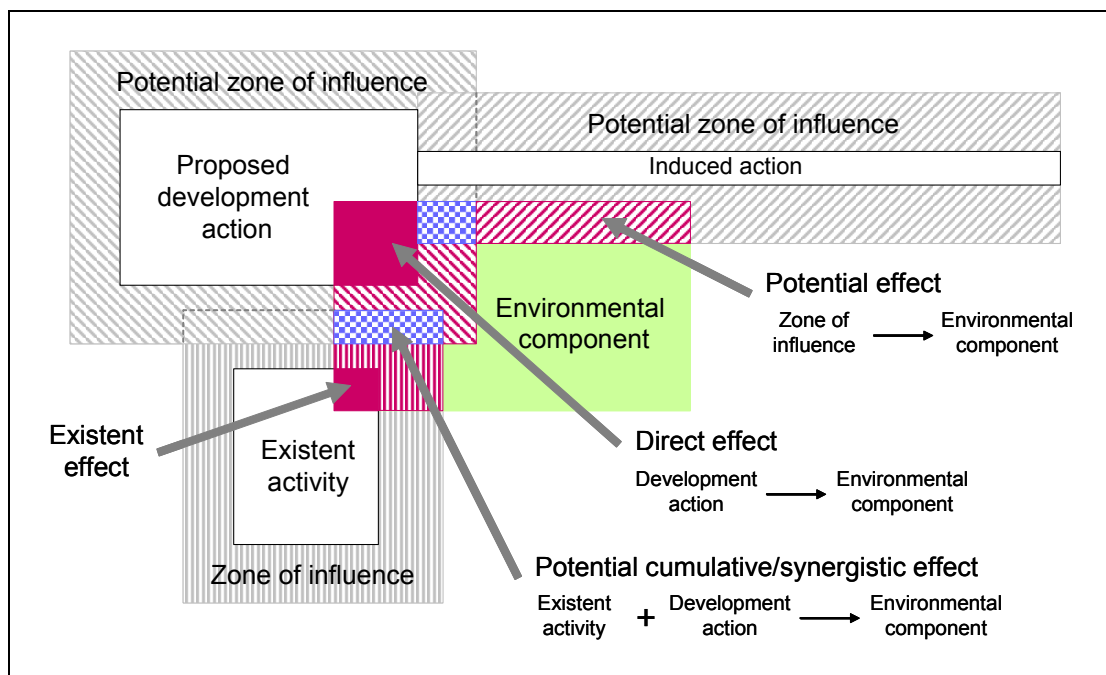


Figure 4.3: Cumulative effect of a development strategy
Source: After Stock and Gründler 2004:8

In this assessment, to determine direct impacts the affectation of individual environmental elements due to the development of New Tulum was calculated (proposed action → environmental component) using the available information and considering the expected urban development location. To estimate potential effects the first issue was to identify the likely area of influence of New Tulum (zone of influence → environmental component). It was calculated, in addition, the urban areas (or the proposed urban areas) that may be affected by the development of other activities or land-uses such as roads, airport, buffer zones required to protect fragile ecosystems, etc. (existent activity → proposed action).

The criteria shown in tables 4.1 and 4.2 were considered to determine the likely areas of influence of the activities in the Tulum region, and to define buffer zones required to protect environmental elements.

Table 4.1: Selection criteria and buffer zones suggested to preserve environmental elements in the Riviera Maya

| Theme | Environmental issue | Buffer zones suggested to protect environmental issues (source) | Criteria for urban development/goal |
|------------------|--|---|---|
| Biodiversity | Key ecosystems | 300 m (PBFRM 2006:359) | The total area should be avoided (ELUPP Cancun-Tulum provisions). |
| | Natural protected areas | 300 m (PBFRM 2006:359) | |
| | Natural corridors (biotope connectivity) | 300 m (PBFRM 2006:359) | |
| Water | Aquifer recharge areas | 300 m (PBFRM 2006:359) | |
| | Cenotes | 300 m (PBFRM 2006 :359) | |
| | Water bodies | 50 m (ELUPP Cancun-Tulum provisions) | |
| Soil | Protected area | 100 m (PBFRM 2006:359) | |
| Landscape | Sites of high scenic quality | 300 m (PBFRM 2006:359) | |
| Cultural aspects | Cultural-historical landscape elements | 300 m (PBFRM 2006:359) | |

Source: based on PBFRM 2006:359 and SEMARNAT 2001b

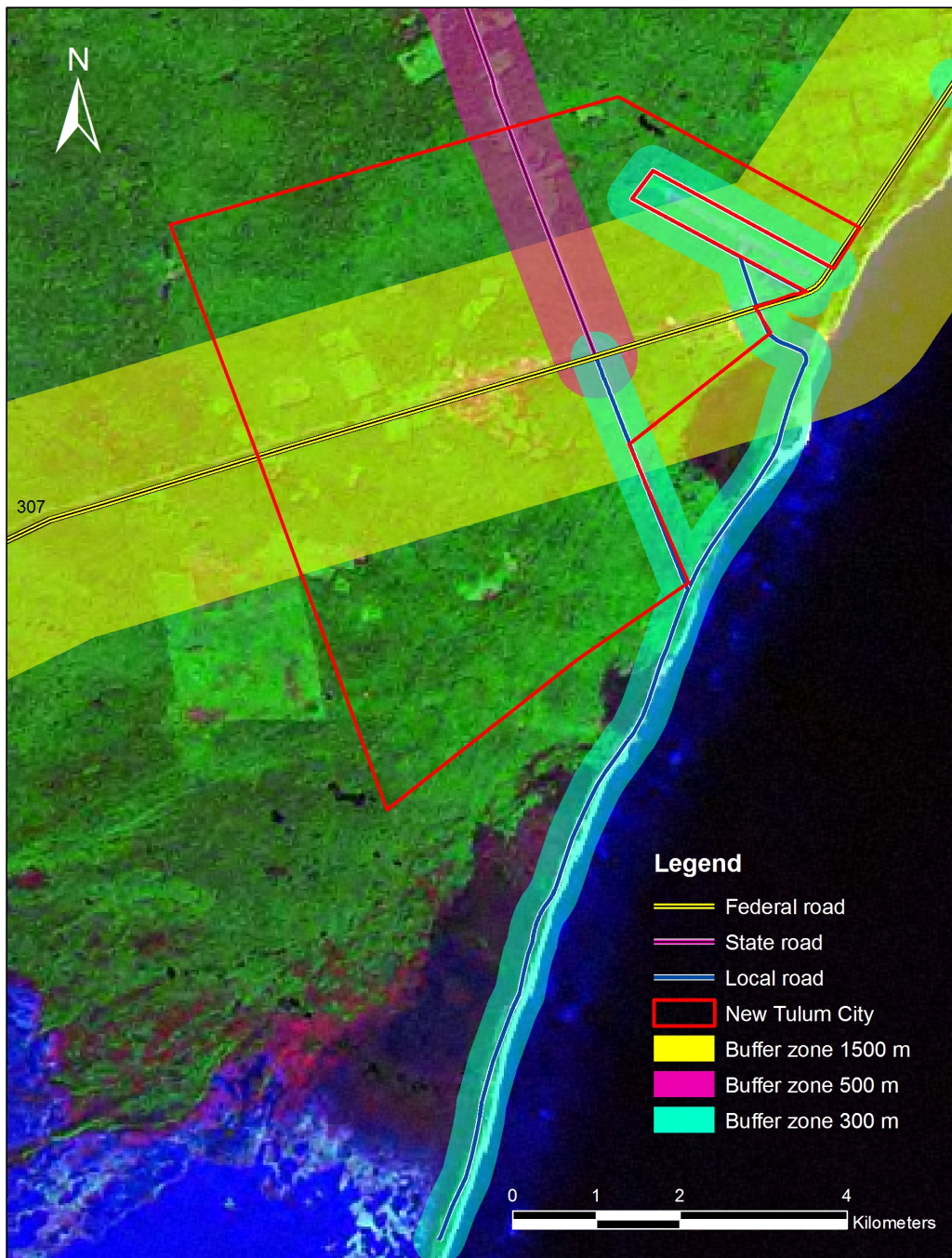
Table 4.2: Potential area of influence of existing activities in the Tulum’s region

| Theme | Environmental issue | Potential area of influence (source) | | | Criteria for urban development/goal |
|--------------------|---------------------|--|----------------------------------|---------------------------------|---|
| Population, health | Traffic noise | Wempe (2004) proposed areas of influence for urban mix-areas (>45 dB nights). These influence areas were considering in the Frankfurt Rein-Main regional land-use programme (PBFRM 2006:402). | | | World Health Organization (WHO) guidelines say that for good sleep, sound level should not exceed 30 dB(A) for continuous background noise, and individual noises events exceeding 45 dB(A) should be avoided (WHO 2006). |
| | | Roadway type | Vehicles/day (thousand) | Influence area (m) | |
| | | Local | ≤10 | 300 | |
| | | State | >10 – 50 | 500 | |
| | | Federal | >50 | 1,500 | |
| | Aircraft noise | According to the US-Federal Aviation Administration (FAA 2005:80) no noise analysis is needed at airports whose forecast operations do no exceed 90,000 annual propeller operations. Aircraft noise analyses have shown that those airports do not produce noise exposure contours at significant levels. In the absence of aircraft noise exposure contours, it is possible to define airport impact zones and identify appropriate land-uses for each impact zone. Typical airport impact zones include: | | | |
| | | Airport Impact Zone | | Runway (1,220-1,830 length) (m) | |
| | | 1 | Runway Protection | 518.1 | |
| | | 2 | Inner Safety | 853.4 | |
| | | 3 | Inner Turning (60-degree sector) | 1,371.6 | |
| 4 | | Outer Safety | 914.4 | | |
| 5 | | Sideline Safety | 304.8 | | |
| 6 | Traffic Pattern | 1,524.0 | | | |

Source: based on Wempe 2004, PBFRM 2006:402, FAA 2005:80 and WHO 2006

Maps 4.6 to 4.9 were developed according to the criteria of tables 4.1 and 4.2.

Map 4.6 shows the areas potentially affected by traffic noise in the Tulum’s region, considering mixed residential/commercial areas and federal, state and local roadway types (see table 4.2). According to the criteria of table 4.2, the areas affected by traffic noise (in absence of noise reduction barriers) are unsuitable for urban development. In contrast, so far the city of Tulum has grown along the right-of-way of the Highway 307 Cancun-Chetumal (approximately 50 m; see figure 4.4).

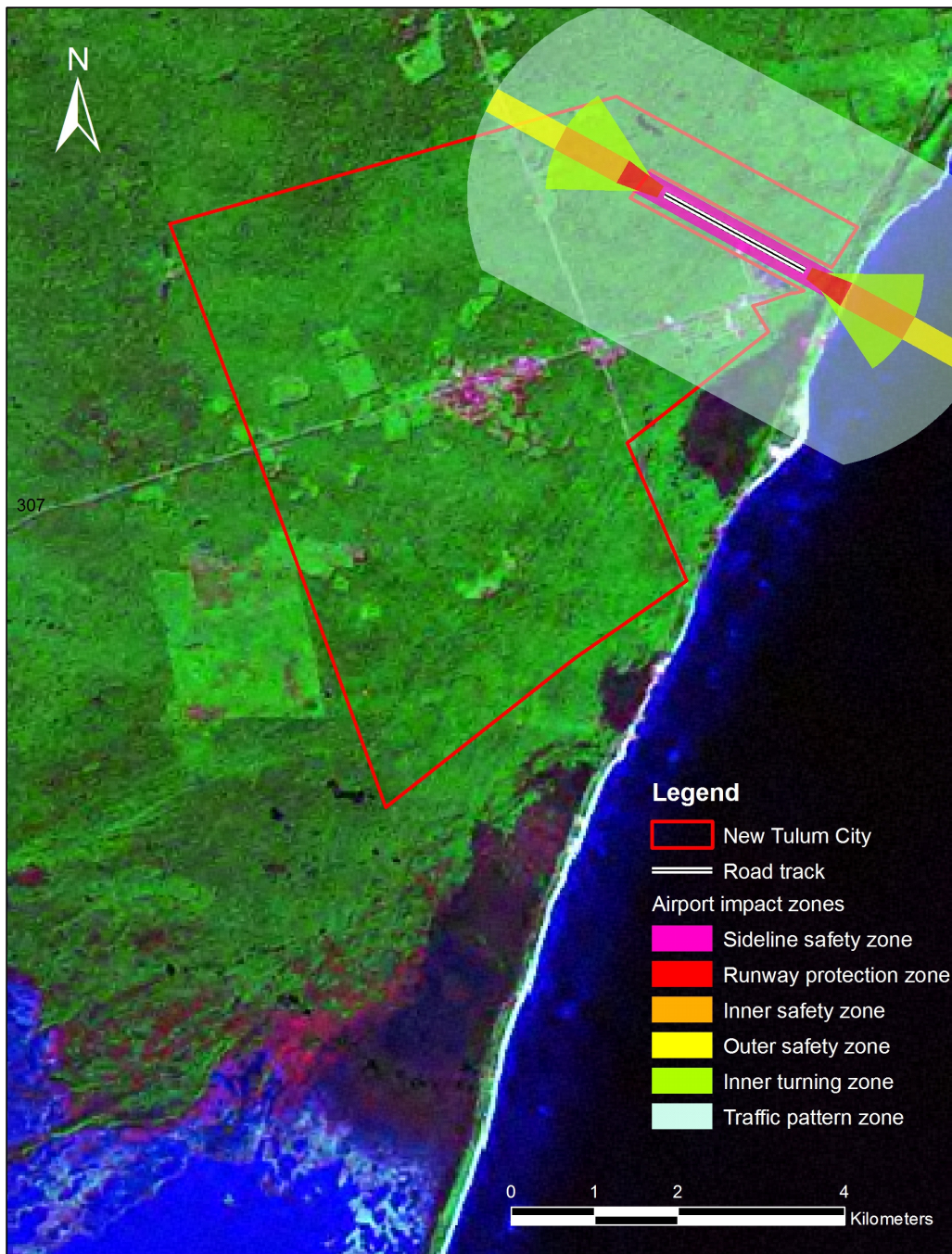


Map 4.6: Traffic noise buffer zones according to roadway type

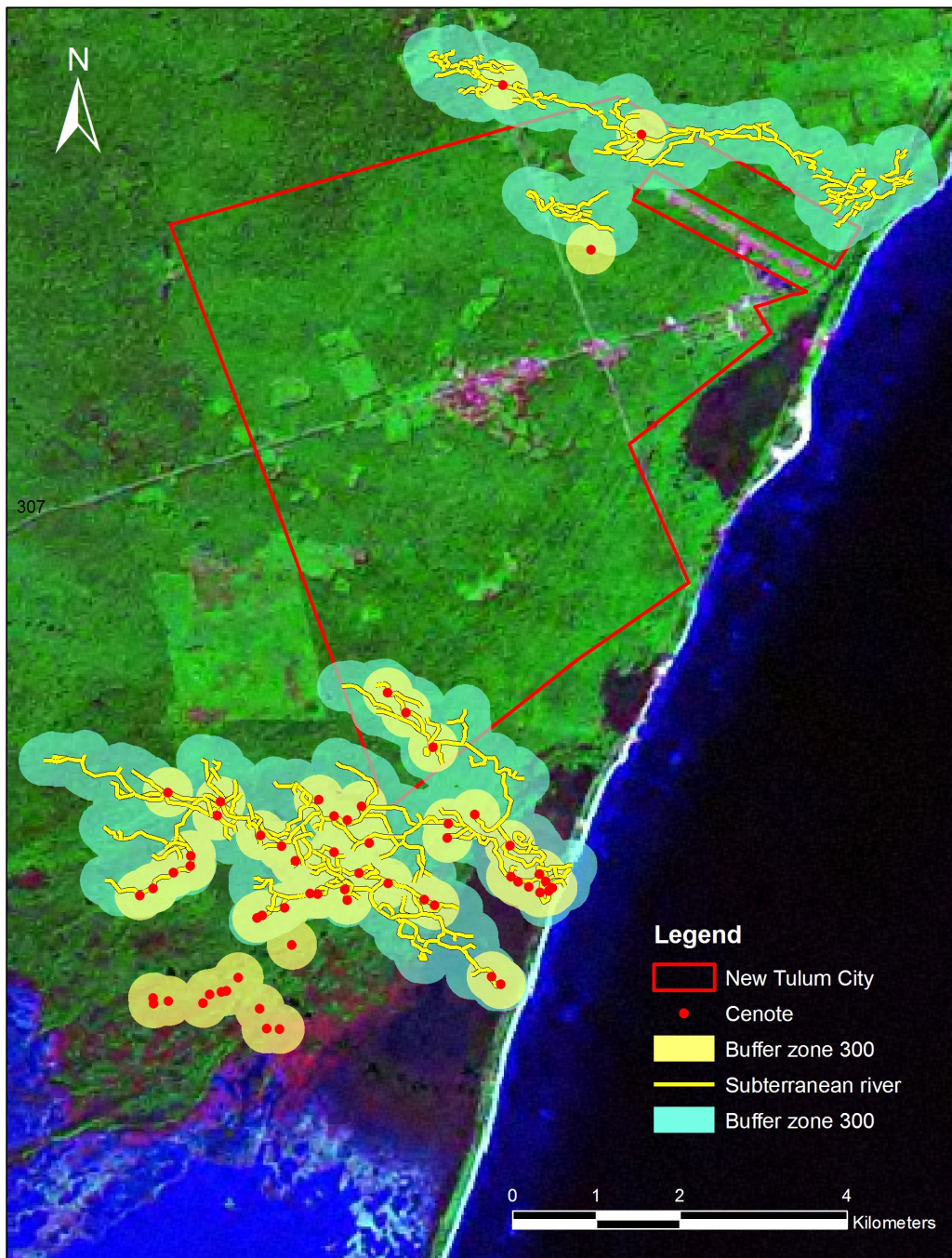
Map 4.7 illustrates the airport impact zones according to aircraft type (in this case aircrafts type Cessna were considered) and road track length (approximately 1,830 m long; see table 4.2). The areas shown in this map can be classified into two types: airport security zones where no residential areas should be developed, and traffic pattern zones where urban development can be, to some extent, carried out depending on other conflict factors such as aircraft noise intensity.

In map 4.8 the Tulum's subterranean river systems and cenotes are presented once more, as well as the buffer zones recommended for their protection (300 m; see table 4.1). Map 4.8 reveals that the development of the city, as it is currently expected in the ELUPP Cancun-Tulum, will have a direct effect on the regional key ecosystems, which is contrary to the programme's environmental objectives.

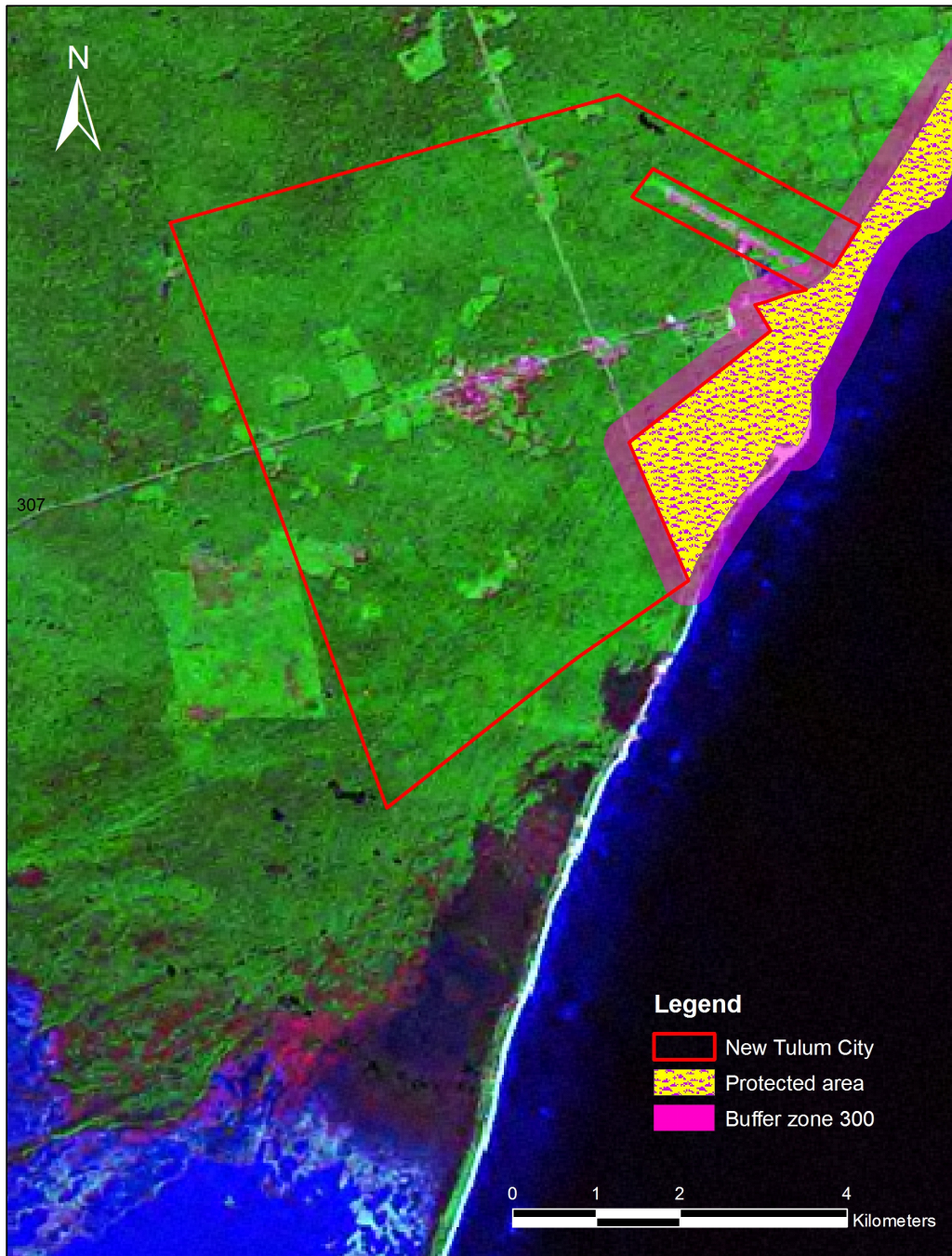
Finally, map 4.9 shows the buffer zone recommended to preserve the National Park Tulum (300 m; see table 4.1), which also overlaps the planned urban area.



Map 4.7: Airport impact zones according to aircraft type and road track length



Map 4.8: Subterranean river systems, cenotes and protection buffer zones



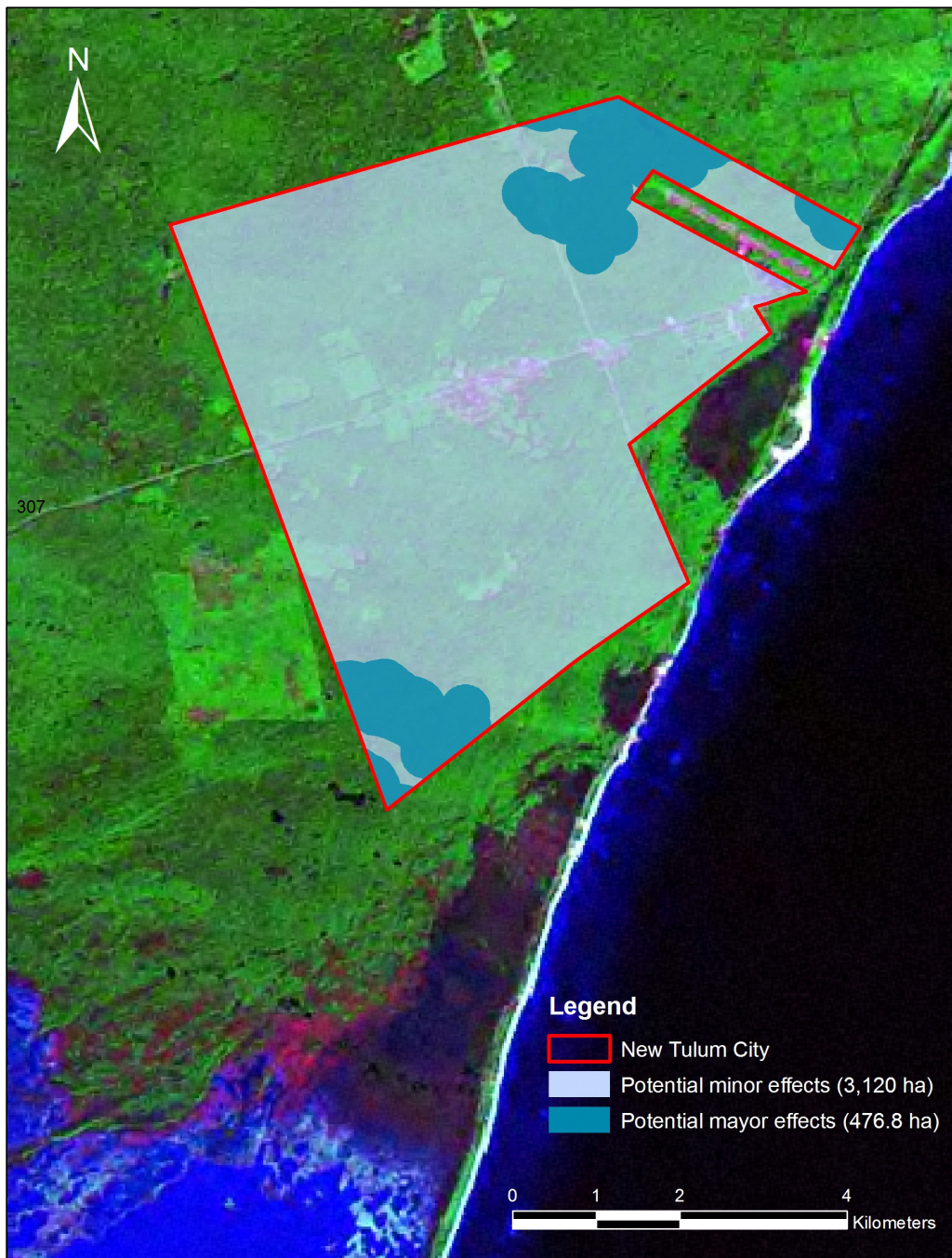
Map 4.9: Natural protected area (NPA) and conservation buffer zone (300m)

4.3.3 Impact classification

The next activity is to determine the likely environmental effects of the proposed action. The effect magnitude of human activities on the environment is a function of the expected development actions and the environmental sensitivity of the ecosystems in that region to those particular actions. In this case, considering the available information, it was decided to distinguish two types of impacts resulting from urban development in Tulum: potential “major” negative effects and potential “minor” negative effects.

In this case, potential mayor negative effects are impacts that can be expected to occur (considering the way in which urban development has been carried out so far in the Riviera Maya) on key ecosystems. For example, discharges of non-treated urban wastewater into subterranean river systems, modification of their hydraulic regime due to overexploitation or foundation construction, primary rainforest or flooded vegetation loss, etc. Due to the importance of key ecosystems for the preservation of species diversity and species composition in the Riviera Maya, the avoidance (or in the worst case minimization) of mayor negative effects should be a primary concern to the ELUPP Cancun-Tulum. Potential “minor” negative effects are impacts on elements that are not considered as key ecosystems such as grassland or secondary rainforest clearance. Map 4.10 shows the distribution of environmental impacts according to the proposed urban area.

According to map 4.10, the development of New Tulum may produce potential major negative effects in 476.8 ha (13.2 percent of the total expected urban area), and potential “minor” negative effects in 3,120.2 ha. This preliminary analysis, as it has been mentioned, has to be verified in further investigations considering additional information such as the location of the aquifer recharge areas and the environmental sensitivity of the land cover classes to urban development.



Map 4.10: Determination of potential effects resulting from the development of New Tulum

It was considered, in addition, the conflict areas showed in maps 4.6 to 4.9. Conflict areas can be classified according to the following criteria (see table 4.3).

