Planning for Ecotourism in Uaxactún, Guatemala

by
Marina Alvarez
and
Lorcan French

A Master's Practicum
Submitted in Partial Fulfillment of the Requirements for the Degree of
Master's of Landscape Architecture at
The University of Michigan
2006

Thesis Committee:
Professor Joan Nassauer
Professor Ivette Perfecto

ABSTRACT

Located within the Maya Biosphere Reserve in northern Guatemala, the village of Uaxactún manages a large concession of land leased to them by the government. Our client the Wildlife Conservation Society (WCS) has played an integral role in helping the community secure this concession by aiding in the development of their sustainable forest management plan. Recently, however, the people of Uaxactún, with the help of WCS, want to pursue ecotourism as an alternative to their current resource use (timber and non-timber harvesting) in order to benefit from the tourism activities already existing in the region. In order to maintain their goal of sustainable forest management while pursuing ecotourism, we feel it is imperative to approach planning at the landscape scale in order to achieve sustainability. Using Geographic Information Systems we developed a model to be used as a framework for planning for ecotourism development. The model is based on principles of landscape ecology and analyses the impact of ecotourism activities on habitat quality and landscape connectivity (habitat fragmentation). This model aims to protect biodiversity and high habitat quality as well as incorporate tourist preferences to increase the success of tourism planning in the future.

Acknowledgments

We would like to express our gratitude and appreciation to the individuals and organizations that have invested time and resources into our project. Without their support this project would not have been possible. First and foremost, we would like to thank our two advisors Joan Nassauer, Professor of Landscape Architecture, and Ivette Perfecto, Professor of Natural Resources, for their invaluable input and insightful guidance throughout the stages of the project. Their commitment and support to the project was vital to its success.

We would also like to sincerely thank our client the Wildlife Conservation Society for their support in Guatemala by providing accommodations, contacts, and access to their resources. In particular, we extend or gratitude to Roan McNab, Director of WCS in Guatemala, for his guidance and support throughout the development and completion of this project. Also in association with WCS we would like to thank Victor Hugo Ramos for providing his technical support with GIS. Also, we want to thank OMYC and the residents of Uaxactún for welcoming us into their community and for providing us with invaluable local knowledge.

Finally, we want to express our gratitude to those organizations that provided us with funding and whose financial support made this project possible: International Institute Experiential Learning Fund, Education Fund of America, Rackham Graduate School at the University of Michigan, and the School for Natural Resources and the Environment at the University of Michigan.

TABLE OF CONTENTS