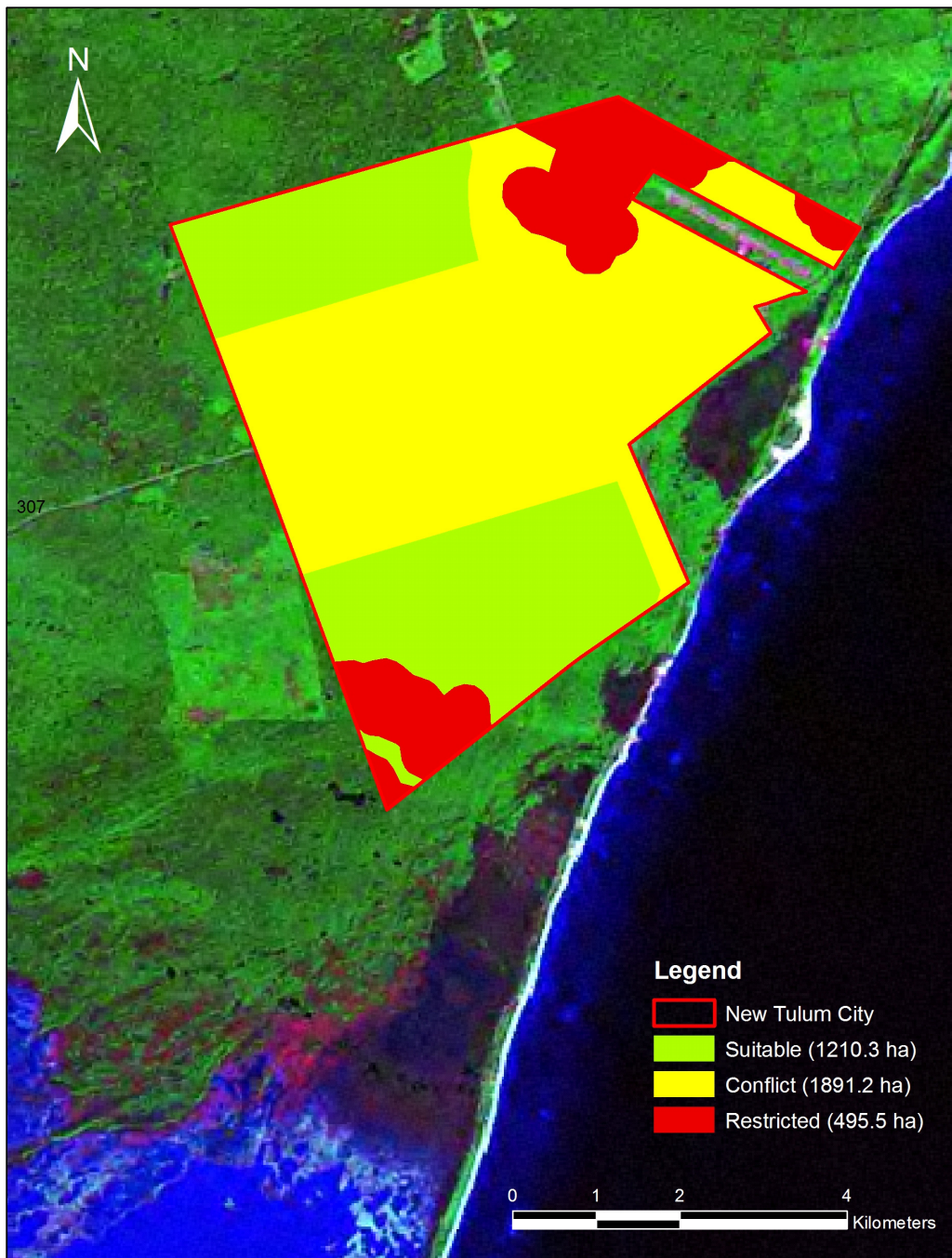
Table 4.3: Classification of likely conflict areas for urban development

| Value | | Criteria |
|-------|------------|---|
| 0 | Suitable | <ul style="list-style-type: none"> ▪ Areas that are not classified as key ecosystems, protected or restricted area, and that are not affected by other development actions and their areas of influence. |
| 1 | Conflict | <ul style="list-style-type: none"> ▪ Buffer zones required to protect key ecosystems. ▪ Areas likely affected by the area of influence of other development actions. |
| 2 | Restricted | <ul style="list-style-type: none"> ▪ Key ecosystems, protected areas or any other restricted areas (such as airport security zones). |

Source: based on PBFMR 2006:361

Based on table 4.3, map 4.11 shows the distribution of conflict areas in Tulum due to urban development. Map 11 resulted by overlaying maps 4.6 to 4.9. Restricted areas (495.5 ha) correspond to airport security zones located inside the expected urban area and to direct impacts on key ecosystems (subterranean rivers and cenotes). Urban development in those areas should not be promoted. First, as it was previously mentioned, to avoid or minimize the affectionation on key ecosystems, and second, to guarantee the security of the residents.

Areas classified as “conflict” (1,891.2 ha) represent the areas affected by other development actions, in this case traffic noise and aircraft operations (corresponding to the traffic pattern zone). Additionally, the buffer zone recommended to protect the NPA (National Park Tulum) was also considered as a conflict area for urban development. The promotion of urban development in “conflict” areas should be conditioned to the compliance of the ELUPP Cancun-Tulum’s environmental objectives, principally the ones related to sustainable urban development (see tables 3.2 to 3.4). Finally, suitable areas (1,210.3 ha) are the areas that, so far, are not classified as key ecosystem or included in any other restricted area, are not affected by other development activity, and are, therefore, appropriate to promote urban development.



Map 4.11: Potential conflict areas resulting from the development of New Tulum according to the ELUPP Cancun-Tulum's development strategy

4.3.4 New Tulum area of influence

The area of influence of New Tulum is a function of the affected environmental element and the intensity of the impact. The area influenced by traffic noise, for example, will be different to the area affected by air pollution or artificial light. In general, according to PBFMR (2006:359), an area of influence of 300 m can be considered. However, pressures on water bodies (subterranean rivers and cenotes) may result in a different, probably much bigger, area of influence that might encompass the neighbour subterranean systems and the coastal zone. To have an idea, it has been estimated that in the subterranean systems of Tulum groundwater flows into the sea in four days (0.41 m/s; CMDA 2006:7).

4.3.5 Alternative site location proposal

A reasonable alternative should minimize potential conflicts and avoid restricted areas. In this case, the control of future development near highways to avoid traffic noise effects is one of the main challenges for the sustainable development of New Tulum. Until now, Tulum has been developed along the Federal Highway 307, just keeping the right-of-way of approximately 50 m free (see figure 4.4).



Figure 4.4: Development of Tulum by 2003
Source: Google Earth 2007

The implementation of the buffer zones recommended in table 4.2 (traffic noise) does not seem to be practicable. Land prices in Tulum have increased exponentially in past few years together with the land tenure conflicts (see section 5.1). Normally, the most expensive properties are located close to the highway.

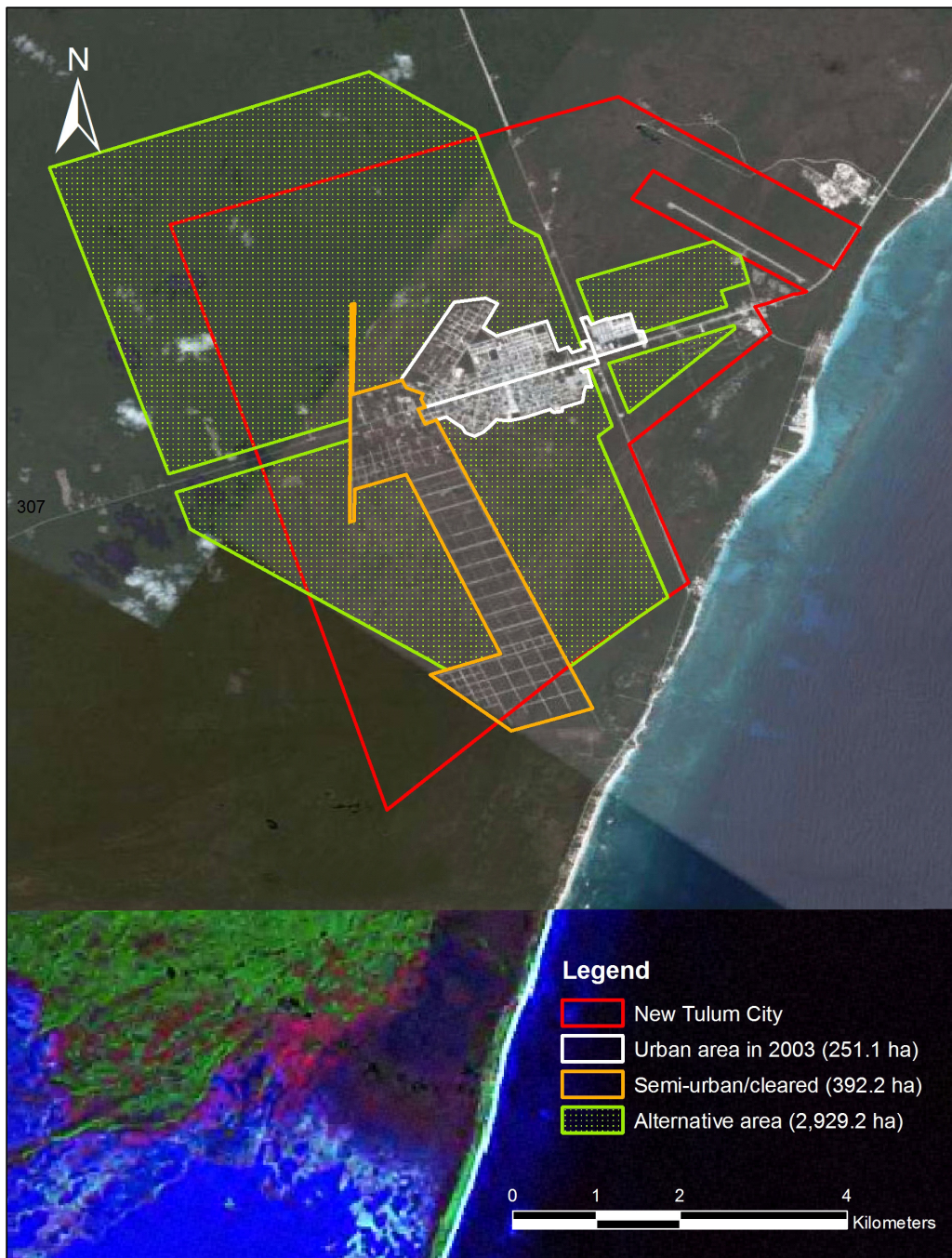
There are three strategies to reduce traffic noise impacts: (i) motor vehicle control and (ii) noise reduction measures on existing roads (carried out at project level); and (iii) control of future development (minimum distances), which should be planned and implemented at strategic level.

According to the US Federal Highway Administration (FHA 2006), a 200 foot width (60.9 m) of dense vegetation (like the one existing along the highway 307) can reduce noise by 10 decibels, which cuts the loudness of traffic noise in half. Based on the aforementioned, it is feasible to consider that a 100 m buffer zone of dense vegetation can minimize (or probably avoid) traffic noise conflicts in Tulum (however, to specify adequate noise barriers the traffic noise levels in the Riviera Maya should be determined).

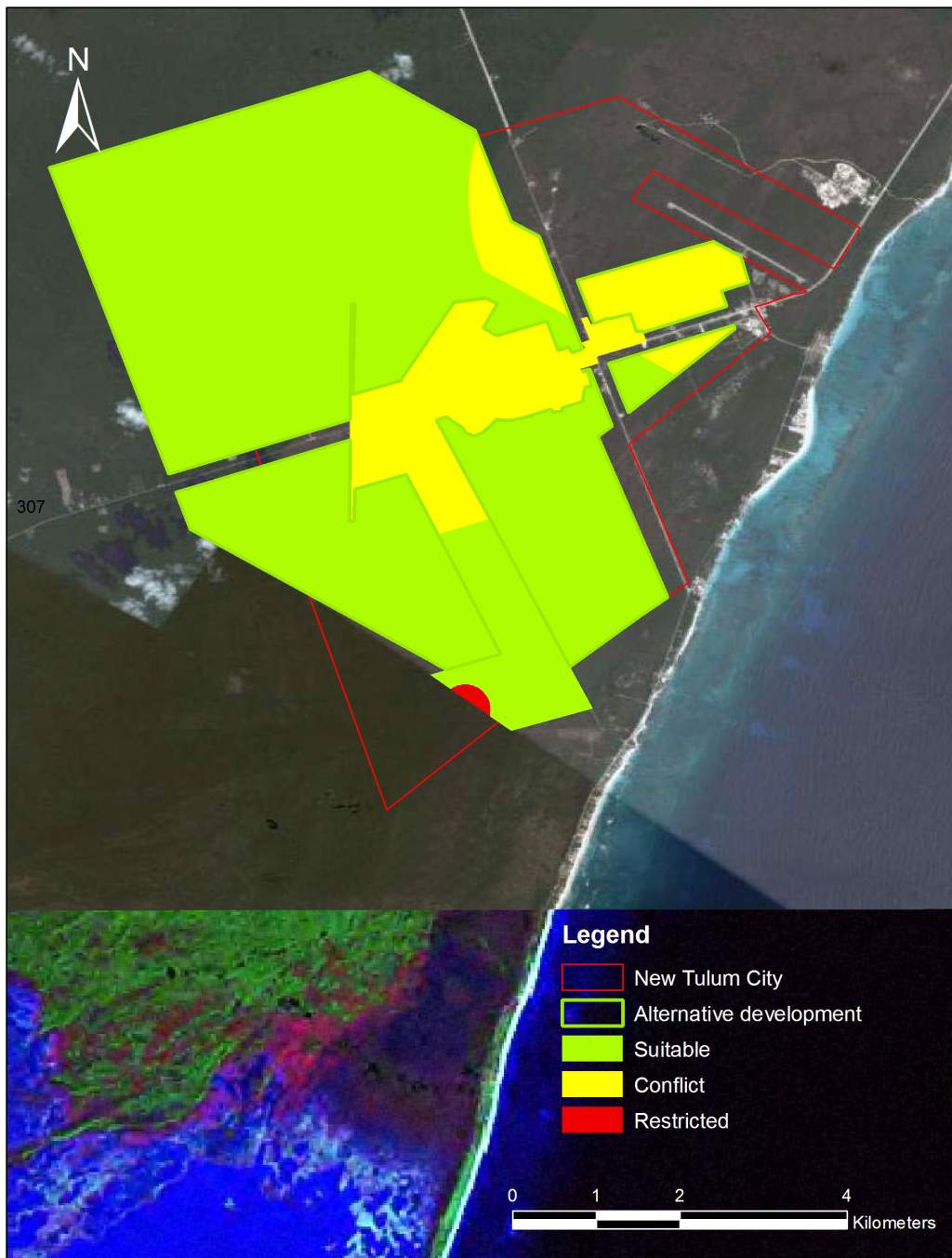
Considering the above, the existing spatial information on the location of key ecosystems, and the urban area already developed in 2003 in Tulum (last satellite available for this analysis; see figure 4.4), the alternative site location presented in map 4.12 can be proposed for the development of New Tulum.

The alternative site proposal was based on three development axis: the Federal Highway 307, the Tulum-Coba Highway, and the natural orientation of the subterranean river systems (perpendicular to the coastal line). The proposed area is equivalent to the area planned in the programme's settlement structure (3,596 ha).

In map 4.12, the region indicated in white (251.1 ha) corresponds to the urban area already developed in 2003 in Tulum. The area presented in yellow (392.2 ha) indicates areas already affected by 2003 (semi urban areas and areas affected by road construction). Finally, areas highlighted in green (2,929.2 ha) represent the alternative site proposal for the development of New Tulum. Map 4.13 shows the likely environmental conflict areas resulting from this alternative, whereas table 4.4 includes a comparison with the ELUPP Cancun-Tulum option.



Map 4.12: Alternative site location proposal for the development of New Tulum
Source: Background satellite imagery (2003) from Google Earth 2006



Map 4.13: Likely environmental conflict areas resulting from the site location alternative

Table 4.4: Comparison between development alternatives considering likely conflict areas

| Value | Area (ha) | |
|------------|-----------------------------------|-------------------------|
| | New Tulum (ELUPP Cancun-Tulum) | Alternative development |
| Suitable | 1,210.3 | 2,915.4 |
| Conflict | 1,891.2 | 672.6 |
| Restricted | 495.5 | 8.2 |
| Total | 3,597.0 | 3,596.2 |

As shown in table 4.4, the alternative site proposal can reduce considerably the likely conflict areas (from 1,891.2 to 672.6 ha) and direct impacts on restricted areas (from 495.5 to 8.2 ha).

4.4 Timing and detailed implementation

When, and in what sequence, should developments be carried out?

The schedule development should be determined by the capacity of the federal, state and local governments to promote sustainable development. Ideally, the existing demand in the Riviera Maya (see section 3.3) must be satisfied before continuing land-use change.

What details matter and what requirements should be defined?

The players involved in the ELUPP Cancun-Tulum should be aware that so far the Riviera Maya's key ecosystems have not been considered during the planning of development actions. In addition, development criteria at strategic level to anticipate environmental conflicts (such as minimum distances to protect NPAs or key ecosystems) do not exist yet. The ELUPP Cancun-Tulum development strategy, therefore, does not meet its own environmental objectives.

Additionally, there is no detailed information (at least 1:50,000) to identify reasonable alternatives. The technical committee responsible to update the ELUPP Cancun-Tulum has to take into account that detailed information on vegetation covers, key ecosystems, aquifer recharge areas, and water bodies is required to review the programme's development strategy.

Beside the comparison of development alternatives, one of the most important tasks for this research is to create an efficient monitoring mechanism to supervise the implementation of ELUP's development strategies. As it was mentioned in chapter 3, so far reports published by SEMARNAT (2006b, SEMARNAP 2000b) suggest that, in the implementation of ELUP, most regional departments have not made serious efforts to analyze the performance of the implemented programmes. Chapter 5 is dedicated to discuss the adoption of a monitoring concept based on an indicator framework to supervise the ELUPP Cancun-Tulum implementation.

5

ELUP-Environmental monitoring framework

Environmental monitoring is defined as “the regular observations in a time period, designed to give information about the environment so that past and existing states can be assessed and future trends predicted in any environmental component” (UNESCO 1974). SEA demands the supervision of the significant environmental effects of the implementation of strategic actions. Monitoring has to cover all kinds of effects, including positive, adverse, foreseen and unforeseen ones. They may usually be the effects described in the environmental report (CEC 2003:46-47).

In this chapter, a conceptual model to monitor the ELUPP Cancun-Tulum implementation is proposed. This innovative environmental monitoring mechanism, based on an indicator framework, represents the first supervision concept intended to monitor the implementation of a development action at strategic level in Mexico. Additionally, this framework is conceived to serve as a model to supervise other ELUP-Programmes in the country.

To supervise the implementation of strategic actions, the first step is to consider the likely significant environmental effects of their implementation (scope of monitoring). In our case, as the ELUPP Cancun-Tulum implementation was initiated more than a decade ago, some of the programme’s environmental effects are already known. However, not all the expected development actions have been carried out to date. The environmental effects likely to occur should be (and will be in the first part of this chapter) therefore predicted. In the second part, a core set of environmental indicators for monitoring is identified. The relevance and methodological description of each indicator is then discussed. Information needs and data availability are determined. Finally, the integration of the conceptual monitoring model into the planning system is examined.

5.1 Scope of monitoring

SEA can help to identify, describe and evaluate the likely significant effects on the environment of the ELUPP implementation and its reasonable alternatives. Impact prediction may be complex, especially in relatively broad-brush or high level plans and programmes. In some cases, however, very detailed information and analysis may not be necessary (CEC 2003:26-28).

Impact prediction should include secondary, cumulative, synergistic, short, medium, and long-term permanent and temporary, positive and negative effects (CEC 2003:32). In this research work, the impact identification/prediction is not exhaustive, but provides the basis to determine the scope of monitoring. An additional check (and continuous revision) should be performed in order to ensure that no adverse effect was overlooked in the assessment.

Impact identification/prediction was based on a simple interaction matrix. Impact magnitude was considered qualitatively. Potential positive effects are represented with “+”, whereas potential negative effects with “-“. The impact identification matrix is shown in table 5.1.

Table 5.1: Environmental impact prediction/identification matrix

| Environmental theme | | Population health | Biodiversity | Water | Soil | Air, climate | Landscape | Cultural aspects |
|---|------------------------|---------------------------|--------------|-------|------|--------------|-----------|------------------|
| | | ELUPP development actions | | | | | | |
| Implementation of Environmental Management Units | | | ++ | ++ | ++ | + | ++ | - |
| Implementation of environmental management policies | Protection | + | ++ | ++ | ++ | ++ | ++ | + |
| | Conservation | | - | - | - | - | - | - |
| | Exploitation | - | - | - | -- | - | -- | - |
| | Restoration | | + | + | + | + | + | |
| Introduction of land-uses | Urban settlement | - + | -- | -- | -- | - | -- | - |
| | Natural area | + | ++ | ++ | ++ | ++ | ++ | ++ |
| | Natural corridor | + | ++ | ++ | ++ | ++ | ++ | ++ |
| | Flora and Fauna | + | ++ | ++ | ++ | ++ | ++ | + |
| | Forestry | | -- | - | -- | - | -- | - |
| | Infrastructure | - + | - | - | - | - | - | |
| | Mining | | -- | - | -- | - | -- | |
| Tourism | | -- | -- | -- | - | - | -- | |
| Main expected development actions | Port and harbour | - | -- | - | - | - | -- | - + |
| | Airport infrastructure | - | -- | - + | - | - | -- | - + |
| | Road and rail network | - | -- | - + | -- | -- | -- | - + |
| | Settlement | - + | -- | -- | -- | - | -- | - |
| | Golf courses | | -- | -- | + | + | + | -- |
| | Tourism | | -- | -- | -- | - | - | -- |

Key: ++ Potential major positive effect + Potential minor positive effect
 -- Potential major negative effect - Potential minor negative effect
 - + Has to be answer case by case

In the identification/prediction procedure it was assumed that the programme provisions are satisfied during the carrying out of the expected development actions. To exemplify the above, the effects related to the introduction of the land-use “urban development” (see table 5.1) are examined.

Twenty three ecological criteria for urban development were implemented in the Riviera Maya (ELUPP provisions; see table 3.8). They specify land-use population densities and green space needs in new settlements. In addition, they demand the protection of valuable ecosystems (see section 4.2.2), and the implementation of urban development programmes to regulate urban growth. Furthermore, twenty ecological criteria related to construction activities (also linked to urban development; see table 3.8) require:

- to recover native flora and fauna prior to the initiation of construction activities;
- to consider and protect underground water flows when preparing and constructing foundations;
- to restrict maximum construction height, which should not exceed the height of local trees; and
- the suitable water and waste management during construction activities.

It is clear that the observance of these criteria may reduce potential negative environmental effects in the Riviera Maya.

It is possible to affirm therefore that the introduction of growth thresholds, requirements for green spaces in urban areas and maximum construction height may reduce potential negative impacts on the environmental theme *landscape*. However, clearing for urban development unavoidable leads to medium and low rainforest loss, which represent a potential major negative effect (see the effect of urban development on landscape in table 5.1). In the same way, urban development leading to habitat loss will result in negative consequences for *biodiversity* in the Riviera Maya (see table 5.1).

In addition, experience in the Cancun-Tulum region has revealed that urban development (as it is currently practiced as part of the ELUPP Cancun-Tulum strategy) has had major negative environmental effects on *water, soil, air* and *population health* (see section 3.1.2). Until now, the programme provisions have not improved this situation. Potential mayor negative effects on these environmental themes were therefore considered in table 5.1.

Urban development also resulted in negative *cultural* impacts in the Riviera Maya. Land-use change has altered the traditional land tenure system (which is called *ejido*³) of the Mayan communities. Local communities in Tulum (see map 4.1), for example, decided to modify and to sell the *ejidos* as land prices exploded due to the implementation of the ELUPP Cancun-Tulum (CONABIO 2004:6). Other indigenous communities were completely relocated to facilitate land-use change. For instance, the town of fishermen of Akumal (around 600 inhabitants) was relocated inland to promote tourism development in the traditional fishing areas.

High level actions (such as ELUP-Programmes in Mexico) may have significant effects on practically all environmental components in their area of influence. Additionally, it is common to have several strategic actions running at the same time in the same region, which can make difficult the supervision of a specific plan or programme. The SEA Directive (CEC 2003:48), however, does not specify that the monitoring has to be done for each action individually. In some cases, the cumulative effects of different actions may be easier to identify when they are monitored together.

In this investigation, it was considered that the ELUPP Cancun-Tulum implementation has had (and will have) significant effects on practically all environmental themes of table 5.1. These issues were therefore considered during the elaboration of the monitoring concept.

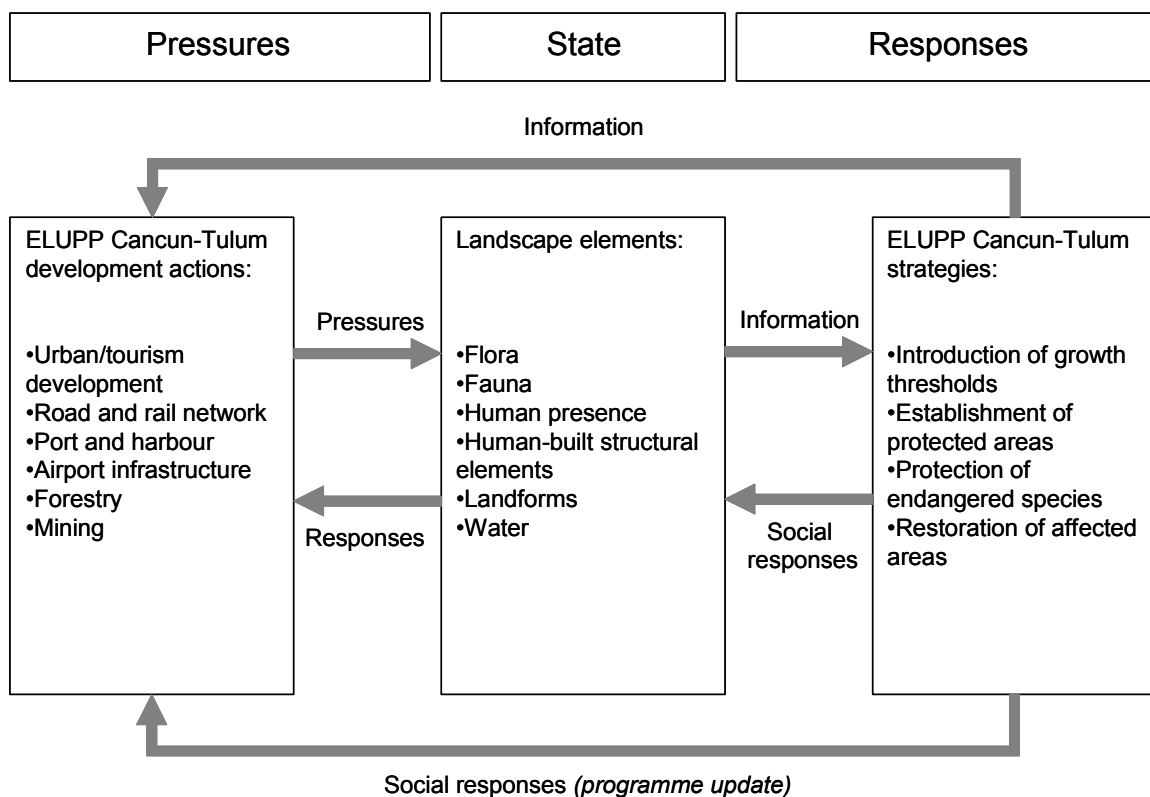
5.2 Monitoring framework

The second step consists in specifying the necessary information for finding out the environmental effects of the strategic action. The information can be obtained directly (measuring changes in the environment) or indirectly, collecting information on the implementation of mitigation measures (foreseen in the plan or programme) or pressure factors such as emissions or the amount of waste. Monitoring schemes must comprise the relevant issues for the follow up of the programme, for example prognosis about impact mitigation, achievement of targets, etc. In this investigation, an indicator framework is proposed for the selection of the relevant environmental information to supervise the ELUPP Cancun-Tulum implementation.

³ Traditional system of land tenure that combines communal ownership with individual use. The *ejido* consist of cultivated land, pastureland, other uncultivated lands, and the *fundo legal* (townsite; Encyclopedia Britannica 2006).

The monitoring scheme proposed here was established on a pressure-state-response (PSR) framework, which is based on a concept of causality (OECD 1993:5): human activities exert pressures on the environment (*pressure*) and change its quality (*state*). People respond to these changes through environmental, economic and sectoral policies (*response*). The latter form a feedback loop to pressures through human activities (see box 5.1).

Box 5.1: Pressure-State-Response framework for the environmental theme landscape in the Riviera Maya



Source: Based on OECD 1993:10

5.2.1 Selection of environmental indicators

Environmental indicators are information tools to indicate the overall status and trends of the environment (UNEP 2005). A key function of indicators is to condense environmental data to information which is understandable also for non-experts (who usually will decide on further action; CEC 2003:64). According to the PSR framework, there are three broad types of indicators (OECD 1993:6-7):

- *environmental pressure indicators*, which describe the pressures exerted on the environment by human activities;
- *environmental state indicators*, which are relate to the quality of the environment; and
- *social response indicators*, which describe the society’s response to environmental changes and concerns.

There are a variety of data sources, many of which have not been fully harmonized. In this research work, the following data sources were considered:

- United Nations Commission on Sustainable Development Core Indicators (CSD 2005)
- OECD Key Environmental Indicators (OECD 2004)
- Convention on Biological Diversity Indicators (CBD 2005)
- SNIA: Mexico’s National System of Environmental Indicators (SEMARNAP 2000d)
- European Environment Agency Core Set of Indicators (EEA 2005)
- World Health Organization Indicators (WHO 2003)

In selecting environmental indicators, three basic criteria were used (OECD 1993:7): policy relevance, analytical soundness, and measurability. Table 5.2 provides a more detailed presentation of the selection criteria.

Table 5.2: Criteria for Indicator Selection*

| Criteria | An environmental indicator should: |
|----------------------|--|
| Policy relevance | a. provide a representative picture of environmental conditions, pressures on the environment or society’s responses; b. be simple, easy to interpret and able to show trends over time ; c. be responsive to changes in the environment and related human activities; d. provide a basis for international comparisons ; e. be either national in scope or applicable to regional environmental issues of national significance; f. have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it. |
| Analytical soundness | g. be theoretically well founded in technical and scientific terms; h. be based on international standards and international consensus about its validity; i. lend itself to being linked to economic models, forecasting and information systems. |
| Measurability | The data required to support the indicator should be: j. readily available or made available at a reasonable cost/benefit ratio; k. adequately documented and of known quality ; l. updated at regular intervals in accordance with reliable procedures. |

* These criteria describe the "ideal" indicator and probably not all of them will be met in practice.

Source: OECD 1993:7

Indicators were identified and evaluated for each environmental theme of table 5.1. To illustrate the identification and selection of indicators, the ones related to the environmental theme *landscape* are discussed in the next section.

Methodology to identify and select indicators (environmental theme: landscape)

Landscape in terms of the physical sense implies the visual interpretation of the land configuration. Landscape can be defined as a heterogeneous area of land containing clusters of interacting ecosystems with repeated distribution (based on Forman and Gordon 1986). Landscape monitoring in the Riviera Maya can be based on the analysis of environmental change (extent or composition of its elements), or indirectly, on the effectiveness of mitigation measures (such as restoration of affected areas; ecological criteria HU-3, see table 3.8) or pressure factors (for example clearing for urban and tourism development).

In order to identify environmental indicators, the first step was to determine the relevant pressure-state-response elements related to each environmental theme of table 5.1. Box 5.1 shows the PSR framework for the theme landscape. The next step was the identification of the environmental indicators that could provide a representative picture of each pressure-state-response element. Table 5.3 shows the environmental indicators identified for the theme landscape. Finally, environmental indicators were evaluated according to the criteria presented in table 5.2.

Evaluation of environmental indicators

The evaluation of the environmental indicator *area of selected key ecosystems* (see table 5.3) is discussed below to exemplify the methodology used in this research.

This indicator uses the extent area of identified key ecosystems to assess the effectiveness of measures for conserving biodiversity at ecosystem level. Area of selected key ecosystems can be useful to determine changes on landscape, vegetation cover, ecosystem fragmentation, flora and fauna diversity, and soil resources. Additionally, this information can be related to the effects on water, soil, air, climate, and cultural features.

Table 5.3: Indicators for the environmental theme landscape

| Environmental theme: | | Landscape | | | | | | | | | | | |
|-----------------------------------|---|------------------|-------------------|-----------------------|---------------------------|-------------------|------------------------|-------------|---------------------------|--------------------------------|-----------------------------|------------------------|------------------|
| | | Policy relevance | | | | | A. S. | | | Measur. | | | |
| | | Representative | Easy to interpret | Responsive to changes | International comparisons | Scope of analysis | Threshold of reference | Methodology | Based on inter. standards | Can be linked to other systems | Availability of information | Quality of information | Update frequency |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Pressures | Indicators | | | | | | | | | | | | |
| Urban/tourism development | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Road and rail network | Transport infrastructure network | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | - | ✓ | ✓ | X | X |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| Mining | Area affected by extraction of raw materials/mining | ✓ | ✓ | ✓ | X | X | X | - | X | - | - | X | X |
| State | Indicators | | | | | | | | | | | | |
| Flora and fauna | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| | Fragmentation of ecosystems and habitats | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| Human presence | Status and trends of linguistic diversity and numbers of speakers of indigenous languages | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Human-built structural elements | Area/number of archaeological/historical sites | - | - | - | X | ✓ | X | - | X | X | - | - | - |
| Landforms | | | | | | | | | | | | | |
| Water | Area of selected key ecosystems (cenotes, aquifer recharge areas) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Responses | Indicators | | | | | | | | | | | | |
| Introduction of growth thresholds | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Establishment of protected areas | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Coverage of protected areas | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| Protection of endangered species | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Restoration of affected areas | Coverage of restored areas | ✓ | ✓ | ✓ | X | - | X | - | X | - | X | X | X |

Key: ✓ Satisfied; - partially satisfied; X not satisfied

Note: The complete description of selection criteria is included in table 5.2.

Source: Indicators selected from SEMARNAP 2000d, CSD 2005, CBD 2005, OECD 2004, EEA 2005

According to the above, it has been considered that this indicator provides a representative picture of environmental conditions, pressures, and society's responses on landscape in the Riviera Maya (criterion "a" of table 5.2, see the evaluation of this indicator in table 5.3). The indicator is easy to interpret and responsive to changes in the environment (criterion b and c).

Area of selected key ecosystems is included in the sets of indicators proposed by the United Nations' Commission on Sustainable Development (CSD 2005), the Organization for Economic Co-operation and Development (OECD 2004), and the Convention on Biological Diversity (CBD 2005). It provides therefore a basis for international comparisons and is applicable to regional environmental issues of national significance (criterion d and e). A threshold or reference value, however, is currently not available in the Riviera Maya (criterion f).

The indicator is theoretically well founded (methodological descriptions can be found in CSD 2005 and CBD 2005), is based on international consensus about its validity, and can be linked to economic models, forecasting and information systems (criteria g, h and i). The data required to support this indicator is not available yet, but can be made available at a reasonable cost/benefit ratio (criterion j). Although key ecosystems were already defined in the Riviera Maya (see section 4.2.2), until now no data on this indicator was neither documented nor updated (criteria k and l).

A similar process was performed for each indicator and environmental theme (see Annex I). This analysis showed the priority for the collection of information. In principle, it may be more significant to collect and analyze the information of indicators that are representative for more than one environmental theme, providing, in addition, information for the supervision of environmental conditions (state), pressures and societal responses (such as the indicator area of selected key ecosystems). Table 5.4 shows the set of environmental indicators for monitoring.

As an unequivocal classification of indicators is difficult to determine, the set of indicators suggested in this research work (table 5.4) is neither necessarily final nor exhaustive. The list is flexible and new issues can be incorporated or old ones abandoned according to their environmental relevance. In the following section, the environmental relevance, data needs and methodological description of each indicator are examined. The datasheets of all indicators are presented in Annex II.

Table 5.4: Indicator framework to supervise the ELUPP Cancun-Tulum implementation

| Environmental theme | Nr. | Indicator | Parameter |
|---------------------|-----|--|---|
| Population, health | 1 | Population of urban formal and informal settlements | Number of people |
| | 2 | Population with adequate sewage disposal facilities | % of the total population |
| | 3 | Population with access to safe drinking water | % of the total population |
| | 4 | Suitable solid-waste management | % of the total population |
| | 5 | Waterborne diseases | Cases/100,000 inhabitants |
| | | Indicators 12, 13 | |
| Biodiversity | 6 | Area of selected key ecosystems | ha |
| | 7 | Fragmentation of ecosystems and habitats | Average patch size |
| | 8 | Abundance of selected key species | Population size |
| | 9 | Coverage of protected areas | ha |
| | 10 | Coverage of restored areas | ha |
| Water | 11 | Intensity of use of water resources | Annual extraction |
| | 12 | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) | Concentration (mg/l) of indicators and MPN |
| | 13 | Marine water quality (chlorophyll concentration, faecal coliform) | Chl concentration, MPN |
| Soil | 14 | Area of urban formal and informal settlements | ha |
| | 15 | Transport infrastructure network | ha |
| | 16 | Coverage of forest areas | ha |
| | 17 | Area affected by extraction of raw materials/mining | ha |
| | | Indicators 6, 9, 10 | |
| Air, climate | 18 | Distance travelled per capita | Passenger-kilometre |
| | | Indicators 6, 9, 10, 14, 16, 17 | |
| Landscape | | Indicators 6, 7, 9, 10, 16, 17 | |
| Cultural features | 19 | Status and trends of linguistic diversity and numbers of speakers of indigenous languages | Number of indigenous languages and speakers |

Source: Indicators selected from SEMARNAP 2000d, CSD 2005, CBD 2005, OECD 2004, EEA 2005

5.2.2 Relevance, data requirements and methodological description of environmental indicators

1. Population of urban formal and informal settlements

Relevance: The indicator measures the size of formal and informal urban settlements by their population. The number of inhabitants can be used to estimate resource depletion, emission of contaminants, etc. The information provided by this indicator can be used to verify the observance of the densities of space use established by the ELUP strategy. In addition, the indicator can be an indirect measure to analyze traffic flows and changes on cultural patterns.

Data needed to compile the indicator: Population of urban formal and informal settlements.

Methodological description: The number of inhabitants in formal and informal settlements is generally measured in censuses. This information is already available at national, regional and local levels in Mexico. It is routinely updated every 2-5 years by the National Institute of Statistics, Geography and Data Processing (INEGI).

2. Population with adequate sewage disposal facilities

Relevance: The indicator provides information on the proportion of population with access to sanitary facilities for human excreta disposal in the dwelling or immediate vicinity. It is a basic indicator for assessing sustainable development, particularly human health, and is therefore suitable to supervise the first management objective of the ELUP strategy, namely, the achievement of sustainable development (see section 3.3). In addition, accessibility to adequate excreta disposal facilities is fundamental to decrease the faecal risk and the frequency of associated diseases (CSD 2005). The information of this indicator can be useful to study soil quality, and fresh and marine water quality in the Riviera Maya.

Data needed to compile the indicator: The number of people with access to improved excreta disposal facilities and the total population.

Methodological description: The percentage of population with adequate sewage disposal facilities is normally collected using censuses and surveys. Sanitary facility has been defined as (CSD 2005): "A unit for disposal of human excreta which isolates faeces from contact with people, animals, crops and water sources. Suitable facilities range from simple but protected pit latrines to flush toilets with sewerage. All facilities, to be effective, must be correctly constructed and properly maintained". In order to arrive at more robust estimates of sanitation coverage, two main data source types are required (CSD 2005): (i) administrative or infrastructure data which report on new and existing facilities; and (ii) population-based data from a household survey. This information is gathered by INEGI in Mexico; however, an additional check considering the information from local authorities (for instance, the Quintana Roo Water and Sewer Commission; CAPA) is required, as contradictory information can be found to date in the Riviera Maya.

3. Population with access to safe drinking water

Relevance: The indicator monitors the progress in the accessibility of the population to improved water sources in a dwelling or located within a convenient distance from the user's dwelling. Accessibility to improved water sources is of fundamental significance to lowering the faecal risk and frequency of associated diseases (CSD 2005). It is considered as a good indicator of human development. The information provided by this indicator can be used to supervise the first management objective of the ELUP strategy.

Data needed to compile the indicator: The number of people with access to improved water sources and the total population. Data on the source of water, for example, house tap or yard pipe, would provide additional meaning to this indicator.

Methodological description: The percentage of population with access to safe drinking water is collected using censuses and surveys. Reasonable access to water is defined as (CSD 2005): In urban areas, distances of not more than 200 metres from a house to a public stand post or any other adequate point source. In rural areas, reasonable access implies that people do not have to spend a disproportionate part of the day fetching water for the family's needs. Two data sources are common: administrative data that report on new and existing facilities, and population data from surveys or censuses. This information is gathered by INEGI in Mexico; however, this information should be verified (considering for instance information from CAPA) as contradictory information can be found to date in the Riviera Maya.

4. Suitable solid-waste management

Relevance: The indicator informs on the percentage of population with access to a suitable solid-waste management. Suitable solid-waste management includes all activities that seek to minimize the health, environmental and aesthetic impacts of solid wastes. In the Riviera Maya, waste management is a primary concern due to the potential impact of inappropriate waste management on water bodies, ecosystems, landscape, and human health. This indicator can show the effectiveness of the strategies implemented to achieve sustainable development through the ELUP programme.

Data needed to compile the indicator: The percentage of population with access to adequate solid waste disposal facilities and the total population.

Methodological description: This information is normally collected using censuses and surveys. Two data sources are common: administrative data that report on new and existing facilities, and population data from surveys or censuses. INEGI provides some information on this indicator. This information might be completed using administrative data in the Riviera Maya.

5. Waterborne diseases

Relevance: The indicator provides information on the occurrence of acute illness associated with drinking water from a public water system or exposure encountered in recreational or occupational settings (EEA 2005). Waterborne diseases are a health threat in Quintana Roo. In 2005, gastrointestinal illnesses were the second largest cause of death in the State (INEGI 2006b). The cause of these diseases is directly linked to poor domestic sanitation and hygiene, lack of safe drinking water and exposures to solid waste (for instance, through waste accumulation in the neighbourhood). These in turn are often associated with poor facilities for waste and water management, lack of adequate safety procedures within the food supply system and inadequate control of environmental pollution (WHO 2003:26). The indicator is intended to provide additional information to determine the effectiveness of the ELUP strategies for sustainable development.

Data needed to compile the indicator: The number of cases of waterborne diseases per 100,000 inhabitants.

Methodological description: This information is normally collected using censuses and surveys. Two data sources are INEGI and the Secretariat of Health of Mexico. They provide reliable routinely updated information.

6. Area of selected key ecosystems

Relevance: This indicator uses trends in the extent area of identified key ecosystems to assess the effectiveness of measures for conserving biodiversity at ecosystem level. The protection of key ecosystems is one of the central environmental objectives of the ELUP strategy. The ELUP Cancun-Tulum identifies as key ecosystems: “coral reefs, *subperennifolia* rainforest, mangroves, cenotes, coves, among others, as well as the habitats of species included in the Mexican Official Standard 059 (NOM-059-ECOL-2001, List of endangered species)” (criterion TU-22, see table 3.8). In addition, the aquifer recharge areas were also recognized as high-priority areas.

The indicator has the potential to illustrate the effectiveness of measures designed to conserve biological diversity in fulfilment of the ELUP provisions. In addition, this information can be useful to study changes on landscape, vegetation cover, ecosystem fragmentation, flora and fauna diversity, soil resources, climatic effects, water quality, and cultural features.

Data needed to compile the indicator: Land cover data to which an agreed ecosystem classification has been applied. Agreement on the classification will depend upon consensus on key ecosystems types and on the type and quality of raw remotely sensed or other primary data (CBD 2005).

Methodological description: Ecosystem area will normally be derived from mapped data on land cover. This is most efficiently done using data in digital form and Geographic Information Systems (GIS) software. The greatest difficulty is in arriving at an agreed ecosystem classification that is compatible with the available data. It is also fundamental to ensure consistency of the classification and the method of measurement, including consideration of spatial scale and resolution, over time (CSD 2005). Currently, this information does not exist in the Riviera Maya. The classification of key ecosystems, according to the available digital information, and a GIS-based database are required to acquire the data on this indicator.

7. Fragmentation of ecosystems and habitats

Relevance: The indicator examines the patch size distribution of terrestrial habitats to evaluate the effectiveness of measures implemented to minimize habitat fragmentation. Mitigation of habitat fragmentation is part of the ELUPP Cancun-Tulum provisions. Expansion of transport infrastructure networks is fragmenting and isolating habitats and creating barriers to wandering and spreading of animals and animals populations. The average size of natural conservation areas is decreasing and the average distance between areas of the same type or function is increasing. Nature's infrastructures conflict more and more with human infrastructures. This indicator is closely linked to the extent of key ecosystems.

Data needed to compile the indicator: Average size of non-fragmented ecosystems and habitats.

Methodological description: Patch size distribution of terrestrial habitats is normally derived from mapped data on land cover. This is most efficiently done using data in digital form and GIS software. Currently, this information does not exist in the Riviera Maya. A GIS-based database is therefore required to acquire the information on this indicator.

8. Abundance of selected key species

Relevance: This indicator uses estimates of population trends in selected species to represent changes in biodiversity and the relative effectiveness of measures to maintain biodiversity (CBD 2005). Biodiversity maintenance is essential for human life and sustainable development. The information provided by this indicator can thus be used to supervise the first management objective of the ELUP strategy. In addition, the indicator has the potential to illustrate the effectiveness of measures implemented in fulfilment of obligations accepted under the Convention on Biological Diversity.

Data needed to compile the indicator: The preferred input would be sets of quantitative data on the population size of selected species within a given area, assessed at suitable time intervals using a standardized method.

Methodological description: Some concepts and definitions are first required (CBD 2005):

Abundance: the number of mature individuals within the population or area under study. Where it is difficult or inappropriate to survey individuals, comparable surrogate units of measurement, such as number of nests (marine turtles) or spawning stock biomass (fishes), may be acceptable.

Key species: the following categories of species might be considered as key species when developing a biodiversity monitoring programme: (i) *keystone species:* the loss of these species will significantly impact upon the population sizes of other species in the ecosystem, potentially leading to further species loss (cascade effect); (ii) *rare or locally endemic species:* conservation of endemic species, particularly those sharing a discrete geographic area, can be a cost-effective way to maintain global biodiversity levels; and (iii) *threatened species:* a threatened species represents actual or potential decline in biodiversity. Recovery of threatened species following management intervention is strongly indicative of successful conservation measures.

Information on species abundance should be collected through the consistent, long-term, application of an appropriate survey technique that is widely accepted by the scientific community (CBD 2005). Retrospective population information may be obtained through review of published literature, including previous field study reports, seeking material that is appropriate for comparison with the ongoing methodologies adopted. While it is in most cases impossible to count every individual within a population or area, knowledge of habitat requirements and species population density in sample areas, coupled with data on climate, altitude, soil type or vegetation cover may be used to estimate population size in the area of interest. A GIS is commonly used to analyse the spatial data. It is important that population size predictions are verified by fieldwork.

So far, the species included in the Mexican Official Standard 059 (NOM-059-ECOL-2001, List of endangered species) are recognized as key species in the Riviera Maya. However, a biodiversity monitoring programme is currently not available. Data on some species can be obtained from NGOs working in the region. The Centro Ecológico Akumal, for example, compiles annual data on the arrival of loggerhead turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*) in the beaches Aventuras Akumal, Akumal and Media Luna (CEA 2003). In order to obtain suitable information, the introduction of a GIS-based monitoring programme may be required.

9. Coverage of protected areas

Relevance: The indicator measures the area of protected land ecosystems, inland water ecosystems, and marine ecosystems, expressed as a percentage of the total area of land ecosystems, inland water ecosystems and marine ecosystems respectively (CSD 2005). This indicator represents the extent to which areas important for conserving biodiversity, cultural heritage, scientific research (including baseline monitoring), recreation, natural resource maintenance and other values are protected from incompatible uses. It is an ideal indicator to supervise the observance of the land-use strategy proposed by the ELUP. Additionally, the information provided by this indicator can be useful to study changes on biodiversity, landscape and cultural features.

Data needed to compile the indicator: A map of the ecosystems, preferably using a classification that is internationally compatible and valid for other countries and regions. A geo-referenced list of the protected areas, giving their sizes and locations, and classifying them by protection category comparable to The World Conservation Union's six management categories of protected area.

Methodological description: The indicator requires the calculation of the area of totally and partially protected areas. The indicator can be mapped in two layers: ecosystems and protected areas. Smaller protected areas can be mapped as points, in which case their size should be recorded in a database separately. The category of protected area should also be entered in the database. This information is already available for the Riviera Maya in digital form. Data sources are the National Commission for the Knowledge and Use of Biodiversity of Mexico (CONABIO) and the ELUPP Cancun-Tulum administrative boundaries shapefiles (SEMARNAT 2001c).

10. Coverage of restored areas

Relevance: The indicator illustrates the effectiveness of measures adopted to recover affected areas, which is one of the mitigation strategies included in ELUP. The information may be useful to evaluate changes on landscape, soil quality, water quality and biodiversity.

Data needed to compile the indicator: Coverage of restore areas.

Methodological description: The area of restore areas can be obtained from mapped data on land cover. This is most efficiently done using data in digital form and GIS software. Currently, this information does not exist in the Riviera Maya. A GIS-based database is required to acquire the information on this indicator.

11. Intensity of use of water resources

Relevance: The purpose of this indicator is to show the degree to which renewable water resources are being exploited. The indicator can show to what extent freshwater resources are already used, and the need for adjusted supply and demand management policy. Scarce water could have negative effects on sustainability constraining economic and regional development, and leading to loss of biodiversity. The adequate use of water resources is indispensable to achieve sustainable development. This indicator can be thus used to supervise the ELUP implementation.

Data needed to compile the indicator: Annual extraction of ground and surface water as a percent of total renewable water resources.

Methodological description: The total renewable water resources (RWR) are defined as the sum of internal RWR and incoming flow originated outside the area under study. The indicator could consider withdrawals and water resources at the basis of a watershed. The indicator could be disaggregated to show total renewable water resources, withdrawals for the different users, and efficiencies for these different users (CSD 2005). A data source can be administrative information from local administration (CAPA). INEGI also gather information on water uses regularly.

12. Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994)

Relevance: The purpose of this indicator is to assess the quality of water available to consumers in localities or communities for basic and commercial needs. Sustainable development is heavily dependant on suitable water availability. Human ill health due to water quality problems can reduce work capability and affect children's growth and education. This indicator may show the effectiveness of ELUP strategies implemented to protect aquifer recharge areas and water bodies in the Riviera Maya.

Data needed to compile the indicator: Records of water authorities' laboratories, hydro-geological institutes, universities, municipal public health laboratories, research institutes, and special studies, which show fresh water quality.

Methodological description: This indicator measures fresh water quality using representative quality indicators such as Biological Oxygen Demand (BOD), faecal coliform, and salinity. Water pollutants included in the Mexican Official Standard NOM-127-SSA1-1994 can be also considered. These indicators have the potential to illustrate the effectiveness of measures designed to the sustainable use of water resources.

BOD may indicate faecal contamination or increases in particulate and dissolved organic carbon. Increased concentrations of dissolved organic carbon can create problems during the production of drinking water if chlorination is used, as disinfection by products, such as trihalomethanes and other compounds toxic to humans, may be produced. Increased oxygen consumption poses a potential threat to aquatic organisms, including fish. It is, therefore, important to monitor organic pollution to identify areas posing a threat to health, to identify sources of contamination, to ensure adequate treatment, and provide information for decision making to enhance water sustainability (CSD 2005).

Faecal indicator bacteria remain the preferred way of assessing the hygienic quality of water (CSD 2005). The concentration of faecal coliforms in freshwater bodies is an indicator of contamination with human and animal excreta. Water contaminated with human and animal excreta represents a serious health risk. This measure indicates situations where treatment is required or has to be improved to guarantee safety of supply.

Considering the characteristics of the Riviera Maya, salinity of freshwater may be another suitable indicator of water quality. Aquifers near the coast are at risk for seawater intrusion as a result of groundwater over-exploitation. The high mineral content of saltwater causes these waters to be unsuitable for many uses, including human consumption.

Finally, the indicators reported in compliance with the Mexican Official Standard NOM-127-SSA1-1994 (Drinking water quality) can also be considered. This standard includes bacteriological, physical, chemical and organoleptic indicators.

Data on the abovementioned indicators are normally available from municipal water supply authorities on a routine basis. The Secretariat of Health of Mexico and research institutes operating in the region may be alternative data sources. In the Riviera Maya, the main data source should be the Quintana Roo Water and Sewer Commission (CAPA).

13. Marine water quality (chlorophyll concentration, faecal coliform)

Relevance: This indicator will use the concentration of algae growing in coastal waters and the number of faecal coliforms to represent the health of the coastal zone ecosystem and the effectiveness of measures aimed at reducing nutrient inputs from run-off and discharge. Coastal ecosystems provide important economic benefits, such as fisheries, tourism and recreation. They are also important for biodiversity, which is recognised by the Convention on Biological Diversity (CBD) as having its own intrinsic value as well as importance for human life and sustainable development. High algal concentrations in coastal waters reflect high nutrient inputs, which can represent serious threats to coastal ecosystem health. A large concentration of algae restricts the available light, reduces dissolved oxygen levels and may increase sedimentation, which smothers other organisms. Increasing concentrations of algae can also indicate threats to human and animal health by toxic algal blooms (EEA 2005).

In addition, bacterial level in water is an indicator of water pollution, which can represent serious threats to coastal ecosystem health. Monitoring of coastal ecosystems is a central issue in the Riviera Maya, as coastal areas are used for recreational activities and fishing. In addition, coastal ecosystems in the Riviera Maya comprise the second longest barrier reef in the world (more than 500 km long).

Data needed to compile the indicator: Standardised quantitative data on chlorophyll concentrations or the population and biomass of algae from an appropriately distributed network of sampling stations. Most Probable Number (MPN) of faecal coliforms per 100 ml.

Methodological description: Guidelines have been produced by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), set up by the United Nations (UN) in 1969, in an effort to standardise the methods used for algae measurements (see: <http://gesamp.imo.org/publicat.htm>). Measurements of chlorophyll concentration using spectrophotometric and fluorometric techniques are often used as an indirect method of assessing algal biomass. At present, this information does not exist in the Riviera Maya. A GIS-remote sensing based database might be a suitable alternative to acquire the information on this indicator.

14. Area of urban formal and informal settlements

Relevance: Urban development is one of the biggest land consumers. This indicator has the capacity to show changes in land-use patterns and landscape. In addition, urban growth can be related to the effects on vegetation cover, ecosystem fragmentation, flora and fauna diversity and cultural patterns. The indicator will be used to supervise the observance of the ELUP provisions, specifically the compliance with designated urban areas and densities of space use.

Data needed to compile the indicator: Area of formal and informal settlements.

Methodological description: Area of formal and informal settlements can be evaluated through aerial photography or land use maps. Informal settlements should not cover dwelling units which have been regularized. They should only include those units which presently occupy land illegally and/or housing which are not in compliance with current regulation.

Where feasible, the interpretation and meaning of this indicator would be supported by the comparison of formal and informal settlement areas to total urban area. Area of formal and informal settlements has not been quantified in the Riviera Maya. A GIS-based database can be used to acquire and manage the information on this indicator.

15. Transport infrastructure network

Relevance: Land is under continuous pressure from new transport infrastructure. In addition, linear infrastructures may lead to ecosystem fragmentation. The indicator has the potential to show changes on landscape, soil and biodiversity. This information can be used to study transportation patterns in the Riviera Maya as a result of the ELUP implementation.

Data needed to compile the indicator: Land take by transport infrastructure.

Methodological description: Land take by transport infrastructure can be evaluated through aerial photography or land use maps. This information has not been quantified in the Riviera Maya to date. The length of the transport infrastructure network was determined by INEGI and the Secretariat of Communications and Transportation of Mexico (SCT). A GIS-based database may be used to acquire and manage the information on this indicator.

16. Coverage of forest areas

Relevance: The indicator measures the total forest area as a percentage of the total area. Forests provide many significant resources and functions included wood products and non-wood products: i.e. recreation, wildlife habitat, water and soil conservation, carbon capture, etc. In addition, forests support employment, traditional uses and biodiversity. They are among the most diverse and widespread ecosystems of the world. Sustainable forest management is a key objective of the ELUP strategy. In addition, the information of this indicator may be relevant to biodiversity, water, air, soil, landscape and cultural patterns.

Data needed to compile the indicator: Coverage of forest areas.

Methodological description: Coverage of forest areas can be examined through aerial photography and land-use maps. Information on forest areas at state and national levels is collected by SEMARNAT and the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico (SAGARPA) yearly. Coverage of forest areas in the Riviera Maya can be obtained using a GIS-database monitoring system.

17. Area affected by extraction of raw materials/mining

Relevance: The indicator measures the land affected by extraction of raw materials and mining. This information can be used to supervise the ELUP land-use strategy. This data can be useful to study changes on landscape, soil quality, groundwater quality, vegetation cover, ecosystem fragmentation, and flora and fauna diversity.

Data needed to compile the indicator: Coverage of land affected by extraction of raw materials and mining.

Methodological description: Coverage of land affected by extraction of raw materials and mining can be examined through aerial photography and land-use maps. This information has not been quantified in the Riviera Maya so far. A GIS-based database may be used to acquire and manage the information on this indicator.

18. Distance travelled per capita

Relevance: The indicator may be helpful to examine the efficiency of the land-use strategy implemented through ELUP in the Riviera Maya by helping to determine energy consumption/efficiency and atmospheric emissions. Travel is an essential part of the economic and social life. However, motorized travel has greater environmental and social impacts, such as pollution, global warming and accidents. Sustainability implies using the most appropriate mode of transport and decoupling travel from economic development. Sustainable policies are thus policies that reduce the need for travel, support a shift towards less environmental damaging means, provide incentives for changes in lifestyle, increase safety, and improve the standard of public transport (based on CSD 2005).

Data needed to compile the indicator: Passenger-kilometre data by means of transport and population.

Methodological description: The indicator should be broken down into the following modes of transport (CSD 2005): walking, cycling, passenger cars, motorcycles and mopeds, buses and coaches, train, ship, and plane. The indicator should be calculated as the total passenger-kilometres travelled per year divided by the total population, according to the different modes of transportation. Data on this indicator are compiled by INEGI in the Riviera Maya. Additional data may be required, which should be collected using surveys.

19. Status and trends of linguistic diversity and numbers of speakers of indigenous languages

Relevance: This indicator illustrates patterns of cultural change by evaluating the number of indigenous languages and speakers. Activities in the Riviera Maya are impacting Mayan communities transforming their habits and customs. Analyses have shown a large overlap between regions that are rich in biodiversity and those rich in languages. Linguists and anthropologists have suggested that the diversity of ideas carried by different languages and sustained by different cultures is as necessary as the biological diversity and ecosystems is for the survival of the humanity and of life on the planet (CBD 2005). The extinction of a language results in the irrecoverable loss of unique cultural, historical, and ecological knowledge. Each language is a unique expression of the human experience of the world.

Data needed to compile the indicator: Number of indigenous languages and speakers.

Methodological description: The number of indigenous languages and speakers is regularly collected and updated by INEGI.

The indicator framework and the main pressure-state-response issues are summarized in table 5.5.

As it was previously mentioned, environmental indicators can be relevant to one or more environmental issues of table 5.1. They can provide, in addition, relevant information on environmental pressures, state and social responses as shown in table 5.5.

Table 5.5: Indicator framework and main pressure-state-response issues in the Riviera Maya

| PSR framework | ELUP Indicator set | | | | | | | | | | | | | | | | | | |
|-----------------------------|---------------------------------|-------------------------------------|-------------------------------|---------------------------------|---------------------|---------------------------------|-----------------------------|--------------------------|-----------------------------|----------------------------|-------------------------------------|---------------------|----------------------|---------------------------|----------------------------------|--------------------------|----------------------------------|-------------------------------|--------------------------------|
| | Population of urban settlements | Adequate sewage disposal facilities | Access to safe drinking water | Suitable solid-waste management | Waterborne diseases | Area of selected key ecosystems | Fragmentation of ecosystems | Abundance of key species | Coverage of protected areas | Coverage of restored areas | Intensity of use of water resources | Fresh water quality | Marine water quality | Area of urban settlements | Transport infrastructure network | Coverage of forest areas | Area affected by mining/raw mat. | Distance travelled per capita | Number of indigenous languages |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Pressure | | | | | | | | | | | | | | | | | | | |
| Urban/tourism development | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | ■ | | | |
| Infrastructure construction | | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | | | ■ | |
| Forestry | | | | | | ■ | ■ | ■ | ■ | | | ■ | ■ | | | ■ | | | |
| Mining | | | | | | ■ | ■ | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | |
| State | | | | | | | | | | | | | | | | | | | |
| Population, health | ■ | ■ | ■ | ■ | ■ | | | | | | | ■ | ■ | | | | | | |
| Biodiversity | | | | | | ■ | ■ | ■ | | | | ■ | ■ | | | ■ | | | |
| Water consumption | | | ■ | | | | | | | | ■ | | | | | | | | |
| Water quality | | | | | ■ | ■ | | | | | | ■ | ■ | | | ■ | | | |
| Land consumption | | | | | | ■ | ■ | | ■ | | | | | ■ | ■ | ■ | ■ | | |
| Landscape | | | | | | ■ | ■ | | ■ | ■ | | | | ■ | ■ | ■ | ■ | | |
| Cultural aspects | | | | | | ■ | | | ■ | | | | | ■ | ■ | ■ | | ■ | ■ |
| Response | | | | | | | | | | | | | | | | | | | |
| ELUP ecological criteria | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | ■ | ■ | ■ | ■ | ■ | | ■ | |
| ELUP protection policy | | | | | | ■ | ■ | ■ | ■ | | | ■ | ■ | | | ■ | | | |
| ELUP conservation policy | | | | | | ■ | ■ | ■ | | | | ■ | ■ | | | ■ | | | |
| ELUP exploitation policy | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ |
| ELUP restoration policy | | | | | | | | | | ■ | | | | | | ■ | | | |

Key: ■ The indicator provides information on the pressure-state-response issue

Table 5.5 indicates, for example, that the indicator fourteen (area of urban formal and informal settlements) provides relevant information on pressure issues (land consumed for urban/tourism development), state (area of landscape that has been used for urban development) and responses (urban growth boundary expansion or control as a result of the implemented urban development strategies).

5.3 Identification of existing sources of information

The next step is to identify existing sources of information required to monitor the significant environmental effects of the ELUPP Cancun-Tulum implementation. Two main sources are data about projects for which the programme sets the framework and general environmental monitoring systems (CEC 2003:65).

Project-related data can help to compare the prediction of effects with the effects which in fact occur. If the monitoring system is to depend on this information, it must be ensured that the data are made available to the monitoring authority (in this case the technical committee of the ELUPP Cancun-Tulum). Furthermore, the information from project level has to be processed, aggregated and summarized in order to use it for the monitoring at strategic level.

The second source of information is general environmental monitoring systems not related specifically to the ELUPP (for instance water quality monitoring, solid waste management, etc.). These data can show changes in the environment, but offer limited conclusions about the effects of the programme (since the cause–effect link is difficult to establish). However, this information can be used to find out whether environmental objectives have been achieved. It also may give an indication about the efficiency of measures undertaken or foreseen to achieve these targets (CEC 2003:65).

As noted in chapter 2, monitoring of specific issues (indicators) is practically nonexistent in Mexico. In the Mexican EIA, environmental monitoring is normally restricted to the supervision of the mitigation measures foreseen or imposed. Considering the lack of information on specific issues, the ELUPP Cancun-Tulum monitoring concept has to be based initially on general information sources.

The identification of information sources carried out in this work only encompassed the information already available on the Internet (since the research was conducted at the BTU Cottbus, Germany). Information not available online or in a non-digital format should be collected and taken into consideration by the authorities responsible to supervise the ELUPP Cancun-Tulum. The sources of information identified were already mentioned during the discussion of each environmental indicator in section 5.2.2, and are included in the indicator data sheets in Annex II.

Information gaps

The next activity is to fill the gaps founded when comparing the existing sources of information to the needs of information. In some cases the information may be sufficient to satisfy the monitoring requirements. In others, the existing systems may have to be enlarged by including additional aspects or measuring points. It should be stressed that monitoring in SEA has a limited purpose, i.e. to detect the deficiencies of the environmental assessment, and that it is not an autonomous scientific exercise (CEC 2003:65).

In determining information needs, information sources were evaluated based on the following criteria (in comparison with the needs of information demanded for each indicator in section 5.2.2):

- *Robustness* – quality assurance
- *Update frequency* – the information is routinely updated as demanded by the indicator
- *Scope* – spatial resolution of the data/information extent
- *Data type format* – suitable data format, digital, analogue, georeferenced, etc.

Table 5.6 provides a general overview of the status of the identified information sources and illustrates data needs. So far, eight of the nineteen expected information sources were identified (see table 5.6). Sources not identified can be divided into two groups: (i) information believed to be already available (since it is required by the Mexican environmental legislation and therefore should be part of the mechanisms already established); and (ii) information that has to be obtained through the enlargement of the existing monitoring systems.

To the first group belong the indicators 4, 11, and 12 (see table 5.6). Information on *suitable solid-waste management* should be part (and therefore available) of the “normal” administrative procedures of the solid-waste management departments in the Riviera Maya.

Monitoring of *fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994)* is legally binding in Mexico. For this reason, although the data source was not identified it is considered that this information must be part of the existing monitoring procedures. The data source should be the Quintana Roo Water and Sewer Commission (CAPA). The same source can be considered to determine the *intensity of use of water resources* as CAPA is the body responsible for the water supply systems in Quintana Roo.

Table 5.6: Status of the identified sources and information needs

| Indicator | | Source identified? | Quality assurance | Update frequency | Scope | Data type format | Status |
|-----------|--|--------------------|-------------------|------------------|-------|------------------|--------|
| 1 | Population of urban formal and informal settlements | Yes | ✓ | ✓ | ✓ | ✓ | + |
| 2 | Population with adequate sewage disposal facilities | Yes | - | ✓ | ✓ | ✓ | - |
| 3 | Population with access to safe drinking water | Yes | - | ✓ | ✓ | ✓ | - |
| 4 | Suitable solid-waste management | No | X | X | X | X | X |
| 5 | Waterborne diseases | Yes | ✓ | ✓ | ✓ | ✓ | + |
| 6 | Area of selected key ecosystems | No | X | X | X | X | X |
| 7 | Fragmentation of ecosystems and habitats | No | X | X | X | X | X |
| 8 | Abundance of selected key species | No | X | X | X | X | X |
| 9 | Coverage of protected areas | Yes | - | - | ✓ | - | - |
| 10 | Coverage of restored areas | No | X | X | X | X | X |
| 11 | Intensity of use of water resources | No | X | X | X | X | X |
| 12 | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) | No | X | X | X | X | X |
| 13 | Marine water quality (chlorophyll concentration, faecal coliform) | No | X | X | X | X | X |
| 14 | Area of urban formal and informal settlements | No | X | X | X | X | X |
| 15 | Transport infrastructure network | Yes | ✓ | - | ✓ | X | - |
| 16 | Coverage of forest areas | Yes | - | ✓ | ✓ | X | - |
| 17 | Area affected by extraction of raw materials/mining | No | X | X | X | X | X |
| 18 | Distance travelled per capita | No | X | X | X | X | X |
| 19 | Status and trends of linguistic diversity and numbers of speakers of indigenous languages | Yes | ✓ | ✓ | ✓ | ✓ | + |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

+

The information source was identified. The evaluation criteria were fulfilled or it was considered that their compliance can be expected in the short-term.

-

The information source was identified. Not all evaluation criteria were fulfilled. Short-term compliance could be difficult.

X

The information source was not identified.

In addition, partial information related to some indicators is currently available in the Riviera Maya. SEMARNAT (2000e) has monitored the presence of faecal coliforms in coastal waters (indicator 13; see table 5.6). The Centro Ecologico Akumal (CEA 2003), as it was previously mentioned, compiles annual data concerning the arrival of loggerhead turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*) in the beaches Aventuras Akumal, Akumal and Media Luna, which are included in the red list of threatened species of Mexico (indicator 8; see table 5.6).

Information on the remaining not identified data sources must be obtained through the enlargement of the existing (or the implementation of new) monitoring systems.

5.4 Integration of monitoring into the planning system

The last step is to integrate monitoring into the planning system. Ideally, monitoring of strategic actions must be part of the regular planning system. If not, time and monitoring frequency have to be laid down. In addition, it has to be determined which authority (or body) is responsible for the different tasks of monitoring: collection of information, data processing and their evaluation. "When developing monitoring schemes it should be noted that monitoring does not end with the collection of environmental information but includes also their evaluation" (CEC 2003:66). Furthermore, it is important that the relevant information is submitted to the respective authority in an appropriate form (for example, environmental data should be explained and put in an understandable document when presented to a decision-making body).

Monitoring of the ELUPP Cancun-Tulum is already integrated (but is not practiced) into the regular planning system of Quintana Roo. Since 2001, the programme must be monitored (yearly) and updated periodically every 3-5 years. A subcommittee is responsible for the different tasks of monitoring. In 2001, this body updated the programme based on the information reported in the EIAs and the opinion of governmental and non-governmental organizations. Experience in practicing monitoring as part of the planning system, however, is up to now not satisfactory (see section 3.3.1).

To implement the monitoring concept suggested in this investigation, this subcommittee should determine the route to obtain the necessary information and the assessment and report procedures based on the methodology proposed. It is considered that the use of GIS software is the most efficient way to support the monitoring tasks in the Riviera Maya.

GIS may facilitate the management and evaluation of the existing information and create, in addition, new information by combining the existing data or by making analysis, simulations and modelling. The capacity of GIS to perform spatial analysis (of past, present and future scenarios) makes it an ideal tool for environmental supervision and management. GIS may facilitate the analysis of:

- Area of urban formal and informal settlements
- Transport infrastructure network
- Area of selected key ecosystems
- Fragmentation of ecosystems and habitats
- Coverage of protected areas
- Coverage of restored areas
- Area affected by extraction of raw materials/mining
- Coverage of forest areas

In the next chapter, six environmental indicators are evaluated: (i) fragmentation of ecosystems and habitats; (ii) coverage of protected areas; (iii) area of urban formal and informal settlements; (iv) transport infrastructure network; (v) coverage of forest areas; and (vi) area affected by extraction of raw materials and mining. The assessment is based on the remote sensing interpretation of two Landsat Geocover Mosaics (LGMs) of 1988 and 2001.

6

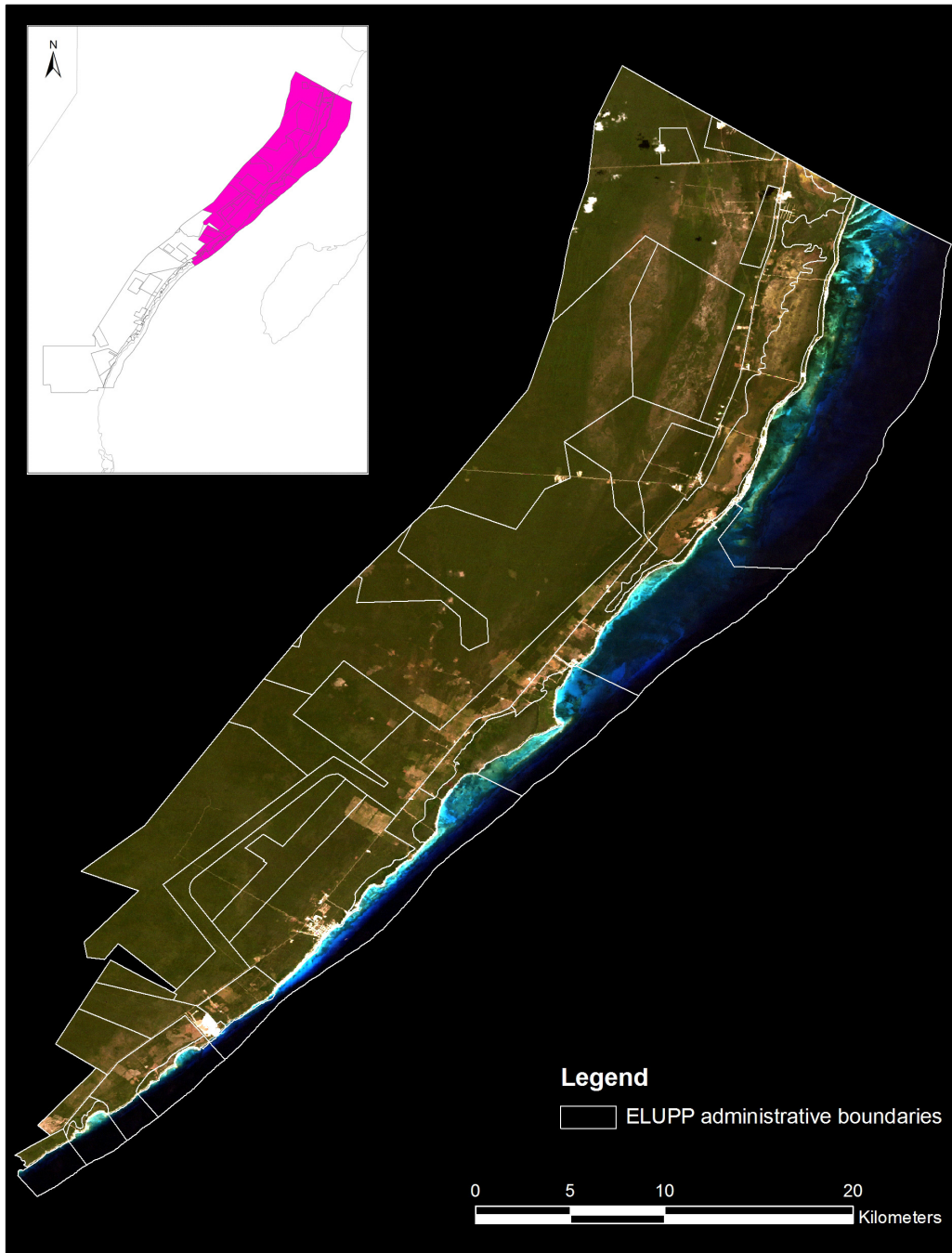
GIS-Environmental monitoring of the ELUPP Cancun-Tulum

Geographical Information Systems (GIS) are a valuable tool for environmental assessment. GIS facilitates the management and evaluation of large data sets. It can create new information by combining the existing data or by making analysis, simulations and modelling. Its capacity to perform spatial analysis of past, present and future scenarios makes GIS an ideal tool for environmental monitoring and management. In this investigation, it has been shown that GIS can have a wide application in all SEA stages, acting as an integrative framework for the whole process, from the generation, storage and display of thematic information required for the preparation of the development action, to impact prediction and evaluation, selection of site alternatives, and finally, for the supervision of proposed strategies.

In this chapter, six environmental indicators are examined to supervise the ELUPP Cancun-Tulum implementation: (i) fragmentation of ecosystems and habitats; (ii) coverage of protected areas; (iii) area of urban formal and informal settlements; (iv) transport infrastructure network; (v) coverage of forest areas; and (vi) area affected by extraction of raw materials and mining.

The assessment was based on the GIS-remote sensing interpretation of two Landsat Geocover Mosaics (LGMs; 30m X 30m cell size resolution) of 1988 (before the start of the programme) and 2001. In the first phase of the analysis, both LGMs were classified using a supervised multi-spectral classification method. Then, to determine extent and patter of fragmentation six landscape indices were calculated: (i) minimum, mean and maximum patch area; (ii) patch perimeter; (iii) the second shape index (S2); (iv) the fractal dimension index (D); (v) the Nearest Neighbour Distance (NND); and (vi) the Normalized Difference Vegetative Index (NDVI).

Due to the lack of information, this analysis was carried out to the programme's north part (94,190 ha; see map 6.1). However, the results obtained in this research improved the requirements of information demanded by these indicators.



Map 6.1: GIS-monitoring study region
Source: based on a Landsat Geocover 1988 Mosaic, ESC 2004

6.1 GIS-database

The first step was to build a GIS-database to manage digital information. The datasets used to build the database are presented in table 6.1. The next step was to identify the spatial reference system for each dataset and to perform all GIS operations to make them compatible (for example transformation of spatial reference systems to a common one, etc.). Finally, the study area was clipped out and all datasets were transformed to a common map projection (in this case Cylindrical Equal Area Projection).

Table 6.1: Information managed to build a GIS-database

| Dataset | File format |
|--|-------------|
| Landsat Geocover Mosaic 1988 | TM Mosaic |
| Landsat Geocover Mosaic 2001 | ETM Mosaic |
| ELUPP Cancun-Tulum administrative boundaries | Shapefile |
| Protected areas in Quintana Roo | Shapefile |
| Road network | Shapefile |
| Vegetation types 1:250,000 | Shapefile |

6.1.1 Digital image classification

A supervised multi-spectral image classification method was used to classify the LGMs. This method is used to extract thematic information from satellite images in a semi-automatic way. Multi-spectral image classification is based on the analysis of N bands simultaneously, where N reflexion values are observed at the same time. These values are finally associated to land cover classes.

The process is divided into two phases: a training phase, where the user “trains” the computer, by assigning for a limited number of pixels to what classes they belong in this particular image, followed by the decision making phase, where the computer assigns a class label to all (other) image pixels, by looking for each pixel to which of the trained classes is most similar (LUMA-GIS 2005:3). During the training phase, the classes to be used are defined. About each class some “ground truth” is needed: a number of places in the image area that are known to belong to that class. This knowledge must have been acquired beforehand, for instance as a result of fieldwork, or from an existing map (assuming that in some areas the class membership has not changed since the map was produced).

Digital image classification was made using the ILWIS 3.3 software (ILWIS 2006). Three colour composites were created to support the training phase, the band combinations are shown in maps 6.2, 6.3 and 6.4. The land-cover classes used to classify LGMs were determined according to the land-use map of INEGI (1997; see table 6.2). The number of training samples was between 30 and 50 per land-cover class.

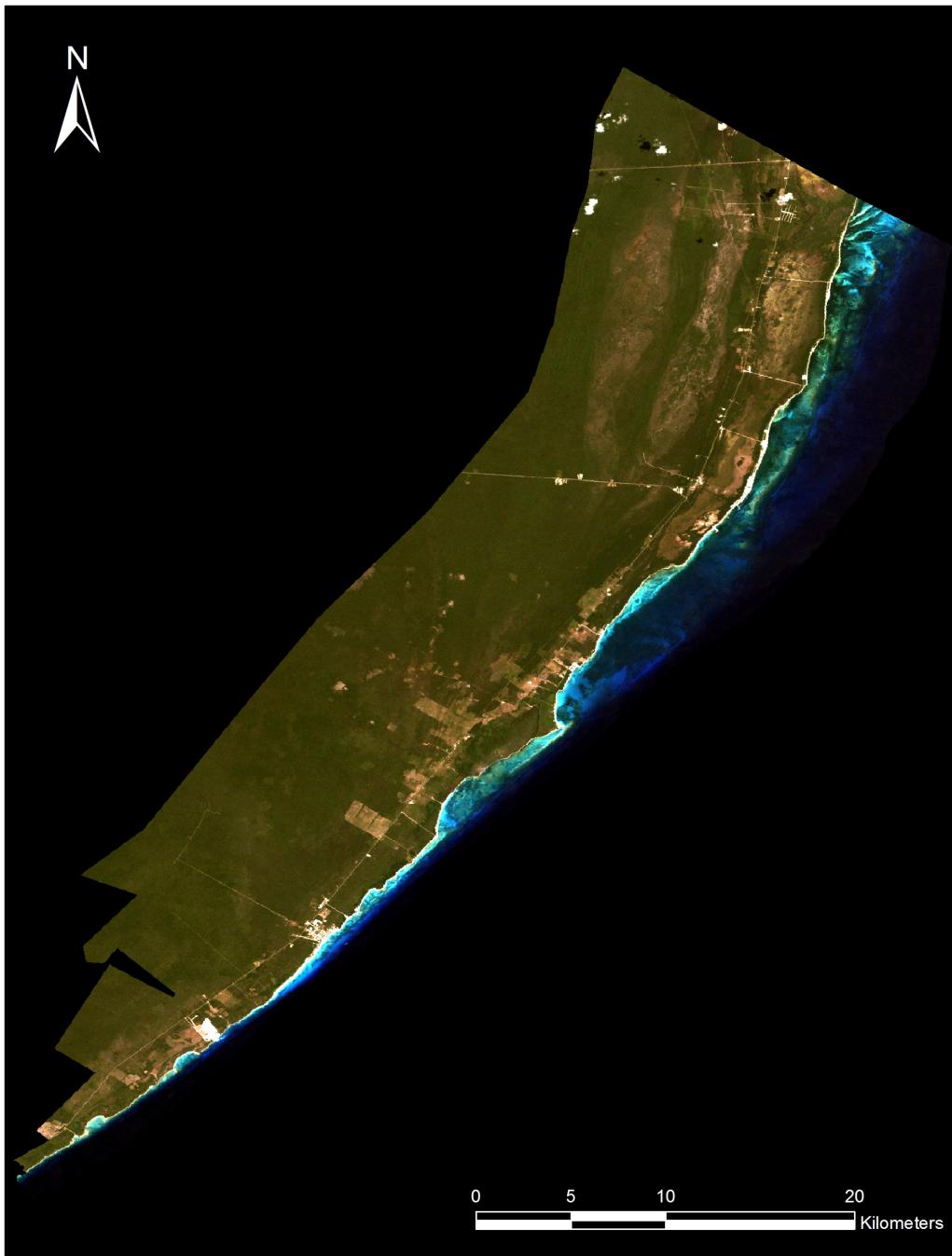
Table 6.2: Land-cover classes in the sample set for a supervised image classification

| Class name | Code |
|---------------------------------------|------|
| Rainforest | R |
| Flooded vegetation | F |
| Deteriorated | D |
| Urban/semi-urban settlement and roads | U |
| Sand | S |
| Water | W |

There are various decision-making algorithms to find the relationship between training samples and reflection values. In this assessment, the *Minimum Distance-to-mean classifier* provided the best classification (in comparison with the land-use map of INEGI and the colour composites). The result of the digital classification is shown in maps 6.5 and 6.6.

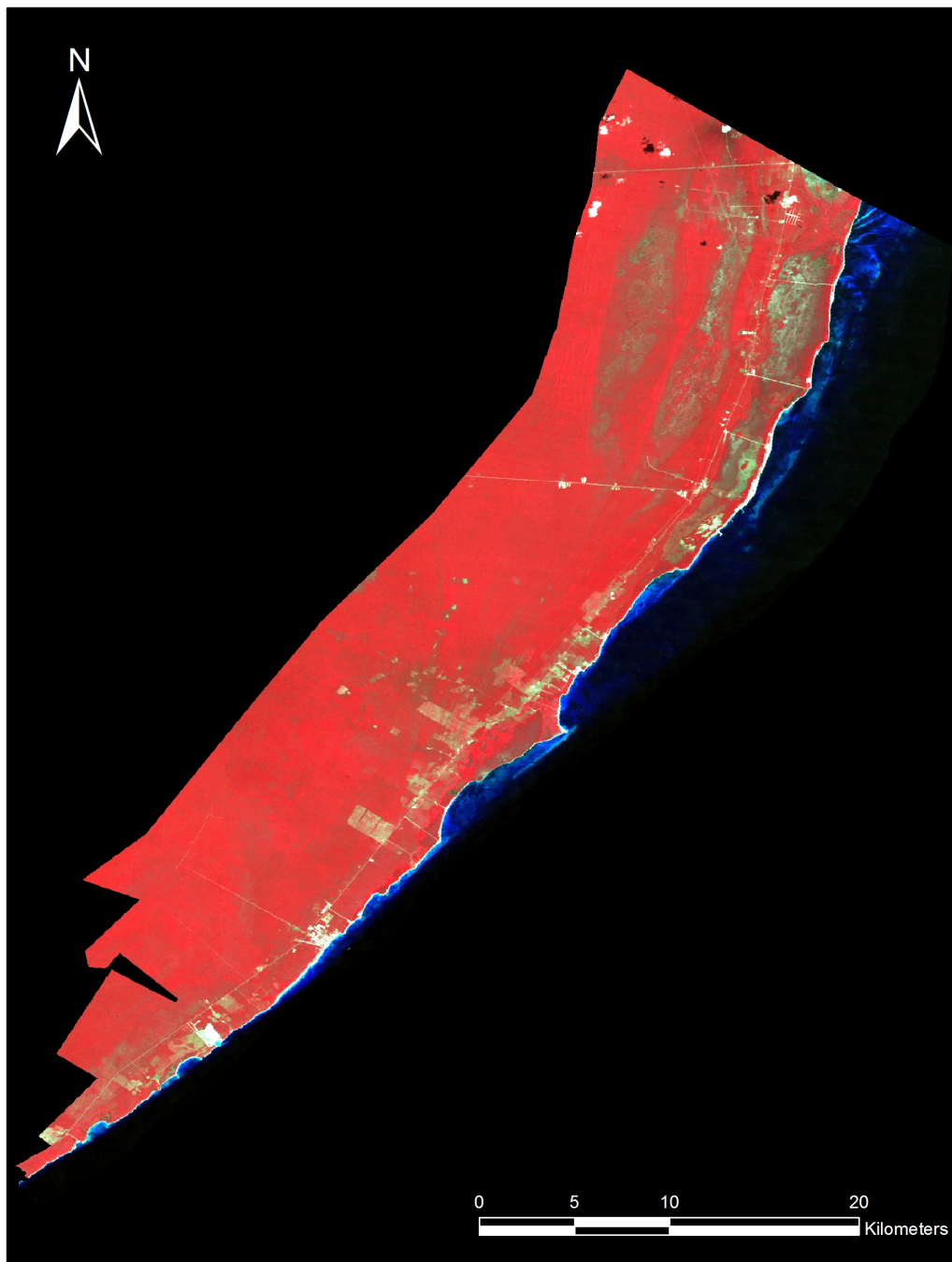
6.1.2 Digitalization of landscape features

Digitalization is the process of converting analogue data to a digital form, or creating new data directly in digital form (LUMA-GIS 2005:2). As shown in the last section, this procedure can be done in a semi-automatic way if the relationships between classes and reflection values are stored. However, digital image classification is influenced by a large amount of factors such as atmospheric conditions, sun angle (as function of latitude, time of day, date and terrain relief), soil types, soil humidity, growing stage of the vegetation, wind (affecting orientation of leafs), etc. Thus, additional data to check the results of the digital classification (for example soil and land-use maps) and the human interpretation of the data are required.



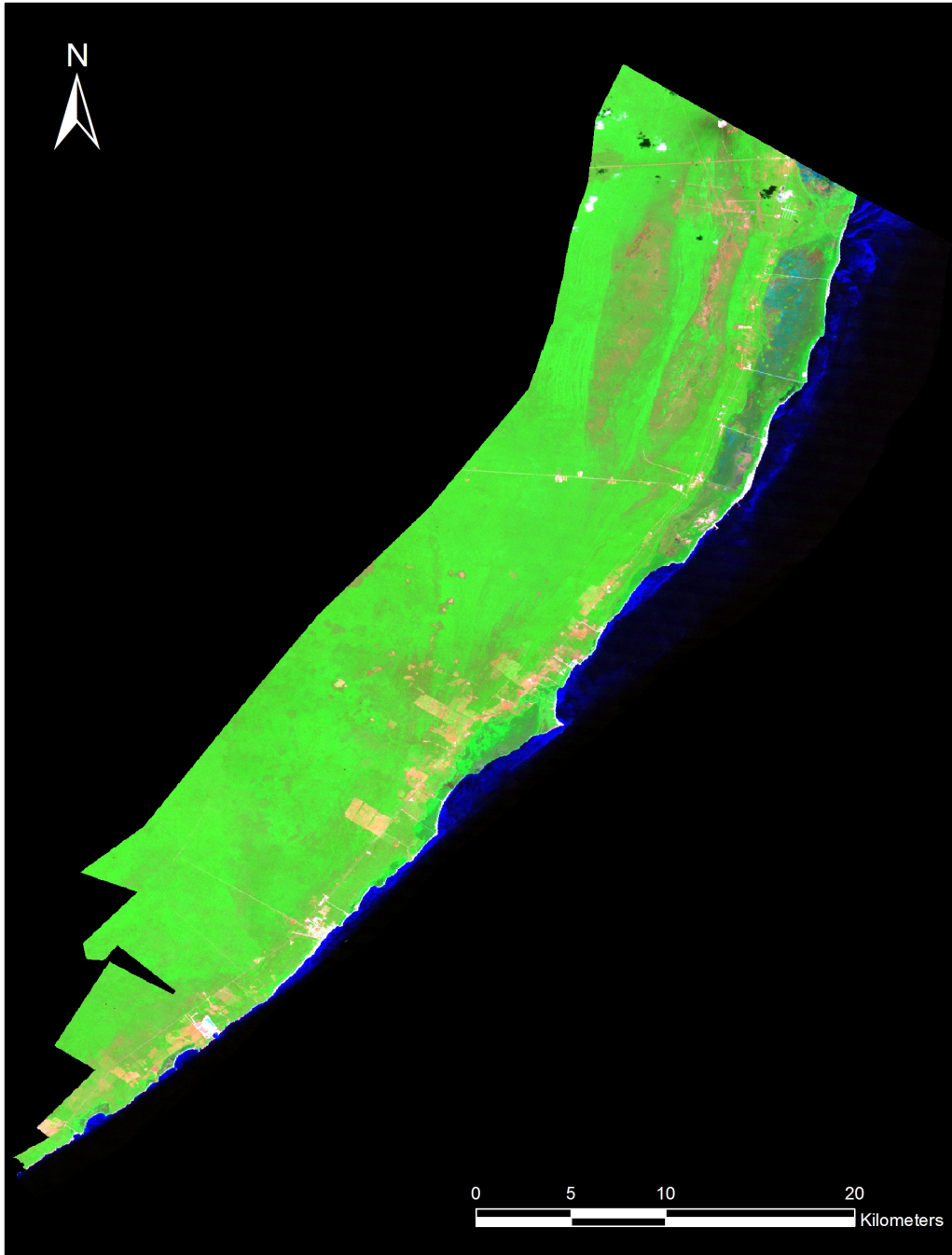
Map 6.2: Landsat band combination 3,2,1 RGB
Source: based on a Landsat Geocover 1988 Mosaic, ESC 2004

This colour composite is as close to true colour that it is possible to get with a Landsat image. It is useful for studying aquatic habitats.



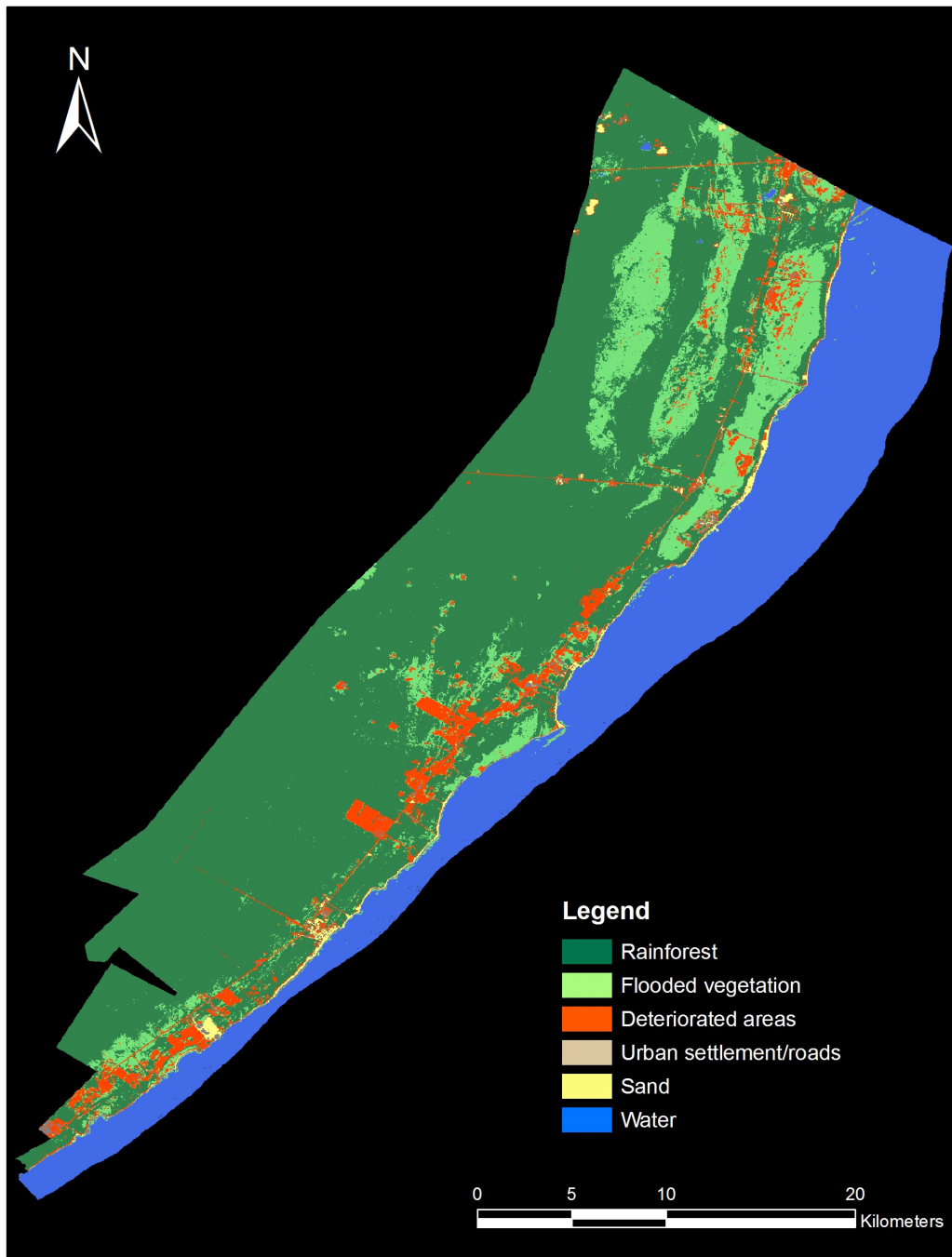
Map 6.3: Landsat band combination 4,3,2 RGB
Source: based on a Landsat Geocover 1988 Mosaic, ESC 2004

This combination has similar qualities to the image with bands 3,2,1, however, since this includes the near infrared channel (band 4) land water boundaries are clearer and different types of vegetation are more apparent.

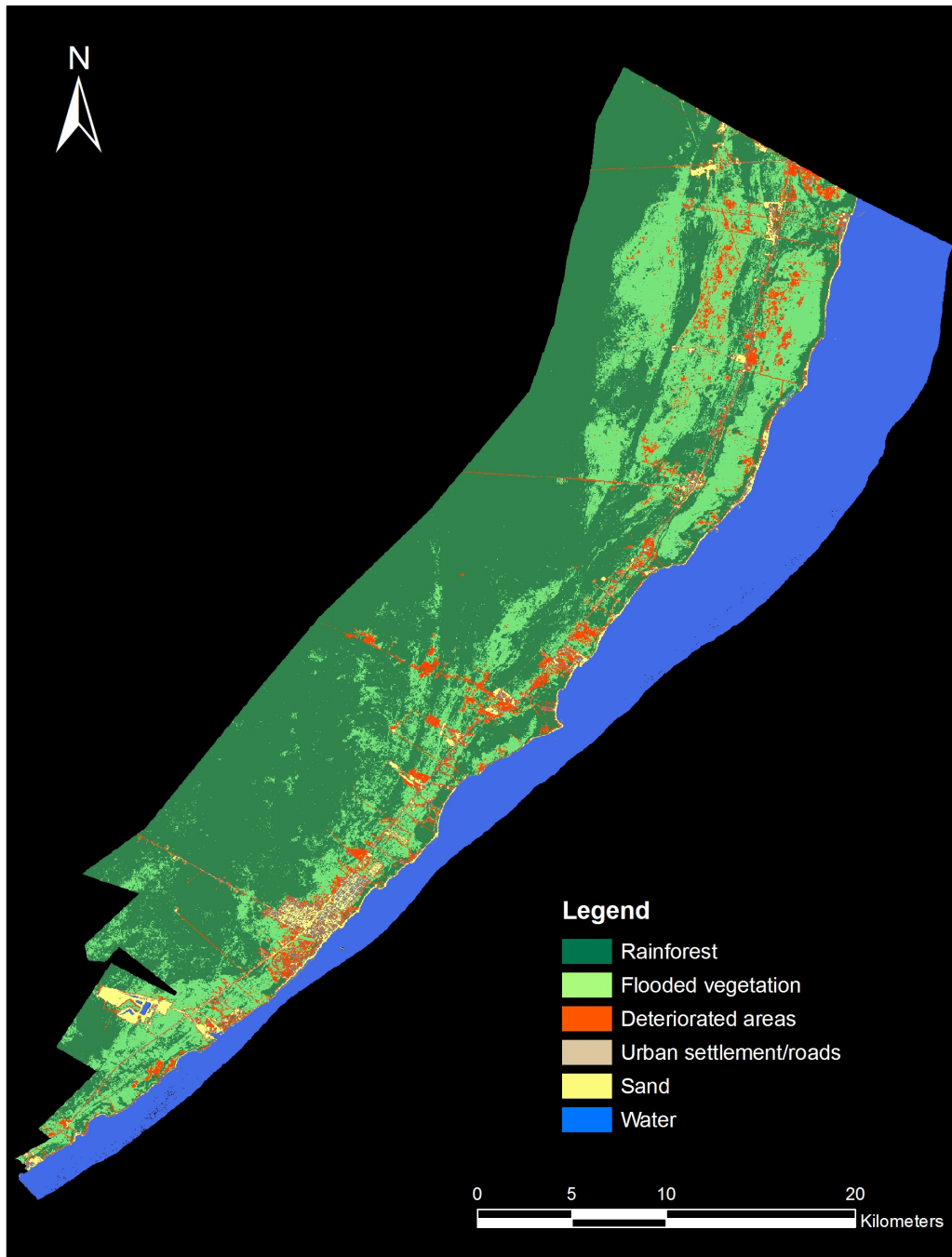


Map 6.4: Landsat band combination 7,4,2 RGB

This band combination displays vegetation in green. Different vegetation types can be more clearly defined and the land/water interface is very clear. This is the band combination that was selected for the global Landsat mosaic created for NASA (CBC 2006).



Map 6.5: Digital image classification 1988, according to the Minimum Distance-to-mean classifier



Map 6.6: Digital image classification 2001, according to the Minimum Distance-to-mean classifier

In this case, the semi-automatic digital image classification procedure (section 6.1.1) was affected principally by the size of the features that had to be classified and the soil types in the Riviera Maya. The land-cover class “sand”, for example, was mixed up with the class “urban/semi-urban settlements and roads” as cleared/unpaved areas appear to be the same colour than sandy areas due to the geology of the Riviera Maya. In addition, secondary roads and paths were difficult to classify (in a semi-automatic way) since they are generally less than twenty meters wide, whereas the cell size of the data was thirty meters.

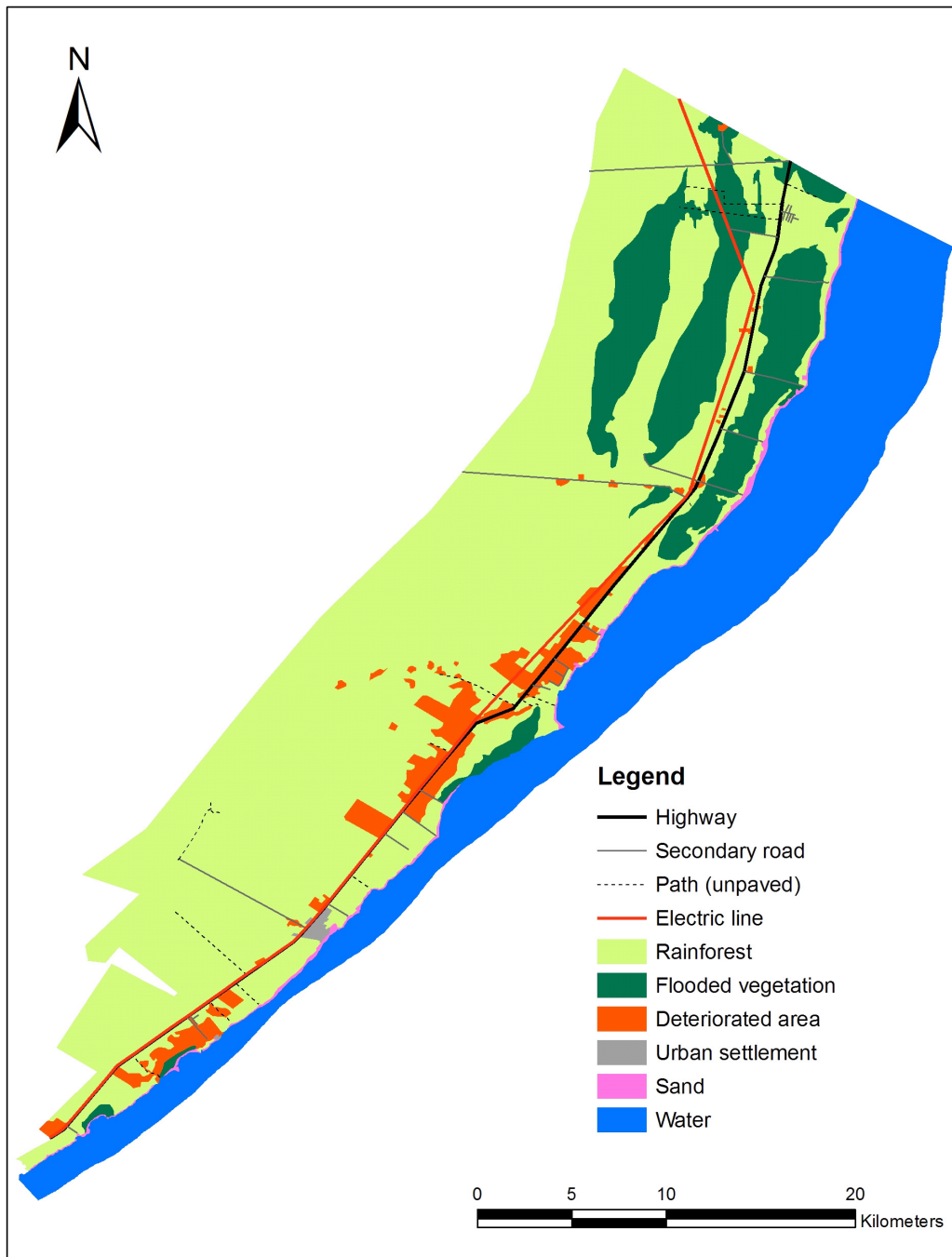
Considering the above, landscape features (linear and polygon) were digitized manually using the digital image classification maps (6.5 and 6.6), the colour composites (maps 6.2, 6.3 and 6.4), high-resolution satellite images seen in Google Earth (2007), and the available vector datasets. The digitalization of landscape features 1988 and 2001 are shown in maps 6.7 and 6.8.

6.2 Fragmentation of ecosystems and habitats

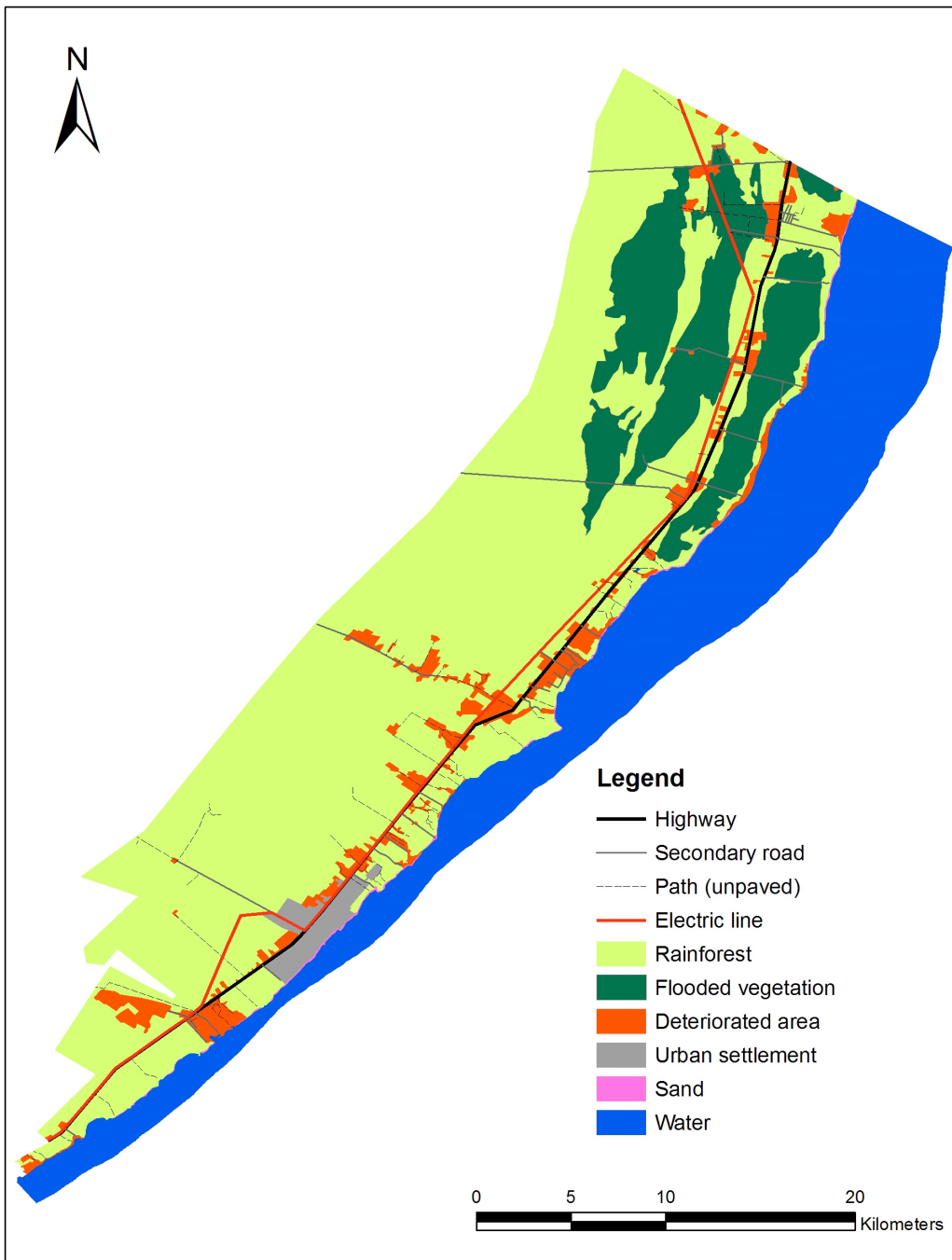
Habitat fragmentation is in a wider sense “a disruption of once large continuous block of habitat into less continuous habitat, primarily by human disturbances such as land clearing and conversion of vegetation from one type to another” (Franklin *et al.* 2002:20). Habitat is defined as the place or type of site where an organism or population naturally occurs (CBD 2006).

Fragmentation of vegetation and habitat fragmentation are often considered synonymously. Franklin *et al.* (2002:22) mention, in contrast, that fragmentation ultimately applies only to the species level because habitat is defined with reference to a particular species. They argue that habitat fragmentation has not occurred when habitat has been separated by non-habitat but occupancy, reproduction or survival of the species has not been affected. For example, a narrow road dividing a large block of habitat may not affect occupancy, reproduction or survival for a wide range of species, such as raptor. However, the road may affect a species with a narrower home range such as a salamander.

To define habitat fragmentation adequately, the requisites included in box 6.1 have been recommended. They were used as a guide to determine fragmentation of ecosystems and habitats in the Riviera Maya.



Map 6.7: Digitalization of land covers and linear components 1988



Map 6.8: Digitalization of land covers and linear components 2001

Box 6.1: Requisites to define habitat fragmentation

a. What is being fragmented?

This requires an understanding of a species habitat.

b. What is the scale of fragmentation?

Is essentially a statement as to where inferences are being made and the level of habitat description being considered.

c. What is the extent and pattern of fragmentation?

It provides a description of the magnitude and type of habitat fragmentation.

d. What is the mechanism causing fragmentation?

This puts habitat fragmentation into a temporal scale (how rapidly changes occur over time) and also into an ecological and conservation context (natural versus anthropogenic).

Source: Franklin *et al.* 2002:25-28

6.2.1 What is being fragmented?

There is a lack of adequate knowledge to date about habitat distribution in the Riviera Maya. It is possible to mention, in a very general way, that the main habitats being fragmented are medium and low rainforest, coastal-dune vegetation, and flooded vegetation (rainforest/palm groves, mangroves). These plant societies were supposed in this research (due to their extension) to hold most of the species in the Cancun-Tulum region.

6.2.2 What is the scale of fragmentation?

The second requisite for defining habitat fragmentation is to determine the scale at which fragmentation is occurring. Based on Johnson (1980), Franklin *et al.* (2002:25) proposed a hierarchical scale composed of three levels: range-wide, population scale and home-range. Fragmentation at wide-range scale can affect dispersal between populations, fragmentation at the population scale can alter local population dynamics, and fragmentation at the home-range scale can affect individual performance measures, such as survival and reproduction. These scales are not mutually exclusive, but provide a unifying nested relationship that allows for understanding mechanisms and processes at different levels (Johnson 1980).

The analysis presented here approached fragmentation of vegetation at regional level. The assessment scale may be considered as range-wide since it was assumed that most of the Riviera Maya's species are concentrated in the habitats mentioned in section 6.2.1. However, there is not enough information to determine the response of species, populations and individuals to fragmentation at this scale. This assessment can be range-wide for some species and population or home-range for others.

6.2.3 What is the extent and pattern of fragmentation?

Extent of habitat fragmentation is the degree to which fragmentation has taken place within a specified spatial scale, whereas the pattern of fragmentation describes patch geometry, including size, shape, distribution and configuration. To determine extent and pattern of fragmentation, six landscape indices were calculated and compared using the information provided by maps 6.7 and 6.8.

Landscape spatial indices analysis

Fragmentation of the landscape produces a series of remnant vegetation patches surrounded by a matrix of different vegetation and/or land-uses. Two primary effects of fragmentation are an alteration of the microclimate within and surrounding the remnant and the isolation of each area from other remnant patches in the surrounding landscape. All remnants are exposed to these effects to greater or lesser degree, according to their size, shape, and position in the landscape (Saunders et al. 1990:20).

In this assessment, patch size was examined according to the minimum, maximum and average remnant area. Patch shape was appraised considering the second shape index (S2) and the fractal dimension index (D). To evaluate remnant distribution, the Nearest Neighbour Distance (NND) was calculated and the percentage of the area occupied by patches determined. In addition, as an indicator of vegetation health, the Normalized Difference Vegetative Index (NDVI) was estimated.

6.2.3.1 Area/edge metrics: minimum, mean and maximum patch area, patch perimeter

Minimum, mean and maximum patch area

In this analysis, 71,828 ha of terrestrial area were evaluated. Rainforest and flooded vegetation covered 66,990 ha in 1988 and 64,996 ha in 2001, which represented 93 and 90 percent of the terrestrial area, respectively. The number of patches (defined as those polygons shaped between roads, electric lines, deteriorated and urban areas) increased and consequently their individual size decreased (see table 6.3).

Table 6.3: Patch size of vegetation in the Riviera Maya (1988-2001)

| Year | Number of patches (rainforest and flooded vegetation) | Area (ha) | | | |
|------|---|-----------|------|---------|--------|
| | | Minimum | Mean | Maximum | Total |
| 1988 | 76 | 0.06 | 881 | 33,483 | 66,990 |
| 2001 | 100 | 2.50 | 649 | 13,652 | 64,996 |

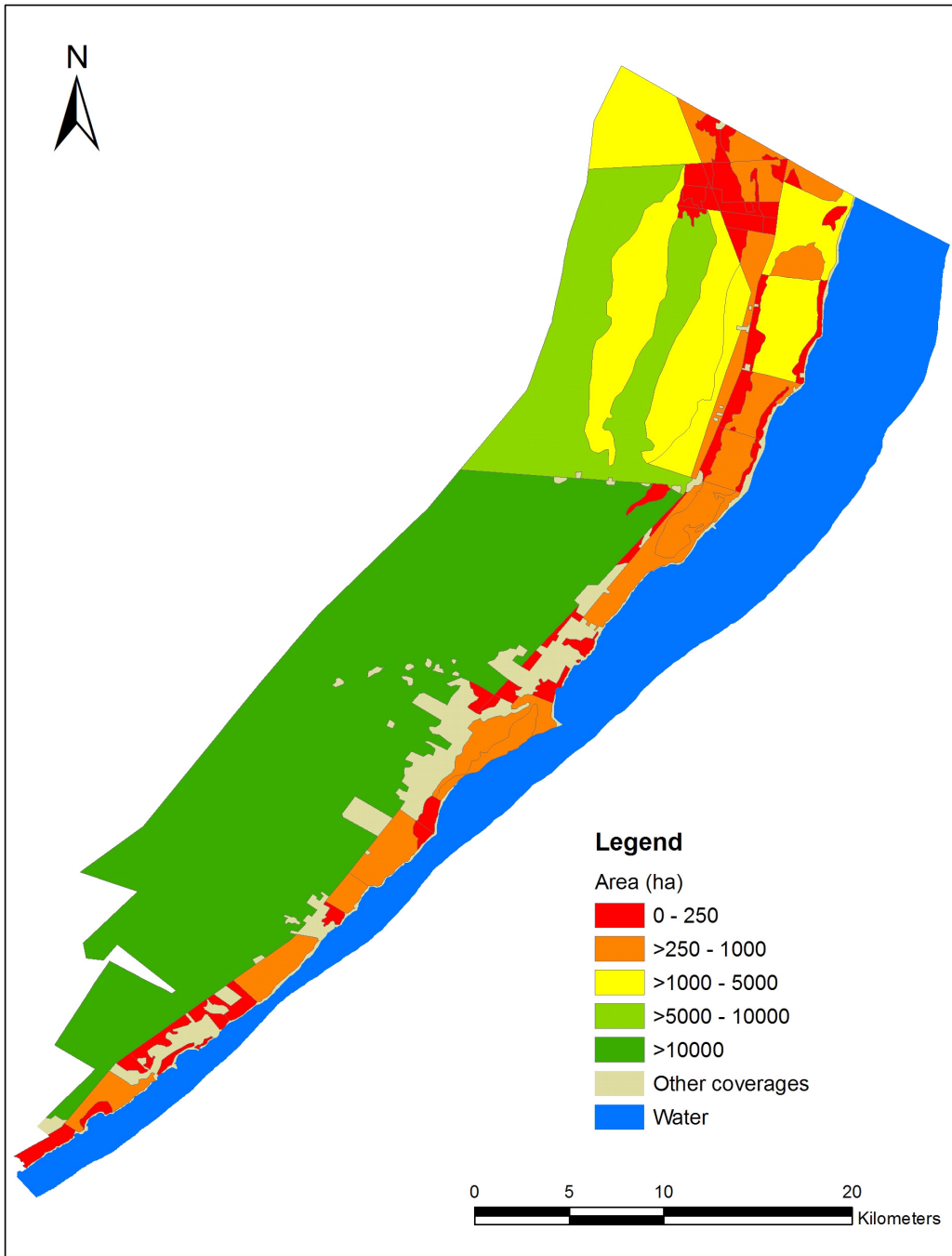
During the period 1988-2001, the number of patches (taking both vegetation types together) grew by 31 percent, whereas their mean size decreased from 881 to 649 ha (-26 percent). In the same period, the maximum polygon size decreased by 59 percent, from 33,483 to 13,652 ha (see table 6.3). Maps 6.9 and 6.10 illustrate patch size distribution.

Patch perimeter

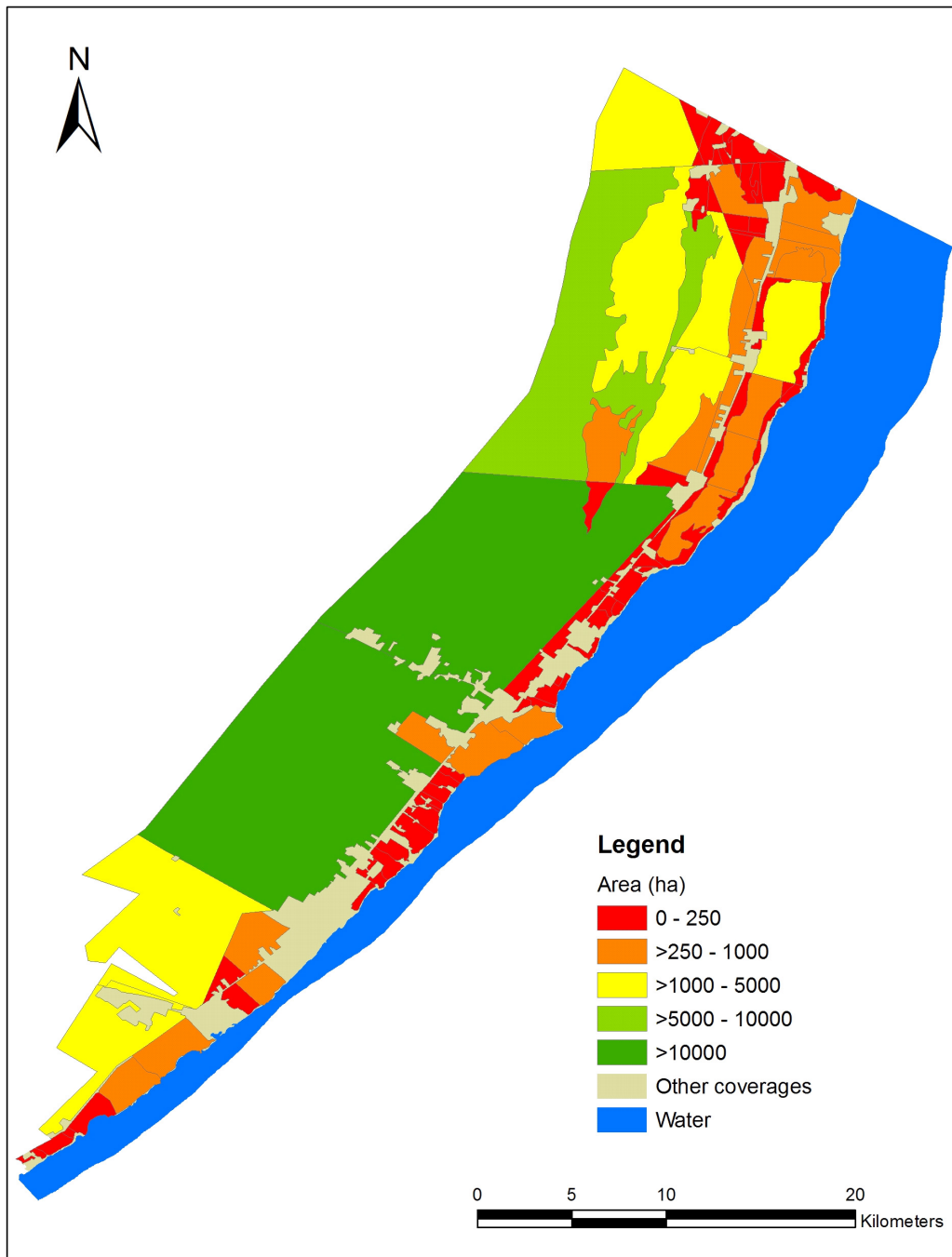
Patch perimeter of rainforest and flooded vegetation is included in table 6.4. Results show that during the analysis period remnant edges grew from 945 to 1,072 km (13 percent), while the mean value decreased by 14 percent.

Table 6.4: Patch perimeter of vegetation types in the Riviera Maya (1988-2001)

| Year | Number of patches (rainforest and flooded vegetation) | Perimeter (km) | | | |
|------|---|----------------|-------|---------|----------|
| | | Minimum | Mean | Maximum | Total |
| 1988 | 76 | 0.16 | 12.43 | 167.97 | 945.20 |
| 2001 | 100 | 0.76 | 10.72 | 101.73 | 1,072.69 |



Map 6.9: Patch size distribution of rainforest and flooded vegetation (1988)



Map 6.10: Patch size distribution of rainforest and flooded vegetation (2001)

6.2.3.2 Shape metrics: second shape index (S2) and fractal dimension index (D)

Second shape index (S2)

The second shape index (S2) is a simple measurement of shape complexity. This index is based on the theory that an iso-diametric shape (such as square or circular) has the largest interior. S2 is a measure of deviation from this iso-diametric shape of each patch:

$$S2 = 1/2\sqrt{(a*\pi)}$$

; where l is the perimeter and a the area of each patch. S2 has values >0 without limit, the bigger the S2 value, the more complex the shape of the patch. Table 6.5 shows the values of the second index considering rainforest and flooded vegetation together.

Table 6.5: Second shape index (S2) in the Riviera Maya (1988-2001)

| Year | Second shape index (S2) (rainforest and flooded vegetation) |
|------|--|
| 1988 | 1.7247 |
| 2001 | 1.6461 |

Fractal dimension index (D)

Fractal dimension is a measure of patch shape complexity. Fractal dimension was calculated as (CBMAS 2006b; Kenkel & Walker 2006; McGarigal *et al.* 2002):

$$D_i = 2 [\ln(P_i/4)/\ln(A_i)]$$

where A_i and P_i are the area and perimeter of the i th patch, respectively. The average fractal dimension (D_m) is finally calculated as:

$$D_m = \sum D_i / N$$

The fractal dimension equation generates values between 1 and 2. Fractal dimension approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters (McGarigal *et al.* 2002). In this assessment, the mean fractal dimension (Dm) was estimated 1.1973 in 1988 and 1.1143 in 2001.

6.2.3.3 Isolation/proximity metrics: Nearest Neighbour Distance (NND)

Nearest-neighbour distance (NND) equals the distance in meters to the nearest neighbouring patch of the same type, based on shortest edge-to-edge distance. Nearest-neighbour distance has been used extensively to quantify patch isolation. According to the results obtained, in 1988 the mean NND value was 1,470 meters, whereas it was estimated in 362 meters in 2001.

6.2.3.4 Health metrics: Normalized Difference Vegetative Index (NDVI)

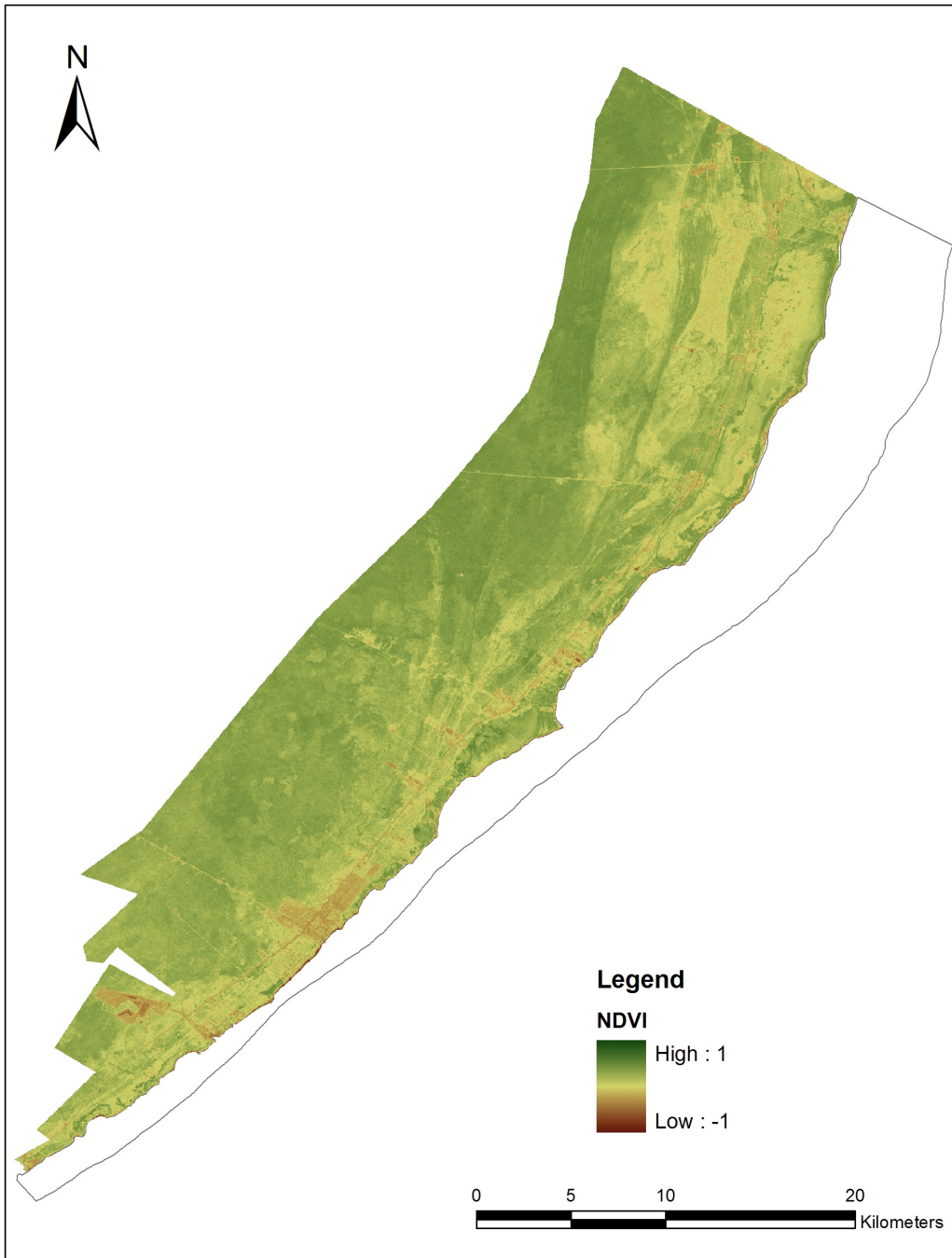
The Normalized Difference Vegetative Index (NDVI) provides an estimation of the health of vegetation. The NDVI is the ratio between the difference and sum of two spectral bands. One band is in the visible electromagnetic spectrum (red) and one band in the Near IR (infrared). NDVI is $(NIR-Visible)/(NIR+Visible)$. These two bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrast between vegetation and soil is at a maximum (CBMAS 2006).

The NDVI equation produces values in the range of -1.0 to 1.0, where vegetated areas will typically have values greater than zero and negative values indicate non-vegetated surface features such as water, barren, ice, snow, or clouds (CBMAS 2006). The calculated NDVI values are illustrated in maps 6.11 and 6.12. In 1988 the average NDVI was 0.4721, and 0.1957 in 2001.

Landscape spatial indices are summarized in table 6.6.



Map 6.11: Normalized Difference Vegetative Index (NDVI), April 1988



Map 6.12: Normalized Difference Vegetative Index (NDVI), April 2001

Table 6.6: Landscape spatial indices 1988-2001

| Indices | Rainforest and flooded vegetation | |
|-------------------------------|-----------------------------------|--------|
| | 1988 | 2001 |
| Number of patches | 76 | 100 |
| Density (n ha ⁻¹) | 0.0011 | 0.0015 |
| Mean area (ha) | 881 | 649 |
| Perimeter (m) | 12,430 | 10,720 |
| S2 | 1.7247 | 1.6461 |
| Dm | 1.1973 | 1.1143 |
| NND (m) | 1,470 | 362 |
| NDVI | 0.4721 | 0.1957 |

6.2.3.5 Discussion

Patch extent affects the potential size of populations. Generally, the larger the remnant, the more likely it is that populations will be large and more likely to resist chance extinctions (Gilpin & Soule 1986). Human activities in the Riviera Maya resulted in a reduction of remnant size, which is a negative impact on both flora and fauna. The reduction of patch size was particularly notorious in the region comprised between the Federal Highway 307 and the shoreline (see maps 6.9 and 6.10).

The total perimeter of patches increased during the analysis period, which might be interpreted as a negative environmental impact. Experience has shown that the effects of fragmentation are bigger at the edge of remnants. Air temperatures due to changes in the radiation balance, for example, can be significantly higher at the edges than those found in the interior of the patches (Geiger 1965; Kapos 1989). This can affect the composition of the remnant edges. Shade-tolerant species may become restricted to the interior parts of the remnant, with different species requiring different distances to the edge (Palik & Murphy 1990). This can ultimately affect larger fauna both directly and indirectly through altering resource availability.

The average values of the second shape index (S2) and the fractal dimension index (D) suggested that, in general, patch shape has changed from irregular forms to forms predominantly square (see maps 6.9 and 6.10). The construction of linear structures (such as roads and electric lines) and urban settlements are the main causes of simplification of shape complexity in the Riviera Maya.

The nearest-neighbour distance (NND) average value decreased from 1998 to 2001. NND was based on the shortest edge-to-edge distance, calculated from cell centre to cell centre. A reduction in the NND may indicate that the patches are getting closer. In this case, however, it indicates that the vegetation remnants are being fragmented. This phenomenon can be explained as follows.

Imagine that there are 2 patches, let's say, 2,000 m away from each other. The construction of a new road (30 meters wide) divide one of them and now we have three remnants, two sharing a NND of 2,030 m (considering the original distance and the cell size), and two with a NND of 60 m (30 m road and 30 m cell size). It is easy to realize that the construction of new roads, which is in fact occurring in the Riviera Maya, will guide to a reduction in the NND average value. In our imaginary example, the average NND value decreased from 2,000 m to 1,045 m.

The Normalized Difference Vegetative Index (NDVI) 1988 and 2001 values indicated that vegetation density decreased considerably in the Riviera Maya, which can be clearly visible in the zone that surrounds the Federal Highway 307 (see maps 6.11 and 6.12). It may be caused by the human activities in the region, however, possible causes for lower than normal NDVI are also lack of precipitation or exceptionally cold temperatures (which can delay or cut short the growing season) and clouds (NASA Earth Observatory 2006). Nevertheless, no historical data on precipitation or temperature could be found to confirm or discard this possibility.

The final step is to determine the mechanisms causing fragmentation. This issue will be discussed at the end of this chapter, considering the results obtained for the other environmental indicators.

6.3 Coverage of protected areas

According to the World Conservation Union (IUCN 2007), the six management categories of protected areas are:

- *Category Ia*. Strict Nature Reserve: Protected Area managed mainly for science.
- *Category Ib*. Wilderness Area: Protected Area managed mainly for wilderness protection.
- *Category II*. National Park: Protected Area managed mainly for ecosystem conservation and recreation.

- *Category III.* Natural Monument: Protected Area managed for conservation of specific natural features.
- *Category IV.* Habitat/Species Management Area: Protected Area managed mainly for conservation through management intervention.
- *Category V.* Protected Landscape/Seascape: Protected Area managed mainly for landscape/seascape conservation and recreation.
- *Category VI.* Managed Resource Protected Areas: Protected Area managed mainly for the sustainable use of natural ecosystems.

Considering these definitions, the ELUPP Cancun-Tulum land-use strategy (see map 3.3; SEMARNAT 2001c), and vector data on protected areas provided by INEGI (2005), in the Riviera Maya the following protection management categories can be identified (see map 6.13). Table 6.7 summarizes extent and category of protected areas.

Table 6.7: Protected areas in the Riviera Maya

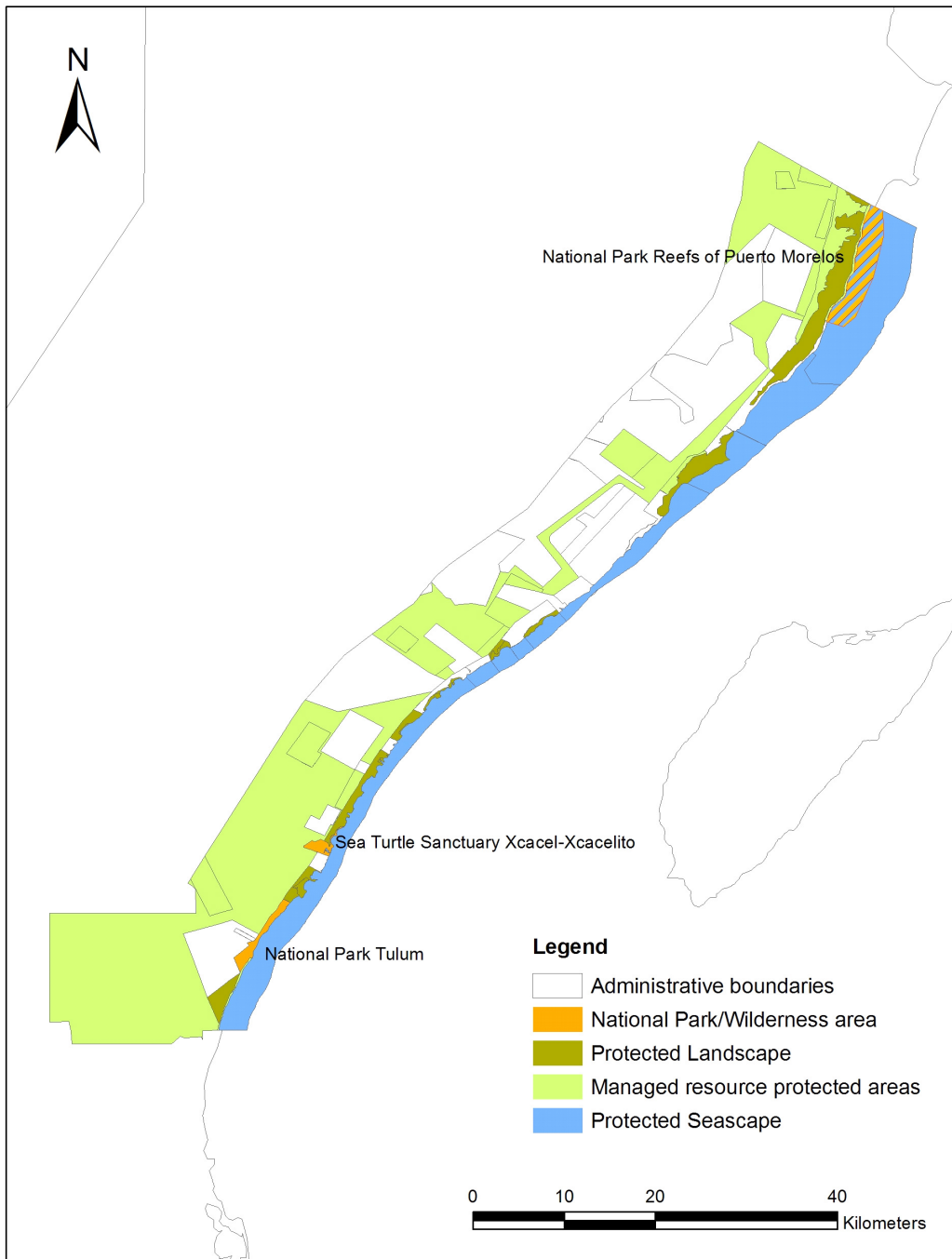
| Protected area | Category | Area (ha) | % of the total area |
|---------------------------------------|----------|-----------|---------------------|
| Sea Turtle Sanctuary Xcacel-Xcacelito | Ib | 362 | 0.2 |
| Tulum and Reefs of Puerto Morelos | II | 9,731 | 5.3 |
| Protected landscape | V | 8,341 | 4.5 |
| Protected seascape | V | 31,853 | 17.5 |
| Managed resource protected areas | VI | 68,560 | 37.8 |
| TOTAL | | 118,847 | 65.4 |

Source: based on data from INEGI 2005 and SEMARNAT 2001c

6.4 Area of urban formal and informal settlements

Area of formal and informal settlements was determined using maps 6.7 and 6.8. In order to classify formal and informal settlements, the ELUPP Cancun-Tulum land-use strategy (see map 3.3; SEMARNAT 2001c) was considered. Dwelling units located inside areas designated for urban development were considered as formal settlements, whereas dwelling units located outside those areas were classified as informal ones. However, due to the cell size resolution of the data only the most consolidated areas could be clearly identified.

According to the above, urban/tourism areas were 173 ha in 1988 and 1,240 in 2001 (increased 616 percent), which corresponded to the City of Playa del Carmen (see maps 6.7 and 6.8).



Map 6.13: Protected areas in the Riviera Maya

This preliminary analysis has to be verified in further investigations considering data with higher resolution (1 meter cell size resolution were optimum) and information on land-tenure (cadastral records).

6.5 Transport infrastructure network

Land take by transport infrastructure was determined using maps 6.7 and 6.8. In the region under study, three road types were identified: highways, secondary roads and paths (unpaved). Table 6.8 shows the length of the road network by road type for the years 1988 and 2001.

Table 6.8: Road network in the Riviera Maya's north part

| Year | Road network (km) | | | |
|------|-------------------|----------------|--------|--------|
| | Highway | Secondary road | Path | Total |
| 1988 | 67.02 | 68.98 | 37.90 | 173.90 |
| 2001 | 67.02 | 99.68 | 114.46 | 281.16 |

To calculate land take by transport infrastructure, the following road widths were considered (based on fieldwork and the available digital photos): 50 meters for highways (see section 4.3.5), 30 meters for secondary roads, and 20 meters for paths.

Taking into account the abovementioned, land take by transportation in the Riviera Maya's north part was 617 ha in 1988 and 863 ha in 2001 (increased 39 percent).

6.6 Coverage of forest areas

Due to the lack of information, coverage of forest areas was calculated considering the area of the land class "rainforest" (see maps 6.7 and 6.8). Table 6.9 presents the area of rainforests in the area under study.

Table 6.9: Coverage of forest areas in the Riviera Maya's north part

| Year | Area (ha) | % of the total area |
|------|-----------|---------------------|
| 1988 | 55,839 | 30.7 |
| 2001 | 53,630 | 29.4 |

6.7 Area affected by extraction of raw materials and mining

Land affected by extraction of raw materials and mining was calculated according to the information of maps 6.7 and 6.8. To identify such areas, the ELUPP land-use strategy was considered (there is only one EMU designated for mining exploitation to date in the Riviera Maya; see map 3.3). Based on the abovementioned, affected areas were not identified in 1988, while they were 400.6 ha in 2001 (about 30.7 ha per year).

6.8 What is the mechanism causing fragmentation?

Mechanisms causing fragmentation can be natural (for example fire, wind, water, etc.) or anthropogenic (logging, agriculture, urbanization, etc). In a given area at a given scale, these mechanisms can simultaneously fragment habitat for some species while creating habitat for others (Forman 1997:413). In conservation issues, the mechanisms causing habitat fragmentation are often of primary concern, especially when these mechanisms are human-induced (Franklin et al. 2002:27).

Construction of transport infrastructures, and clearing for urban and tourism development are the main mechanisms causing fragmentation in the Riviera Maya. As previously mentioned, road network grew by 61 percent, reaching 281 kilometres in 2001. During the period 1988-2001, urban and tourism areas (considering only Playa del Carmen as urban area; see map 3.4) grew by 616 percent. In addition, deteriorated areas increased by 30 percent, from 4,007 ha to 5,220 ha.

6.9 Conclusions

The analysis presented here demonstrated that there was a reduction in the total area of habitat available and that fragmentation of vegetation increased in the Riviera Maya. Construction of transport infrastructures and clearing for urban and tourism development are the main mechanisms causing fragmentation.

It was not possible to conclude, however, that fragmentation of vegetation is leading (or has led) to habitat fragmentation (because to date there is no information on habitat distribution in the Riviera Maya), and in such a case, which species are being affected.

Gascon (2003:37) mentioned that not all the cases of fragmentation of vegetation have led to a decline in species richness after isolation. On the contrary, some taxonomic groups (such as mammals and amphibians) have shown an increase in species richness due to the appearance of open-area associated species. However, this author also pointed out that in Central Amazonia “regardless of whether a particular taxonomic group showed an increase or decrease in species richness after isolation, larger remnants maintained more species than smaller ones”. Thus, a reduction in species richness as a result of the reduction in the total area of habitat available in the Riviera Maya might be expected.

Results suggest, in addition, that the ELUPP Cancun-Tulum has neither mitigated fragmentation in the Riviera Maya nor controlled anthropogenic activities.

Maps 6.9 to 6.12 showed that fragmentation (considering the distribution of patch size) and deterioration of vegetation (taking into account the distribution of NDVI values) were not influenced by the management schemes implemented through the ELUP-Programme (see map 3.3 and map 6.13). On the contrary, fragmentation and deterioration of vegetation took place along roads, affecting principally the area between the Federal Highway 307 and the coastal line. In fact, the areas designated as landscape protected areas (which are located near the coast; see map 6.13) were the areas most affected by fragmentation and deterioration of vegetation.

The above mentioned may be caused by the inadequate implementation of the programme’s strategies (see section 3.3.1). Nevertheless, it is also questionable that the ELUPP Cancun-Tulum’s requirements can ultimately lead to the mitigation of fragmentation. So far, the ecological criteria designed to mitigate fragmentation (see table 3.8) have been formulated at project level. In addition, there is a lack of environmental objectives at strategic level to specify the minimum area of habitats that have to be preserved, and the connectivity areas (corridors) required between those habitats.

Future work

The analysis of habitat fragmentation requires a better knowledge on the distribution of species and communities in the Riviera Maya, and the relations between components of the landscape. To determine a more accurate habitat

fragmentation assessment it will be necessary: (i) to determine species-specific habitat distribution for the entire Cancun-Tulum region; and (ii) to evaluate additional datasets (satellite images) according to the requirements of landscape indices.

In order to determine a detailed vegetation health pattern of change, for example, it has been recommended (NASA Earth Observatory 2006) to compare the average NDVI for a particular month of a given year with the average NDVI for the same month over the last 20 years, which is called NDVI anomaly.

In addition, it is necessary to determine clear environmental objectives concerning habitat fragmentation, i.e. the minimum critical size that the habitats need to be to preserve their characteristics species diversity and species composition (Lovejoy & Oren 1981), habitat connectivity (corridors needed), land consumption rates (by urban/tourism, transport network and mining), and monitor targets against which the effectiveness of implemented strategies can be tested.

Finally, in the case of urban and tourism development, additional information is required (e.g. satellite images with higher resolution, cadastral data) to determine adequately the extent of formal and informal settlements in the Riviera Maya.

7

Conclusions and proposals

This final chapter serves as a review of the preceding six, providing a final opportunity to comment on the analyses reported, and to present the conclusions and proposals for future research resulting from this investigation. In the last part of the chapter, based on the results and experiences of this study, a discussion is initiated towards the identification of strengths and weaknesses, opportunities and threats to adopt SEA in Mexico.

Conclusions

In this research work some of the key stages of SEA were carried out on the ELUPP Cancun-Tulum, an environmental monitoring concept was proposed and a GIS-monitoring assessment was carried out.

In the first section, the baseline environment in the Riviera Maya was examined and the ELUPP Cancun-Tulum implementation discussed. According to this analysis, it was concluded that so far the programme's environmental objectives have not been met, as the ELUP provisions have not been observed. Deficiencies in the compliance of the programme's provisions were related to the absence of an oversight body and clear environmental goals and objectives, as well as to the lack of commitment by authorities and investors. This analysis highlighted the necessity to develop a monitoring mechanism to verify and control the implementation of the ELUP's development strategies.

An identification of alternative site locations for the development of the New Tulum City was effectuated. The assessment was based on the identification of feasible sites for urban development and the estimation of likely environmental effects with Geographical Information Systems (GIS). This analysis showed that so far the Riviera Maya's key ecosystems have not been considered during the planning of development actions. The development of New Tulum, as it is currently expected in the ELUPP Cancun-Tulum, will have a direct impact on the regional key ecosystems (subterranean river systems and cenotes), which is contrary to the programme's environmental objectives. The alternative site location identified can reduce considerably the likely environmental effects of the programme implementation in Tulum.

The analysis of alternatives showed, in addition, that to date there is a lack of development criteria at strategic level within the ELUPP framework to avoid or minimize environmental conflicts, for example minimum distances between roadways and residential areas to reduce traffic noise effects.

A monitoring concept was developed for the supervision of the ELUP strategy in the Riviera Maya. Based on a pressure-state-response framework, a set of 19 environmental indicators was selected. The environmental relevance, methodological description and data needs of each indicator were discussed, and all datasheets elaborated. The identification of data sources revealed that so far there is a lack of environmental information in the Riviera Maya. Eight of the nineteen expected information sources were identified.

A GIS-based assessment was used to implement the monitoring concept proposed in this research. According to the available information, six environmental indicators were examined: (i) fragmentation of ecosystems and habitats; (ii) coverage of protected areas; (iii) area of urban formal and informal settlements; (iv) transport infrastructure network; (v) coverage of forest areas; and (vi) area affected by extraction of raw materials and mining. The assessment was based on the GIS-remote sensing interpretation of two Landsat Geocover Mosaics of 1988 and 2001. To determine extent and pattern of fragmentation six landscape indices were calculated: (i) minimum, mean and maximum patch area; (ii) patch perimeter; (iii) the second shape index (S2); (iv) the fractal dimension index (D); (v) the Nearest Neighbour Distance (NND); and (vi) the Normalized Difference Vegetative Index (NDVI).

The assessment indicated that there was a reduction in the total area of habitat available and that fragmentation of vegetation increased in the Riviera Maya. Construction of transport infrastructures and clearing for urban and tourism development are the main mechanisms causing fragmentation. Results suggested, in addition, that the ELUPP Cancun-Tulum implementation has neither mitigated fragmentation nor controlled anthropogenic activities. Fragmentation and deterioration of vegetation patterns in the Riviera Maya were not influenced by the implementation of the programme's management strategies. Finally, this analysis highlighted the lack of clear ELUPP environmental objectives and monitoring targets against which the effectiveness of implemented strategies can be tested.

Considering the results of this study, it is possible to corroborate the first research hypothesis: most of the significant environmental effects of the ELUPP Cancun-Tulum implementation were not considered during its preparation.

The consideration of the significant environmental effects of ELUP-Programmes implementation is not demanded by the Mexican legislation. However, ELUP main objectives are to protect the environment and to promote sustainable use of resources. Why the ELUPP Cancun-Tulum's development strategy has failed to achieve these objectives?

The analyses performed in this research pointed out that there is a gap between the ELUPP Cancun-Tulum's environmental objectives and the proposed (and partially implemented) development strategy. For example, the protection of key ecosystems and aquifer recharge areas (two of the programme's key environmental objectives) was not considered to determine the New Tulum's urban area. In addition, the programme's ecological criteria (for example the ones related to mitigate fragmentation) are not controlling development in the Riviera Maya, since most of them were formulated at project level. A central aspect is however the non-compliance with the programme's provisions, due to the lack of commitment by authorities and investors and monitoring/control mechanisms.

The evaluation of the ELUPP Cancun-Tulum also revealed that it is necessary to carry out the environmental assessment at the level at which the strategic decisions are taken (second research hypothesis). SEA's findings stressed the methodological deficiencies of the ELUPP Cancun-Tulum (i.e. lack of clear environmental objectives and targets, lack of development criteria at strategic level to minimize/avoid environmental conflicts, and lack of supervision procedures to evaluate the programme implementation), and improved the programme (for example with the identification of a feasible alternative for the New Tulum City and the introduction of the monitoring procedure).

The monitoring concept proposed in this investigation has the potential to improve the ELUPP Cancun-Tulum. This innovative supervision mechanism might also serve as a model to supervise the ELUP strategy in Mexico.

Proposals

In order to improve the ELUPP Cancun-Tulum, the following activities are required:

A. *To identify spatially the key environmental elements that must be protected.* Such as primary rainforest, aquifer recharge areas, mangroves, water bodies (cenotes, subterranean rivers, and aquifers), habitats of endangered species, etc.

B. *To determine clear environmental goals and objectives.* For example, the extent of aquifer recharge areas that have to be protected, the minimum critical size that habitats need to be to preserve their characteristics species diversity and species composition, the connectivity areas (corridors) required between those habitats, the annual land consumption rate (urban, tourism, mining, forestry), etc.

C. *To establish development criteria at strategic level.* For instance, minimum distance to highways to minimize/avoid traffic noise impacts, buffer zones to preserve key ecosystems and natural protected areas, etc.

D. *To update the current ELUP development strategy considering the abovementioned activities.* Specially to corroborate that human actions (mainly urban and tourism development) are not affecting (and will not affect) key environmental elements.

E. *To implement the monitoring concept proposed in this research,* to supervise and control the programme implementation.

F. *To improve transparency and public participation in decision making.* Particularly, to clarify the procedure to determine densities of space use, allocation of land-uses and the mechanisms for public participation, and to provide periodically updated information on the status and results of the programme implementation (distance to target).

Considering the results and experiences of this investigation, it is possible to identify some strengths and weakness, opportunities and threats to adopt SEA in Mexico.

Strengths

- SEA can overcome the limitations of the project-level assessment, and at the same time integrate environmental issues intrinsically into project planning by influencing the context within which project decisions are made.
- SEA has the potential to improve strategic actions by identifying environmental consequences, alternatives, mitigation measures, and monitoring targets that go beyond individual projects.

Weakness

- Data collection and analysis can be very complex as SEA can cover a large area and large number of alternatives.
- The analysis at strategic level may be subject to greater levels of uncertainty than project-EIA, since it has to cope with limited or incompatible information.
- Monetary costs.
- Policies, plans and programmes are generally non-linear, complex and iterative, which makes it difficult to know when a SEA should be carried out and what exactly the strategic action is that is being assessed.

Opportunities

- SEA can promote the development and implementation of strategies for sustainable development in Mexico.
- SEA can play a significant role in the fields of development cooperation and international trade.
- SEMARNAT has demonstrated its intention to adopt SEA.

Threats

- There has been a very limited application of SEA to date in Mexico.
- The practice of EIA has showed that there are still many challenges to achieve the objectives of environmental assessment.
- Non-linearity of PPP making, which may be one of the main procedural problems for SEA in Mexico.
- Limited or incompatible environmental information.
- Lack of clear environmental goals and objectives.
- Environmental monitoring is normally not practiced in Mexico.
- Lack of public participation mechanisms.
- Lack of political and institutional will (bureaucratic resistance, corruption) as SEA can be seen as a control mechanism.

Bureaucratic resistance was a central feature during the environmental assessment of the ELUPP Cancun-Tulum. The analyses effectuated in this research were limited by the access to public information.

Political will is decisive to introduce SEA in Mexico. The implementation of this decision aiding tool, however, can be motivated by the role that SEA is achieving in the fields of development cooperation and international trade. The Mexican Government should be aware that the most important trading partners of Mexico (USA, Canada and Europe) and the international institutions that traditionally have supported the development of the country (such as the World Bank and the Inter-American Development Bank) have already adopted or are adopting this procedure.

An implementation schedule is not proposed in this research work. It is considered, however, that the strategic environmental assessment of ELUP-programmes, due to the relevance of this strategy to achieve sustainable development, could be the start of implementing SEA in Mexico.

Literature cited

Azuara-Monter, I. (2006) *Planeación y Política Ambiental en México*. Internet address: <http://www.union.org.mx/publicaciones/guia/derechosyobligaciones/planeacion.htm> Last access: 14.03.2006.

BID (2006) *Revisión de los sistemas de EIA en Latinoamérica y el Caribe: Caso México*. Banco Interamericano de Desarrollo. Centro de Estudios para el Desarrollo, pages: 39-41.

CBC (2006) *Common Landsat Band Combinations*. Center for Biodiversity and Conservation. Practical Guides to Remote Sensing. American Museum of Natural History.

CBD (2005) *Indicators for Assessing Progress towards the 2010 Biodiversity Target*. Convention on Biological Diversity. Internet address: <http://www.biodiv.org/2010-target/indicators/default.aspx> Last access: 09.02.2005.

CBMAS (2006b) *Quantifying forest fragmentation with indices*. Chesapeake Bay & Mid-Atlantic from Space. Internet address: <http://chesapeake.towson.edu/> Last access: 11.12.2006.

CDI (2006) *Diagnostico de los pueblos mayas de Quintana Roo*. Comisión Nacional para el desarrollo de los pueblos indígenas. Internet address: <http://cdi.gob.mx/index.php> Last access: 15.03.2006.

CEA (2003) *Marine Turtle*. Centro Ecológico Akumal. Internet address: <http://ceakumal.org/research.html> Last access: 13.11.2006.

CEC (1993). *Report from the Commission of the Implementation of Directive 85/337/EEC on the Assessment of the Effects of Certain Public and Private Projects on the Environment*. Commission of the European Communities, Luxembourg.

CEC (2001) *Directive 2001/42/EC of the European Parliament and of the Council on the Assessment of the Effects of Certain Plans and Programmes on the Environment*. Commission of the European Communities, pages: 16 and Annex I, pages: 25.

- CEC (2003) *Implementation of Directive 2001/42 on the Assessment of the Effects of Certain Plans and Programmes on the Environment*. Commission of the European Communities, pages: 22-66.
- CECADESU (2006) *Una visión estatal de la educación ambiental, la capacitación para el desarrollo sustentable y la comunicación educativa en Quintana Roo (2002-2006)*. Centro de Educación y Capacitación para el Desarrollo Sustentable. Mexico, pages: 7.
- CMDA (2006) *Conclusiones del Taller de expertos para analizar la propuesta de actualización del Plan Director de Desarrollo Urbano de Tulum*. Centro Mexicano de Derecho Ambiental, pages: 7.
- CONABIO (2004) *Second National Report on Biological Diversity*. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Internet address: <https://www.biodiv.org/doc/world/mx/mx-nr-02-es.pdf> Last accessed: 10.02.2005.
- CONABIO (2006) *Corredor Cancún-Tulum*. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Internet address: http://www.conabio.gob.mx/conocimiento/regionalizacion/doctos/rhp_105.html Last access: 06.07.2007.
- CSD (2005) *CSD Theme Indicator Framework*. Commission for Sustainable Development. United Nations. Internet address: http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/table_4.htm Last access: 17.02.2005
- Dalal-Clayton, B. and Sadler, B. (2005) *Strategic Environmental Assessment: A sourcebook and reference guide to international experience*. OECD, UNEP, IIED. Earthscan, UK, pages: 4-22.
- EEA (2005) *EEA core set of indicators*. European Environment Agency.
- Encyclopedia Britannica (2006) *Encyclopedia Britannica Online*. Internet address: <http://www.britannica.com/> Last access: 13.11.2006.
- ESC (2004) *Landsat GeoCover (2000/ETM+ and 1990/TM) Edition Mosaics; Tile 88-04-13-TM and 01-04-17-ETM+*. Earth Satellite Corporation. Sioux Falls, South Dakota: USGS. Source for this dataset was the Global Land Cover Facility, Internet Address: <http://www.landcover.org> Last access: 22.11.2006.

FAA (2005) *Land Use Compatibility and Airports. A Guide for Effective Land Use Planning*. United States Federal Aviation Administration, Southern Region Airports Division Office, pages: 80.

FHA (2006) *Highway traffic noise*. United States Federal Highway Administration. Internet address: <http://www.fhwa.dot.gov/environment/htnoise.htm> Last access: 12.10.2006

FONATUR (2001) *Firma del Convenio Corredor Cancún Riviera Maya*. Fondo Nacional de Fomento al Turismo. Power Point presentation.

FONATUR (2004a) *Barómetros Históricos-Cancún*. Fondo Nacional de Fomento al Turismo. Internet address: http://www.fonatur.gob.mx/ESTA_DISTICAS/historicos-cancun-2.htm Last access: 26.08.2004.

FONATUR (2004b) *Cancún: Visión a futuro*. Fondo Nacional de Fomento al Turismo. Internet address: <http://www.fonatur.gob.mx/cancun.html> Last access: 26.08.2004.

Forman, R.T.T., and Gordon, M. (1986) *Landscape Ecology*. John Wiley and Sons, Inc, USA.

Forman, R.T.T. (1997) *Land mosaics: the ecology of landscapes and regions*. Cambridge University Press. Cambridge, UK.

Franklin, A., Noon, B., and George, L. (2002) *What is habitat fragmentation?* Studies in Avian Biology No.25, pages: 20-29.

Gascon, C., Laurance, W., Tovejoy, T. (2003) *Forest fragmentation and Biodiversity in Central Amazonia*. Ecological Studies, Vol.162. in G.A. Bradshaw and P.A. Marquet (Eds.) *How Landscapes Change*. Springer-Verlag Berlin Heidelberg.

Geiger, R. (1965) *The climate near the ground*. Harvard University Press, Cambridge, Massachusetts, in Saunders *et al.* *Biological Consequences of Ecosystem Fragmentation: A Review*.

Gilpin, M.E. and Soule, M.E. (1986) *Minimum viable populations: processes of species extinctions*, pages: 19-34, in Saunders *et al.* *Biological Consequences of Ecosystem Fragmentation: A Review*.

Google Earth (2006) Internet address: <http://earth.google.de/> Last access: 06.07.2006.

- Google Earth (2007) Internet address: <http://earth.google.de/> Last access: 11.07.2007.
- GM (2001) *Programa Nacional de Desarrollo (2001-2006)*. Gobierno de México, pages 124-125.
- GM (2003) *Acuerdo de coordinación Corredor Cancún-Tulum*. Gobierno de Mexico, pages 10-12.
- GQR (2000) *Plan estratégico de desarrollo integral del Estado de Quintana Roo 2000-2025*. Gobierno de Quintana Roo. Internet address: <http://www.qroo.gob.mx/qroo/Documentos/planestra1/situacion.htm> Last access: 26.08.2004.
- GQR (2001) *Decreto por el que se expide el programa de ordenamiento ecológico territorial de la región denominada Corredor Cancún-Tulum*. Gobierno de Quintana Roo, México, pages: 4.
- GQR (2006) *Objetivos y estrategias ambientales y de desarrollo sustentable de Quintana Roo*. Gobierno de Quintana Roo, México, pages: 46-47.
- ILWIS (2006) *ILWIS 3.3 The Remote Sensing and GIS software*. International Institute for Geo-Information Science and Earth Observation. Internet address: <http://www.itc.nl/ilwis/> Last access: 29.11.2006.
- INE (1999) *Resumen ejecutivo Programa de Ordenamiento Ecológico Corredor Cancún-Tulum*. Instituto Nacional de Ecología, Mexico, pages: 1-4.
- INE (2000) *La evaluación del impacto ambiental; logros y retos para el desarrollo sustentable 1995-2000*. Instituto Nacional de Ecología, Mexico, pages: 25-119.
- INE (2006a) *Taller: Descentralización de la gestión ambiental y fomento de la corresponsabilidad social*. Instituto Nacional de Ecología. Internet address: <http://www.ine.gob.mx/ueajei/publicaciones/libros/9/tallere.html> Last access: 01.03.2006.
- INE (2006b) *Problemas de interpretación, aplicación y vacíos de la legislación ambiental municipal*. Instituto Nacional de Ecología. Internet address: <http://www.ine.gob.mx/ueajei/publicaciones/libros/9/amejia.html> Last access: 01.03.2006.

- INE (2006c) *1996, Las Reformas a la LGEEPA*. Instituto Nacional de Ecología. Internet address: <http://www.ine.gob.mx/ueajei/publicaciones/libros/384/cap2.html> Last access: 31.01.2006.
- INEGI (1997) *Diccionario de datos de uso de suelo y vegetación (vectorial) 1:250,000*. Instituto Nacional de Estadística, Geografía e Informática.
- INEGI (2000a) *Quintana Roo, XII Censo General de Población y Vivienda 2000*. Instituto Nacional de Estadística, Geografía e Informática, México.
- INEGI (2000b) *Conjunto de datos vectoriales de la serie topográfica 1:1'000,000*. Instituto Nacional de Estadística, Geografía e Informática.
- INEGI (2005) *Áreas naturales protegidas por entidad federativa, según categoría y ecosistema, 2005*. Geografía e Informática. Información estadística. Internet address: <http://www.inegi.gob.mx/est/contenidos/espanol/rutinas/ept.asp?t=mamb05&c=5862> Last access: 25.10.2007.
- INEGI (2006a) *II Conteo de Población y Vivienda 2005*. Instituto Nacional de Estadística, Geografía e Informática. Información estadística. Internet address: <http://www.inegi.gob.mx> Last access: 24.05.2006.
- INEGI (2006b) *Casos de morbilidad hospitalaria por entidad federativa y principales causas de egreso según sexo, 2004*. Instituto Nacional de Estadística, Geografía e Informática. Información estadística. Internet address: <http://www.inegi.gob.mx/est/contenidos/espanol/rutinas/ept.asp?t=msal05&c=5645&e=23> Last access: 13.11.2006.
- IUCN (2007) *Management categories of protected areas*. The World Conservation Union. Internet address: <http://www.iucn.org> Last access: 30.10.2007.
- Jacobs, J. W., and Wescoat, J. L. (2002) *Managing river resources: Lessons from Glen Canyon Dam*. Environment 44(2).
- João E. (2005) *Key Principles of SEA*. Pages: 3-14, in Schmidt *et al.* Implementing Strategic Environmental Assessment. Environmental Protection in the European Union. Springer Verlag. Germany.

- Johnson, D.H. (1980) *The comparison of usage and availability measurements for evaluating resource preference*. Ecology 61, pages: 65-71. Northern Prairie Wildlife Research Center Online. Internet address: <http://www.npwrc.usgs.gov/resource/methods/prefer/index.htm> Last access: 12.07.2007.
- Kapos, V. (1989) *Effects of isolation on the water status of forest patches in the Brazilian Amazon*. Journal of Tropical Ecology 5. Pages: 173-185, in Saunders et al. Biological Consequences of Ecosystem Fragmentation: A Review.
- Kenkel, N.C. and Walker, D.J. (2006) *Fractals in the biological sciences*. Quantitative Plant Ecology Laboratory, Department of Botany, University of Manitoba. Internet address: <http://www.umanitoba.ca/faculties/science/botany/LABS/ECOLOGY/> Last access: 11.12.2006.
- La Jornada (2002) *Cancún: ¿feliz cumpleaños?* Ivan Restrepo. La Jornada Lunes 29 de abril de 2002. Internet address: <http://www.jornada.unam.mx/2002/abr02/020429/019a1pol.php?origen=opinion>. Last access: 03.02.2004.
- Lee, K. N. (1999) *Appraising Adaptive Management*. Conservation Ecology 3(2), pages: 3.
- LGEEPA (2003) *Ley General del Equilibrio Ecológico y la Protección al Ambiente*. Secretaría de Medio Ambiente y Recursos Naturales. Version 2003, pages: 3-23.
- Loveioy, T.E., and Oren, D.C. (1981) *The minimum critical size of ecosystems*. pp:7-12, in Saunders et al. Biological Consequences of Ecosystem Fragmentation: A Review.
- LUMA-GIS (2005) *Digital image classification. Course textbook*. Lund University Master's program in Geographical Information Systems (GIS), pages: 2-3.
- Maldonado, J. (2005) *Transboundary Environmental Impact Assessment. Part 1: Mexico's EIA Process*. Environmental Impact Assessment Committee Newsletter, Vol. 1, No. 1, USA, pages: 13-15.
- McGarigal, K., Cushman, S.A., and Neel, M.C. (2002) *FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps*. Computer software program produced by the authors at the University of Massachusetts, Amherst.

- NACEC (2006) *Summary of Environmental Law in Mexico*. North American Commission for Environmental Cooperation. Internet address: http://www.cec.org/pubs_info_resources/law_treat_agree/summary_enviro_la_w/publication/mxdoc.cfm?varlan=english&topic=7#4 Last access: 30.01.2006.
- NASA Earth Observatory (2006) *Measuring Vegetation (NDVI & EVI)*. NASA Earth Observatory. Internet address: <http://earthobservatory.nasa.gov/> Last access: 07.12.2006.
- NOM-059-ECOL-2001 (2001) *Protección Ambiental. Especies nativas de México de flora y fauna silvestres. Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio. Lista de especies en riesgo*. Secretaría de Medio Ambiente y Recursos Naturales, pages 48-49.
- NOM-127-SSA1-1994 (2000) *Salud ambiental, agua para uso y consumo humano-límites permisibles de calidad y tratamientos a que debe someterse el agua para su potabilización*. Estados Unidos Mexicanos. Secretaría de Salud.
- OECD (1993) *OECD Core Set of Indicators for Environmental Performance Reviews*. Organisation for Economic Co-Operation and Development. Paris, pages: 5-10.
- OECD (2004) *Key Environmental Indicators*. Organisation for Economic Co-Operation and Development. OECD Environment Directorate, Paris.
- ODPM (2002) *Draft guidance on the Strategic Environmental Assessment Directive. Proposals for practice guidance on applying Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment to land use and spatial plans in England*. Office of the Deputy Prime Minister. Draft guidance prepared for the Office of the Deputy Prime Minister by Levett-Thérivel Sustainability Consultants.
- Palik, B.J., and Murphy, P.G. (1990) *Disturbance versus edge effects in sugar-maple/beech forest fragments*. *Forest Ecology and Management* 32, pages: 187-202, in Saunders et al. *Biological Consequences of Ecosystem Fragmentation: A Review*.
- Partidário M. R. (1999) *Strategic Environmental Assessment - principles and potential*. Ch 4, in Petts, Judith (Ed.), *Handbook on Environmental Impact Assessment*, Blackwell, London, pages: 7.

- PBFRM (2006) *Prüfverfahren der Umweltprüfung*. Planungsverband Ballungsraum Frankfurt Rhein-Main. Vorentwurf 2006, pages: 359-402.
- Pisanty, L. J. (2004) *Sectoral Environmental Assessment in Mexico: a Methodological Approach*. International Association for Impact Assessment. Vancouver, Canada.
- QRSS (2006) *List of Long Underwater Caves in Quintana Roo Mexico*. Quintana Roo Speleological Survey. Internet address: <http://www.caves.org/project/qrss/qrss.htm> Last access: 27.10.2006
- Sadler, B., and R. Verheem (1996) *Strategic Environmental Assessment: Status, Challenges and Future Directions*. Publication No.53. Ministry of Housing, spatial Planning and the Environment. Den Haag, The Netherlands, pages: 27.
- Saunders, D., Hobbs, R., and Margules, C. (1990) *Biological Consequences of Ecosystem Fragmentation: A Review*. Conservation Biology, Volume 5, No. 1, March 1991, pages: 20.
- Schmidt M., João E., Albrecht E. (2005) *Implementing Strategic Environmental Assessment*. Environmental Protection in the European Union. Springer Verlag. Germany, pages: 3-14.
- SECTUR (2001) *Plan Nacional de Turismo de México 2001-2006*. Secretaría de Turismo de México, pages: 140.
- SECTUR (2003) *Los desafíos del turismo mexicano*. Secretaría de Turismo de México, pages: 7-15.
- SEDETUR (2005) *Indicadores turísticos*. Secretaria de Turismo de Mexico.
- SEGOB (2004) *Comunicado de prensa 42 / 04: 90.2 millones de mexicanos vivirán en ciudades en 2030*. Secretaría de Gobernación de México, pages: 1.
- SEMARNAP (2000a) *Reglamento de la Ley General del Equilibrio Ecológico y la Protección al Ambiente en materia de Evaluación de Impacto Ambiental*. Secretaría del Medio Ambiente, Recursos Naturales y Pesca, México, pages: 9-29.

- SEMARNAP (2000b) *El ordenamiento ecológico del territorio. Logros y retos para el desarrollo sustentable 1995-2000*. Secretaría de Medio Ambiente Recursos Naturales y Pesca. México, pages: 9-31.
- SEMARNAP (2000c) *Indicadores para la evaluación del desempeño ambiental, reporte 2000*. Secretaría de Medio Ambiente Recursos Naturales y Pesca., Dirección General de Gestión e Información Ambiental, pages: 24.
- SEMARNAP (2000d) *Sistema de Indicadores Ambientales y Registro de Emisiones y Transferencias de Contaminantes. Logros y retos para el desarrollo sustentable 1995-2000*. Secretaría de Medio Ambiente Recursos Naturales y Pesca. Instituto Nacional de Ecología, Dirección General de Gestión e Información Ambiental.
- SEMARNAP (2000e) *La calidad del agua en los ecosistemas costeros de México*. Secretaría de Medio Ambiente Recursos Naturales y Pesca. Instituto Nacional de Ecología.
- SEMARNAT (2001a) *Glosario de términos para el Programa de Ordenamiento Ecológico Territorial del Corredor Cancún-Tulum*. Delegación Federal de la SEMARNAT en Quintana Roo. Pages: 3.
- SEMARNAT (2001b) *Criterios de Ordenamiento Ecológico para la región del Corredor Cancún-Tulum*. Delegación Federal de la SEMARNAT en Quintana Roo.
- SEMARNAT (2001c) *ELUPP Cancun-Tulum vector data*. Delegación Federal de la SEMARNAT en Quintana Roo.
- SEMARNAT (2002a) *Descentralización de la gestión ambiental*. Secretaría de Medio Ambiente y Recursos Naturales, México, pages: 37.
- SEMARNAT (2002b) *Desarrollo Turístico Sustentable. Cancún – Riviera Maya 2025*. Delegación Federal de la SEMARNAT en Quintana Roo. Secretaría de Medio Ambiente y Recursos Naturales, México. Presentación de Power Point.
- SEMARNAT (2002c) *Informe Anual 2002*. Delegación Federal de SEMARNAT en Quintana Roo, Mexico.
- SEMARNAT (2003a) *Reglamento de la Ley General del Equilibrio Ecológico y la Protección al Ambiente en Materia de Ordenamiento Ecológico*. Secretaría de Medio Ambiente y Recursos Naturales. Publicado en el Diario Oficial el 8 de agosto de 2003, pages: 43-50.

- SEMARNAT (2003b) *Informe de la situación ambiental de México. Secretaría de Medio Ambiente y Recursos Naturales.*
- SEMARNAT (2004) *Laguna Nichupté, Cancún Quintana Roo. Secretaría de Medio Ambiente y Recursos Naturales.* Internet address: <http://www.semarnat.gob.mx/regiones/laguna-nichupte/desarrollo.shtml> Last access: 26.08.2004
- SEMARNAT (2006a) *Observaciones a la Aplicación del POET del Corredor Cancún-Tulum.* Secretariat of Environment and Natural Resources. Internet address: http://www.semarnat.gob.mx/dgeia/web_ingles/programa/3.shtml Last access: 05.10.2006.
- SEMARNAT (2006b) *The Mexico we desire. Secretariat of Environment and Natural Resources.* Internet address: http://www.semarnat.gob.mx/dgeia/web_ingles/programa/3.shtml Last access: 05.09.2006.
- SEMARNAT-QRoo (2001) *Actualización del Ordenamiento Ecológico del Corredor Cancún-Tulum.* Delegación Federal de la SEMARNAT en Quintana Roo.
- Stock, P. and Gründler, K. (2004) *Umweltprüfung des Regionalen Flächennutzungsplans.* Planungsverband Ballungsraum Frankfurt/Rhein-Main, Abt. Landschaft/Umwelt, pages: 6-8.
- Thérivel, R., Wilson, E., Thompson, S., Heaney, D., & Pritchard, D. (1992) *Strategic Environmental Assessment.* Earthscan. London.
- Thérivel, R. and Partidário, M. (1996) *The Practice of Strategic Environmental Assessment.* Earthscan Publ., London (UK).
- Thérivel, R. and Partidário, M. (2002) *The Practice of Strategic Environmental Assessment.* Earthscan Publications Ltd, London, pages: 5-10.
- Tortajada, C. (2002) *Environmental Impact Assessment of Water Projects in Mexico.* Third World Centre for Water Management, Mexico, pages: 3.
- UN (2003) *Indicators for Monitoring the Millennium Development Goals.* United Nations, New York, 2003.
- UNDSA (2006) *Agenda 21.* Division for Sustainable Development. UN Department of Economic and Social Affairs. Internet Address: <http://www.un.org/esa/sustdev/documents/agenda21> Last access: 12.12.2006.

- UNEP (2005) *Convention on Biological Diversity*. United Nations Environment Programme. Internet address: <http://www.biodiv.org/welcome.aspx> Last access: 14.02.2005
- UNESCO (1974) *Pollution monitoring and research in the framework of the MAB-Programme*. United Nations Educational, Scientific and Cultural Organization. MAB report series No. 20.
- Wempe, J. (2004) *Hausintern ermittelte mittlere Abstandswerte für Lärmbelastungen*. In Prüfverfahren der Umweltprüfung. Planungsverband Ballungsraum Frankfurt Rhein-Main.
- WHO (2003) *Making a Difference: Indicators to Improve Children's Environmental Health*. World Health Organization.
- WHO (2006) *Noise and health*. World Health Organization, Regional Office for Europe. Internet address: http://www.euro.who.int/Noise/activities/20040304_1 Last access: 06.10.2006
- Wood, C., and Djeddour, M. (1991) *Strategic Environmental Assessment; EA of Policies, Plans and Programmes*. The Impact Assessment Bulletin 10(1), pages: 3-22.
- Wood, C. (1995) *Environmental Impact Assessment: A Comparative Review*. Longman, Harlow. Cited in Thérivel and Partidário (2002).
- World Bank (2001) *Proyecto: Corredor Biológico Mesoamericano-México*. Banco Mundial, Oficina Regional para América Latina y el Caribe. Informe No: 21136-ME, pages: 9-15.
- World Bank (2002) *Strategic Environmental Assessment in World Bank Operations*. Experience to Date - Future Potential. ECON Centre for Economic Analysis, Oslo, Norway, pages: 12-30.
- World Bank (2005a) *Integrating Environmental Considerations in Policy Formulation*. Lessons from Policy-Based SEA Experience. The International Bank for Reconstruction and Development / The World Bank, USA, pages: 12-35.
- World Bank (2005b) *Evaluación Ambiental Estratégica del Sector Turismo en México*. Banco Mundial – SECTUR, Mexico.

Annex I

Identification of environmental indicators

| Environmental issue: | | Population, health | | | | | | | | | | | |
|---|---|--------------------|---|---|---|---|----------------------|---|---|-----------|---|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | Analytical soundness | | | Measurab. | | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Population with access to safe drinking water | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X |
| | Noise level | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | ✓ | - | X | X | X |
| | Concentration of air pollutants in urban areas | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| Road and rail network | Transport infrastructure network | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | - | ✓ | ✓ | X | X |
| | Noise level | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | ✓ | - | X | X | X |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | Noise level | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | ✓ | - | X | X | X |
| Forestry | | | | | | | | | | | | | |
| Mining and quarrying | | | | | | | | | | | | | |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Air | Concentration of air pollutants in urban areas | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| Noise | Noise level | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | ✓ | - | X | X | X |
| Water and sanitation | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Population with access to safe drinking-water | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Fresh water quality (BOD, faecal coliform, water pollutants included in NOM-127-SSA1-1994) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Recreational water quality (BOD, faecal coliform in coastal waters, chlorophyll concentration) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| | Waterborne diseases | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | ✓ | ✓ | ✓ | ✓ |
| Others | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X |
| Response | Social response indicators | | | | | | | | | | | | |
| Establishment of urban/construction ecological criteria | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Population with access to safe drinking-water | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Drinking-water quality (BOD, faecal coliform, water pollutants included in NOM-127-SSA1-1994) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Recreational water quality (BOD, faecal coliform in coastal waters, chlorophyll concentration) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | - | X | X | X |
| | Waterborne diseases | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | ✓ | ✓ | ✓ | ✓ |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

| Environmental issue: | | Biodiversity | | | | | | | | | | | |
|----------------------------------|--|---------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Intensity of use of water resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Road and rail network | Transport infrastructure network | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | - | ✓ | ✓ | X | X |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| Mining and quarrying | Area affected by extraction of raw materials/mining | ✓ | ✓ | ✓ | X | X | X | - | X | - | - | X | X |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Flora | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Fragmentation of ecosystems and habitats | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| Fauna | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Water | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Groundwater level | ✓ | ✓ | ✓ | X | ✓ | X | - | X | - | - | X | X |
| | Marine water quality (chlorophyll concentration, faecal coliform) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | - | X | X | X |
| Response | Social response indicators | | | | | | | | | | | | |
| Establishment of protected areas | Coverage of protected areas | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Protection of endangered species | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Restoration of affected areas | Coverage of restored areas | ✓ | ✓ | ✓ | X | - | X | - | X | - | X | X | X |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

| Environmental issue: | | Water | | | | | | | | | | | |
|--|--|------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Intensity of use of water resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X |
| Road and rail network | | | | | | | | | | | | | |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| Mining and quarrying | Area affected by extraction of raw materials/mining | ✓ | ✓ | ✓ | X | X | X | - | X | - | - | X | X |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Water bodies (cenotes, subterranean rivers, etc.) | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Aquifer recharge areas | | | | | | | | | | | | | |
| Fresh water | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Groundwater level | ✓ | ✓ | ✓ | X | ✓ | X | - | X | - | - | X | X |
| Marine water | Marine water quality (chlorophyll concentration, faecal coliform) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | - | X | X | X |
| Response | Social response indicators | | | | | | | | | | | | |
| Establishment of urban/construction ecological criteria | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X |
| | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | Marine water quality (chlorophyll concentration, faecal coliform) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | - | X | X | X |
| Introduction of growth thresholds | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Protection of key ecosystems (cenotes, aquifer recharge areas, etc.) | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

| Environmental issue: | | Soil | | | | | | | | | | | | |
|---|--|------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|--|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l | |
| Urban/tourism development | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X | |
| | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - | |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X | |
| Road and rail network | Transport infrastructure network | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | - | ✓ | ✓ | X | X | |
| Port and harbour | Area of port and harbour infrastructure | - | ✓ | - | X | X | X | X | X | X | - | X | X | |
| Airport infrastructure | Area of airport infrastructure | - | ✓ | - | X | X | X | X | X | X | - | X | X | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - | |
| Mining and quarrying | Area affected by extraction of raw materials/mining | ✓ | ✓ | ✓ | X | X | X | - | X | - | - | X | X | |
| State | Environmental condition indicators | | | | | | | | | | | | | |
| Flora | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X | |
| Fauna | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X | |
| Water quality | Proportion of fresh water with high nitrate and phosphate levels | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | - | - | X | X | X | |
| Water quantity | Groundwater level | ✓ | ✓ | ✓ | X | ✓ | X | - | X | - | - | X | X | |
| Soil quality | Area of land potentially vulnerable to water contamination by nitrate and pesticides | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | - | - | X | X | X | |
| | Erosion risk | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | - | - | X | X | X | |
| Response | Social response indicators | | | | | | | | | | | | | |
| Establishment of urban/construction ecological criteria | Population with adequate sewage disposal facilities | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - | |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | X | - | X | - | - | X | X | |
| Introduction of growth thresholds | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X | |
| Protection of aquifer recharge areas | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X | |
| Establishment of protected areas | Coverage of protected areas | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | |
| Restoration of affected areas | Coverage of restored areas | ✓ | ✓ | ✓ | X | - | X | - | X | - | X | X | X | |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

| Environmental issue: | | Air, climate | | | | | | | | | | | |
|----------------------------------|--|------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Concentration of air pollutants in urban areas | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| | Greenhouse gas emission intensities | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| | Annual energy consumption per capita | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | - | ✗ | ✗ |
| | Consumption of ozone-depleting substances | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| | Suitable solid-waste management | ✓ | ✓ | ✓ | - | - | ✗ | - | ✗ | - | - | ✗ | ✗ |
| Road and rail network | Distance travelled per capita | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | - | ✓ | ✓ |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | - | - | - |
| Mining and quarrying | | | | | | | | | | | | | |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Air quality | Concentration of air pollutants in urban areas | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| Climate change | Greenhouse gas emission intensities | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| Ozone depletion | Consumption of ozone-depleting substances | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| Energy consumption | Annual energy consumption per capita | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | - | ✗ | ✗ |
| Response | Social response indicators | | | | | | | | | | | | |
| Protection of ecosystems | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | - | ✗ | ✗ |
| Establishment of protected areas | Coverage of protected areas | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| Restoration of affected areas | Coverage of restored areas | ✓ | ✓ | ✓ | ✗ | - | ✗ | - | ✗ | - | ✗ | ✗ | ✗ |

Key: ✓ Satisfied - Partially satisfied ✗ Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

| Environmental issue: | | Landscape | | | | | | | | | | | |
|-----------------------------------|---|------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Road and rail network | Transport infrastructure network | ✓ | ✓ | ✓ | - | ✓ | X | ✓ | - | ✓ | ✓ | X | X |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| Mining | Area affected by extraction of raw materials/mining | ✓ | ✓ | ✓ | X | X | X | - | X | - | - | X | X |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Flora | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Fauna | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| | Fragmentation of ecosystems and habitats | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | X | X | X |
| Human presence | Status and trends of linguistic diversity and numbers of speakers of indigenous languages | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Human-built structural elements | Area/number of archaeological/historical sites | - | - | - | X | ✓ | X | - | X | X | - | - | - |
| Landforms | | | | | | | | | | | | | |
| Water | Area of selected key ecosystems (cenotes, aquifer recharge areas) | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Response | Social response indicators | | | | | | | | | | | | |
| Introduction of growth thresholds | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Establishment of protected areas | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Coverage of protected areas | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| Protection of endangered species | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Restoration of affected areas | Coverage of restored areas | ✓ | ✓ | ✓ | X | - | X | - | X | - | X | X | X |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

| Environmental issue: | | Cultural features | | | | | | | | | | | |
|----------------------------------|---|--------------------------|---|---|---|---|---|----------------------|---|---|-----------|---|---|
| Pressure | Environmental pressure indicators | Policy relevance | | | | | | Analytical soundness | | | Measurab. | | |
| | | a | b | c | d | e | f | g | h | i | j | k | l |
| Urban/tourism development | Population of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Area of urban formal and informal settlements | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| Road and rail network | | | | | | | | | | | | | |
| Port and harbour | | | | | | | | | | | | | |
| Airport infrastructure | | | | | | | | | | | | | |
| Forestry | Intensity of use of forest resources | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | - | - |
| Mining | | | | | | | | | | | | | |
| State | Environmental condition indicators | | | | | | | | | | | | |
| Traditional communities | Status and trends of linguistic diversity and numbers of speakers of indigenous languages | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Traditional way of life | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |
| | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Human-built structural elements | Coverage of protected areas (archaeological/historical sites) | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| | | | | | | | | | | | | | |
| Response | Social response indicators | | | | | | | | | | | | |
| Establishment of protected areas | Coverage of protected areas (archaeological/historical sites) | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - |
| Protection of endangered species | Abundance of selected key species | ✓ | ✓ | ✓ | ✓ | ✓ | X | - | - | - | X | X | X |
| Restoration of ecosystems | Area of selected key ecosystems | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | - | X | X |

Key: ✓ Satisfied - Partially satisfied X Not satisfied

Source: Indicators selected from INE 2000b, CSD 2005, CBD 2005, OECD 2004, EEA 2005

Annex II

Environmental indicator datasheets

| | | |
|---------------------------------------|---|--|
| Indicator: | 1 | Population of urban formal and informal settlements |
| Brief definition: | Number of inhabitants living in urban formal and informal settlements. | |
| Unit of measurement: | Number of inhabitants | |
| Relevance: | The indicator measures the size of formal and informal urban settlements by their population. The number of inhabitants can be used to estimate resource depletion, emission of contaminants, etc. The information provided by this indicator can be used to verify the observance of the densities of space use established by the ELUP strategy. In addition, the indicator can be an indirect measure to analyze traffic flows and changes on cultural patterns. | |
| Methodological description: | The number of inhabitants in formal and informal settlements is generally measured in censuses. This information is already available at national, regional and local levels in Mexico. It is routinely updated every 2-5 years by the National Institute of Statistics, Geography and Data Processing (INEGI). | |
| Data needed to compile the indicator: | Population of urban formal and informal settlements. | |
| Data source: | INEGI Internet Address: http://www.inegi.gob.mx | |
| Status: | + | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ✓ ▪ <i>Update frequency:</i> 5-10 years ▪ <i>Scope:</i> information by locality ▪ <i>Data type format:</i> digital maps may exist |

| | | |
|---------------------------------------|---|---|
| Indicator: | 2 | Population with adequate sewage disposal facilities |
| Brief definition: | Proportion of population with access to a sanitary facilities for human excreta disposal in the dwelling or immediate vicinity. | |
| Unit of measurement: | % | |
| Relevance: | The indicator provides information on the proportion of population with access to sanitary facilities for human excreta disposal in the dwelling or immediate vicinity. It is a basic indicator for assessing sustainable development, particularly human health, and is therefore suitable to supervise the first management objective of the ELUP strategy, namely, the achievement of sustainable development (see section 3.3). In addition, accessibility to adequate excreta disposal facilities is fundamental to decrease the faecal risk and the frequency of associated diseases (CSD 2005). The information of this indicator can be useful to study soil quality, and fresh and marine water quality in the Riviera Maya. | |
| Methodological description: | The percentage of population with adequate sewage disposal facilities is normally collected using censuses and surveys. Sanitary facility has been defined as (CSD 2005): "A unit for disposal of human excreta which isolates faeces from contact with people, animals, crops and water sources. Suitable facilities range from simple but protected pit latrines to flush toilets with sewerage. All facilities, to be effective, must be correctly constructed and properly maintained". In order to arrive at more robust estimates of sanitation coverage, two main data source types are required (CSD 2005): (i) administrative or infrastructure data which report on new and existing facilities; and (ii) population-based data from a household survey. This information is gathered by INEGI in Mexico; however, an additional check with the local authorities (for instance, the Quintana Roo Water and Sewer Commission; CAPA) is required, as contradictory information can be found to date in the Riviera Maya. | |
| Data needed to compile the indicator: | The number of people with access to improved excreta disposal facilities, and the total population. | |
| Data source: | INEGI Internet Address: http://www.inegi.gob.mx | |
| Status: | — | <ul style="list-style-type: none"> ▪ <i>Quality assurance</i>: there are sources that contradict the main source ▪ <i>Update frequency</i>: 5-10 years ▪ <i>Scope</i>: information by locality ▪ <i>Data type format</i>: digital maps may be limited or nonexistent. |

| | | |
|---------------------------------------|---|---|
| Indicator: | 3 | Population with access to safe drinking water |
| Brief definition: | Proportion of population with access to an improved water source in a dwelling or located within a convenient distance from the user's dwelling. | |
| Unit of measurement: | % | |
| Relevance: | The indicator monitors the progress in the accessibility of the population to improved water sources in a dwelling or located within a convenient distance from the user's dwelling. Accessibility to improved water sources is of fundamental significance to lowering the faecal risk and frequency of associated diseases (CSD 2005). It is considered as a good indicator of human development. The information provided by this indicator can be used to supervise the first management objective of the ELUP strategy. | |
| Methodological description: | The percentage of population with access to safe drinking water is collected using censuses and surveys. Reasonable access to water is defined as (CSD 2005): In urban areas, distances of not more than 200 metres from a house to a public stand post or any other adequate point source. In rural areas, reasonable access implies that people do not have to spend a disproportionate part of the day fetching water for the family's needs. Two data sources are common: administrative data that report on new and existing facilities, and population data from surveys or censuses. This information is gathered by INEGI in Mexico; however, this information should be verified (considering, for instance, information from CAPA) as contradictory information can be found to date in the Riviera Maya. | |
| Data needed to compile the indicator: | The number of people with access to improved water sources, and the total population. | |
| Data source: | INEGI Internet Address: http://www.inegi.gob.mx | |
| Status: | ■■■■■ | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> there are sources that contradict the main source ▪ <i>Update frequency:</i> 5-10 years ▪ <i>Scope:</i> information by locality ▪ <i>Data type format:</i> digital maps may be limited or nonexistent. |

| | | |
|---------------------------------------|--|--|
| Indicator: | 4 | Suitable solid-waste management |
| Brief definition: | Percent of population with adequate solid waste disposal facilities. | |
| Unit of measurement: | % | |
| Relevance: | The indicator informs on the percentage of population with access to a suitable solid-waste management. Suitable solid-waste management includes all activities that seek to minimize the health, environmental and aesthetic impacts of solid wastes. In the Riviera Maya, waste management is a primary concern due to the potential impact of inappropriate waste management on water bodies, ecosystems, landscape, and human health. This indicator can show the effectiveness of the strategies implemented to achieve sustainable development through the ELUP programme. | |
| Methodological description: | This information is normally collected using censuses and surveys. Two data sources are common: administrative data that report on new and existing facilities, and population data from surveys or censuses. INEGI provides some information on this indicator. This information might be completed using administrative data in the Riviera Maya. | |
| Data needed to compile the indicator: | Percent of population with adequate solid waste disposal facilities and the total population. | |
| Data source: | INEGI | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |


| | | |
|---------------------------------------|---|---|
| Indicator: | 5 | Waterborne diseases |
| Brief definition: | Occurrence of acute illness associated with drinking water from a public water system or exposure encountered in recreational or occupational settings. | |
| Unit of measurement: | Number of cases of waterborne diseases per 100,000 inhabitants | |
| Relevance: | <p>The indicator provides information on the occurrence of acute illness associated with drinking water from a public water system or exposure encountered in recreational or occupational settings (EEA 2005). Waterborne diseases are a health threat in Quintana Roo. In 2005, gastrointestinal illnesses were the second largest cause of death in the State (INEGI 2006). The cause of these diseases is directly linked to poor domestic sanitation and hygiene, lack of safe drinking water and exposures to solid waste (for instance, through waste accumulation in the neighbourhood). These in turn are often associated with poor facilities for waste and water management, lack of adequate safety procedures within the food supply system and inadequate control of environmental pollution (WHO 2003:26). The indicator is intended to provide additional information to determine the effectiveness of the ELUP strategies for sustainable development.</p> | |
| Methodological description: | This information is normally collected using censuses and surveys. Two data sources are INEGI and the Secretariat of Health of Mexico. They provide reliable routinely updated information. | |
| Data needed to compile the indicator: | Number of cases of waterborne diseases per 100,000 inhabitants | |
| Data source: | INEGI Internet Address: http://www.inegi.gob.mx | |
| Status: | + | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ✓ ▪ <i>Update frequency:</i> 5-10 years ▪ <i>Scope:</i> information by locality ▪ <i>Data type format:</i> ✓ |

| | | |
|---------------------------------------|---|--|
| Indicator: | 6 | Area of selected key ecosystems |
| Brief definition: | This indicator will use trends in the extent area of identified key ecosystems to assess the effectiveness of measures for conserving biodiversity at ecosystem level. | |
| Unit of measurement: | ha | |
| Relevance: | <p>The protection of key ecosystems is one of the central environmental objectives of the ELUP strategy. The ELUPP Cancun-Tulum identifies as key ecosystems: “coral reefs, subperennifolia rainforest, mangroves, cenotes, coves, among others, as well as the habitats of species included in the Mexican Official Standard 059 (NOM-059-ECOL-2001, List of endangered species)” (criterion TU-22, see table 3.8). In addition, the aquifer recharge areas were also recognized as high-priority areas.</p> <p>The indicator has the potential to illustrate the effectiveness of measures designed to conserve biological diversity in fulfilment of the ELUP provisions. In addition, this information can be useful to study changes on landscape, vegetation cover, ecosystem fragmentation, flora and fauna diversity, soil resources, climatic effects, water quality, and cultural features.</p> | |
| Methodological description: | Ecosystem area will normally be derived from mapped data on land cover. This is most efficiently done using data in digital form and Geographic Information Systems (GIS) software. The greatest difficulty is in arriving at an agreed ecosystem classification that is compatible with the available data. It is also fundamental to ensure consistency of the classification and the method of measurement, including consideration of spatial scale and resolution, over time (CSD 2005). Currently, this information does not exist in the Riviera Maya. The classification of key ecosystems, according to the available digital information, and a GIS-based database are required to acquire the data on this indicator. | |
| Data needed to compile the indicator: | Land cover data to which an agreed ecosystem classification has been applied. Agreement on the classification will depend upon consensus on key ecosystems types and on the type and quality of raw remotely sensed or other primary data (CBD 2005). | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|---|--|
| Indicator: | 7 | Fragmentation of ecosystems and habitats |
| Brief definition: | Patch size distribution of terrestrial habitats (forests and possibly other habitat types). | |
| Unit of measurement: | Average size of non-fragmented ecosystems and habitats (ha) | |
| Relevance: | The indicator examines the patch size distribution of terrestrial habitats to evaluate the effectiveness of measures implemented to minimize habitat fragmentation. Mitigation of habitat fragmentation is part of the ELUPP Cancun-Tulum provisions. Expansion of transport infrastructure networks is fragmenting and isolating habitats and creating barriers to wandering and spreading of animals and animals populations. The average size of natural conservation areas is decreasing and the average distance between areas of the same type or function is increasing. Nature's infrastructures conflict more and more with human infrastructures. This indicator is closely linked to the extent of key ecosystems. | |
| Methodological description: | Patch size distribution of terrestrial habitats is normally derived from mapped data on land cover. This is most efficiently done using data in digital form and GIS software. Currently, this information does not exist in the Riviera Maya. A GIS-based database is thus required to acquire the information on this indicator. | |
| Data needed to compile the indicator: | Average size of non-fragmented ecosystems and habitats in ha. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|-----------------------------|---|--|
| Indicator: | 8 | Abundance of selected key species |
| Brief definition: | This indicator uses estimates of population trends in selected species to represent changes in biodiversity, and the relative effectiveness of measures to maintain biodiversity. | |
| Unit of measurement: | Number of mature individuals or other relevant indicator of abundance within a given area or population. | |
| Relevance: | Biodiversity maintenance is essential for human life and sustainable development. The information provided by this indicator can thus be used to supervise the first management objective of the ELUP strategy. In addition, the indicator has the potential to illustrate the effectiveness of measures implemented in fulfilment of obligations accepted under the Convention on Biological Diversity. | |
| Methodological description: | <p>Some concepts and definitions are first required (CBD 2005):</p> <p>Abundance: the number of mature individuals within the population or area under study. Where it is difficult or inappropriate to survey individuals, comparable surrogate units of measurement, such as number of nests (marine turtles) or spawning stock biomass (fishes), may be acceptable.</p> <p>Key species: the following categories of species might be considered as key species when developing a biodiversity monitoring programme: (i) keystone species: the loss of these species will significantly impact upon the population sizes of other species in the ecosystem, potentially leading to further species loss (cascade effect); (ii) rare or locally endemic species: conservation of endemic species, particularly those sharing a discrete geographic area, can be a cost-effective way to maintain global biodiversity levels; and (iii) threatened species: a threatened species represents actual or potential decline in biodiversity. Recovery of threatened species following management intervention is strongly indicative of successful conservation measures.</p> <p>Information on species abundance should be collected through the consistent, long-term, application of an appropriate survey technique that is widely accepted by the scientific community (CBD 2005). Retrospective population information may be obtained through review of published literature, including previous field study reports, seeking material that is appropriate for comparison with the ongoing methodologies adopted. While it is in most cases impossible to count every individual within a population or area, knowledge of habitat requirements and species population density in sample areas, coupled with data on climate, altitude, soil type or vegetation cover may be used to estimate population size in the area of interest. A GIS is commonly used to analyse the spatial data. It is important that population size predictions are verified by fieldwork.</p> <p>So far, the species included in the Mexican Official Standard 059 (NOM-059-ECOL-2001, List of endangered species) are recognized as key species in the Riviera Maya. However, a biodiversity monitoring programme is currently not available. Data on some species can be obtained from NGOs working in the region. The Centro Ecológico Akumal, for example, compiles annual data on the arrival of loggerhead turtle (<i>Caretta caretta</i>) and green turtle (<i>Chelonia mydas</i>) in the beaches Aventuras Akumal, Akumal and Media Luna (CEA 2003). In order to obtain suitable information, the introduction of a GIS-based monitoring programme may be required.</p> | |


| | |
|---------------------------------------|--|
| Data needed to compile the indicator: | The preferred input would be sets of quantitative data on the population size of selected species within a given area, assessed at suitable time intervals using a standardised method. |
| Data source: | The Centro Ecologico Akumal (CEA 2003) develops annual data sets of loggerhead turtle (<i>Caretta caretta</i>) and green turtle (<i>Chelonia mydas</i>) arrivals in the beaches: Aventuras Akumal, Akumal y Media Luna. Other sources not identified |
| Status: | <div style="background-color: red; color: black; text-align: center; width: 40px; height: 40px; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;"> X </div> <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|--|--|
| Indicator: | 9 | Coverage of protected areas |
| Brief definition: | The indicator measures the area of protected land ecosystems, inland water ecosystems, and marine ecosystems, expressed as a percentage of the total area of land ecosystems, inland water ecosystems and marine ecosystems respectively. | |
| Unit of measurement: | Protected area as a percent of the total area | |
| Relevance: | This indicator represents the extent to which areas important for conserving biodiversity, cultural heritage, scientific research (including baseline monitoring), recreation, natural resource maintenance and other values are protected from incompatible uses. It is an ideal indicator to supervise the observance of the land-use strategy proposed by the ELUP. Additionally, the information provided by this indicator can be useful to study changes on biodiversity, landscape and cultural features. | |
| Methodological description: | The indicator requires the calculation of the area of totally and partially protected areas. The indicator can be mapped in two layers: ecosystems and protected areas. Smaller protected areas can be mapped as points, in which case their size should be recorded in a database separately. The category of protected area should also be entered in the database. This information is already available for the Riviera Maya in digital form. Data sources are the National Commission for the Knowledge and Use of Biodiversity of Mexico (CONABIO) and the ELUPP Cancun-Tulum administrative boundaries shapefiles (SEMARNAT 2001c). | |
| Data needed to compile the indicator: | A map of the ecosystems, preferably using a classification that is internationally compatible and valid for other countries and territories in the region. A geo-referenced list of the protected areas, giving their sizes (area in hectares) and locations, and classifying them by protection category comparable to The World Conservation Union's six management categories of protected area. | |
| Data source: | CONABIO Internet Address: http://www.conanp.gob.mx - Last access: 13.11.2006 The World Database on Protected Areas Internet Address: http://glcf.umiacs.umd.edu/data/wdpa.shtml - Last access: 25.5.2006 | |
| Status: |  | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> no ecosystem classification is used. ▪ <i>Update frequency:</i> not indicated ▪ <i>Scope:</i> information by natural protected area ▪ <i>Data type format:</i> digital database |

| | | |
|---------------------------------------|---|--|
| Indicator: | 10 | Coverage of restored areas |
| Brief definition: | Reforested/restored areas affected by extraction of raw materials and mining. | |
| Unit of measurement: | ha | |
| Relevance: | The indicator illustrates the effectiveness of measures adopted to recover affected areas, which is one of the mitigation strategies included in ELUP. The information may be useful to evaluate changes on landscape, soil quality, water quality and biodiversity. | |
| Methodological description: | The area of restore areas can be obtained from mapped data on land cover. This is most efficiently done using data in digital form and GIS software. Currently, this information does not exist in the Riviera Maya. A GIS-based database is required to acquire the information on this indicator. | |
| Data needed to compile the indicator: | Coverage of restored areas in hectares. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|---|--|
| Indicator: | 11 | Intensity of use of water resources |
| Brief definition: | Annual extraction of ground and surface water as a percent of total renewable water. | |
| Unit of measurement: | % | |
| Relevance: | The purpose of this indicator is to show the degree to which renewable water resources are being exploited. The indicator can show to what extent freshwater resources are already used, and the need for adjusted supply and demand management policy. Scarc water could have negative effects on sustainability constraining economic and regional development, and leading to loss of biodiversity. The adequate use of water resources is indispensable to achieve sustainable development. This indicator can be thus used to supervise the ELUP implementation. | |
| Methodological description: | The total renewable water resources (RWR) are defined as the sum of internal RWR and incoming flow originated outside the area under study. The indicator could consider withdrawals and water resources at the basis of a watershed. The indicator could be disaggregated to show total renewable water resources, withdrawals for the different users, and efficiencies for these different users (CSD 2005). A data source can be administrative information from local administration (CAPA). INEGI also gather information on water uses regularly. | |
| Data needed to compile the indicator: | Annual water withdrawals divided by total renewable water resources. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|------------------------------------|--|---|
| Indicator: | 12 | Fresh water quality (BOD, faecal coliform, salinity, water pollutants included in NOM-127-SSA1-1994) |
| Brief definition: | The indicator measures fresh water quality using representative quality indicators such as BOD, faecal coliform, and salinity. Water pollutants included in the Mexican Official Standard NOM-127-SSA1-1994 can be also considered. | |
| Unit of measurement: | mg/l except where indicated | |
| Relevance: | The purpose of this indicator is to assess the quality of water available to consumers in localities or communities for basic and commercial needs. Sustainable development is heavily dependant on suitable water availability. Human ill health due to water quality problems can reduce work capability and affect children's growth and education. This indicator may show the effectiveness of ELUP strategies implemented to protect aquifer recharge areas and water bodies in the Riviera Maya. | |
| Methodological description: | <p>This indicator measures fresh water quality using representative quality indicators such as Biological Oxygen Demand (BOD), faecal coliform, and salinity. Water pollutants included in the Mexican Official Standard NOM-127-SSA1-1994 can be also considered. These indicators have the potential to illustrate the effectiveness of measures designed to the sustainable use of water resources.</p> <p>BOD may indicate faecal contamination or increases in particulate and dissolved organic carbon. Increased concentrations of dissolved organic carbon can create problems during the production of drinking water if chlorination is used, as disinfection by products, such as trihalomethanes and other compounds toxic to humans, may be produced. Increased oxygen consumption poses a potential threat to aquatic organisms, including fish. It is, therefore, important to monitor organic pollution to identify areas posing a threat to health, to identify sources of contamination, to ensure adequate treatment, and provide information for decision making to enhance water sustainability (CSD 2005).</p> <p>Faecal indicator bacteria remain the preferred way of assessing the hygienic quality of water (CSD 2005). The concentration of faecal coliforms in freshwater bodies is an indicator of contamination with human and animal excreta. Water contaminated with human and animal excreta represents a serious health risk. This measure indicates situations where treatment is required or has to be improved to guarantee safety of supply.</p> <p>Considering the characteristics of the Riviera Maya, salinity of freshwater may be another suitable indicator of water quality. Aquifers near the coast are at risk for seawater intrusion as a result of groundwater over-exploitation. The high mineral content of saltwater causes these waters to be unsuitable for many uses, including human consumption.</p> <p>Finally, the indicators reported in compliance with the Mexican Official Standard NOM-127-SSA1-1994 (Drinking water quality) can also be considered. This standard includes bacteriological, physical, chemical and organoleptic indicators.</p> <p>Data on the abovementioned indicators are normally available from municipal water supply authorities on a routine basis. The Secretariat of Health of Mexico and research institutes operating in the region may be alternative data sources. In the Riviera Maya, the main data source should be the Quintana Roo Water and Sewer Commission (CAPA).</p> | |

| | |
|---------------------------------------|---|
| Data needed to compile the indicator: | Records of water authorities' laboratories, hydro-geological institutes, universities, municipal public health laboratories, research institutes, and special studies, which show fresh water quality. |
| Data source: | Not identified. The observance of the NOM-127-SSA1-1994 is, however, compulsory. The information must be included in the records of the water authorities. |
| Status: |  <ul style="list-style-type: none">▪ <i>Quality assurance:</i>▪ <i>Update frequency:</i>▪ <i>Scope:</i>▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|---|--|
| Indicator: | 13 | Marine water quality (chlorophyll concentration, faecal coliform) |
| Brief definition: | This indicator will use the concentration of algae growing in coastal waters and the number of faecal coliforms to represent the health of the coastal zone ecosystem and the effectiveness of measures aimed at reducing nutrient inputs from run-off and discharge. | |
| Unit of measurement: | mg of chlorophyll per m ³ , most-probable-number (MPN) of faecal coliform per 100 ml | |
| Relevance: | <p>Coastal ecosystems provide important economic benefits, such as fisheries, tourism and recreation. They are also important for biodiversity, which is recognised by the Convention on Biological Diversity (CBD) as having its own intrinsic value as well as importance for human life and sustainable development. High algal concentrations in coastal waters reflect high nutrient inputs, which can represent serious threats to coastal ecosystem health. A large concentration of algae restricts the available light, reduces dissolved oxygen levels and may increase sedimentation, which smothers other organisms. Increasing concentrations of algae can also indicate threats to human and animal health by toxic algal blooms (EEA 2005).</p> <p>In addition, bacterial level in water is an indicator of water pollution, which can represent serious threats to coastal ecosystem health. Monitoring of coastal ecosystems is a central issue in the Riviera Maya, as coastal areas are used for tourism and recreational activities. In addition, coastal ecosystems in the Riviera Maya comprise the second longest barrier reef in the world (more than 500 km long).</p> | |
| Methodological description: | Guidelines have been produced by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), set up by the United Nations (UN) in 1969, in an effort to standardise the methods used for algae measurements (see: http://gesamp.imo.org/publicat.htm). Measurements of chlorophyll concentration using spectrophotometric and fluorometric techniques are often used as an indirect method of assessing algal biomass. At present, this information does not exist in the Riviera Maya. A GIS-remote sensing based database might be a suitable alternative to acquire the information on this indicator. | |
| Data needed to compile the indicator: | Standardised quantitative data on chlorophyll concentrations or the population and biomass of algae from an appropriately distributed network of sampling stations. MPN of faecal coliforms per 100 ml. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|--|--|
| Indicator: | 14 | Area of urban formal and informal settlements |
| Brief definition: | Urban residential area occupied by formal and informal settlements. | |
| Unit of measurement: | ha | |
| Relevance: | Urban development is one of the biggest land consumers. This indicator has the capacity to show changes in land-use patterns and landscape. In addition, urban growth can be related to the effects on vegetation cover, ecosystem fragmentation, flora and fauna diversity and cultural patterns. The indicator will be used to supervise the observance of the ELUP provisions, specifically the compliance with designated urban areas and densities of space use. | |
| Methodological description: | <p>Area of formal and informal settlements can be evaluated through aerial photography or land use maps. Informal settlements should not cover dwelling units which have been regularized. They should only include those units which presently occupy land illegally and/or housing which are not in compliance with current regulation.</p> <p>Where feasible, the interpretation and meaning of this indicator would be supported by the comparison of formal and informal settlement areas to total urban area. Area of formal and informal settlements has not been quantified in the Riviera Maya. A GIS-based database can be used to acquire and manage the information on this indicator.</p> | |
| Data needed to compile the indicator: | Area of formal and informal settlements. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|--|--|
| Indicator: | 15 | Transport infrastructure network |
| Brief definition: | Land take by transport infrastructure. | |
| Unit of measurement: | ha | |
| Relevance: | Land is under continuous pressure from new transport infrastructure. In addition, linear infrastructures may lead to ecosystem fragmentation. The indicator has the potential to show changes on landscape, soil and biodiversity. This information can be used to study transportation patterns in the Riviera Maya as a result of the ELUP implementation. | |
| Methodological description: | Land take by transport infrastructure can be evaluated through aerial photography or land use maps. This information has not been quantified in the Riviera Maya to date. The length of the transport infrastructure network was determined by INEGI and the Secretariat of Communications and Transportation of Mexico (SCT). A GIS-based database may be used to acquire and manage the information on this indicator. | |
| Data needed to compile the indicator: | Land take by transport infrastructure. | |
| Data source: | INEGI-SCT Internet address: http://www.inegi.gob.mx | |
| Status: | — | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> annual ▪ <i>Scope:</i> information by municipality, length and road type. ▪ <i>Data type format:</i> digital maps may be limited or nonexistent. |

| | | |
|---------------------------------------|---|--|
| Indicator: | 16 | Coverage of forest areas |
| Brief definition: | The indicator measures the total forest area as a percentage of the total area. | |
| Unit of measurement: | % | |
| Relevance: | Forests provide many significant resources and functions included wood products and non-wood products: i.e. recreation, wildlife habitat, water and soil conservation, carbon capture, etc. In addition, forests support employment, traditional uses and biodiversity. They are among the most diverse and widespread ecosystems of the world. Sustainable forest management is a key objective of the ELUP strategy. In addition, the information of this indicator may be relevant to biodiversity, water, air, soil, landscape and cultural patterns. | |
| Methodological description: | Coverage of forest areas can be examined through aerial photography and land-use maps. Information on forest areas at state and national levels is collected by SEMARNAT and the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico (SAGARPA) yearly. Coverage of forest areas in the Riviera Maya can be obtained using a GIS-database monitoring system. | |
| Data needed to compile the indicator: | Coverage of forest areas in hectares. | |
| Data source: | Forest yearbook, SEMARNAT/SAGARPA Internet Address: http://www.semarnat.gob.mx | |
| Status: | — | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> information at state level ▪ <i>Data type format:</i> digital information may be limited or nonexistent. |

| | | |
|---------------------------------------|---|--|
| Indicator: | 17 | Area affected by extraction of raw materials/mining |
| Brief definition: | Land affected by extraction of raw materials/mining. | |
| Unit of measurement: | ha | |
| Relevance: | The indicator measures the land affected by extraction of raw materials and mining. This information can be used to supervise the ELUP land-use strategy. This data can be useful to study changes on landscape, soil quality, groundwater quality, vegetation cover, ecosystem fragmentation, and flora and fauna diversity. | |
| Methodological description: | Coverage of land affected by extraction of raw materials and mining can be examined through aerial photography and land-use maps. This information has not been quantified in the Riviera Maya so far. A GIS-based database may be used to acquire and manage the information on this indicator. | |
| Data needed to compile the indicator: | Coverage of land affected by extraction of raw materials and mining. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|---|--|
| Indicator: | 18 | Distance travelled per capita |
| Brief definition: | The number of kilometres travelled per person in a given year by different modes of transport. | |
| Unit of measurement: | Kilometres per year | |
| Relevance: | The indicator may be helpful to examine the efficiency of the land-use strategy implemented through ELUP in the Riviera Maya by helping to determine energy consumption/efficiency and atmospheric emissions. Travel is an essential part of the economic and social life. However, motorized travel has greater environmental and social impacts, such as pollution, global warming and accidents. Sustainability implies using the most appropriate mode of transport and decoupling travel from economic development. Sustainable policies are thus policies that reduce the need for travel, support a shift towards less environmental damaging means, provide incentives for changes in lifestyle, increase safety, and improve the standard of public transport (based on CSD 2005). | |
| Methodological description: | The indicator should be broken down into the following modes of transport (CSD 2005): walking, cycling, passenger cars, motorcycles and mopeds, buses and coaches, train, ship, and plane. The indicator should be calculated as the total passenger-kilometres travelled per year divided by the total population, according to the different modes of transportation. Data on this indicator are compiled by INEGI in the Riviera Maya. Additional data may be required, which should be collected using surveys. | |
| Data needed to compile the indicator: | Passenger-kilometre data by means of transport and population. | |
| Data source: | Not identified | |
| Status: | X | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> ▪ <i>Scope:</i> ▪ <i>Data type format:</i> |

| | | |
|---------------------------------------|---|--|
| Indicator: | 19 | Status and trends of linguistic diversity and numbers of speakers of indigenous languages |
| Brief definition: | The number of indigenous languages and speakers. | |
| Unit of measurement: | Number of indigenous languages and speakers. | |
| Relevance: | This indicator illustrates patterns of cultural change by evaluating the number of indigenous languages and speakers. Activities in the Riviera Maya are impacting Mayan communities transforming their habits and customs. Analyses have shown a large overlap between regions that are rich in biodiversity and those rich in languages. Linguists and anthropologists have suggested that the diversity of ideas carried by different languages and sustained by different cultures is as necessary as the biological diversity and ecosystems is for the survival of the humanity and of life on the planet (CBD 2005). The extinction of a language results in the irrecoverable loss of unique cultural, historical, and ecological knowledge. Each language is a unique expression of the human experience of the world. | |
| Methodological description: | The number of indigenous languages and speakers is regularly collected and updated by INEGI | |
| Data needed to compile the indicator: | Number indigenous languages and speakers. | |
| Data source: | INEGI Internet Address: http://www.inegi.gob.mx | |
| Status: | + | <ul style="list-style-type: none"> ▪ <i>Quality assurance:</i> ▪ <i>Update frequency:</i> 5 years ▪ <i>Scope:</i> information by locality ▪ <i>Data type format:</i> |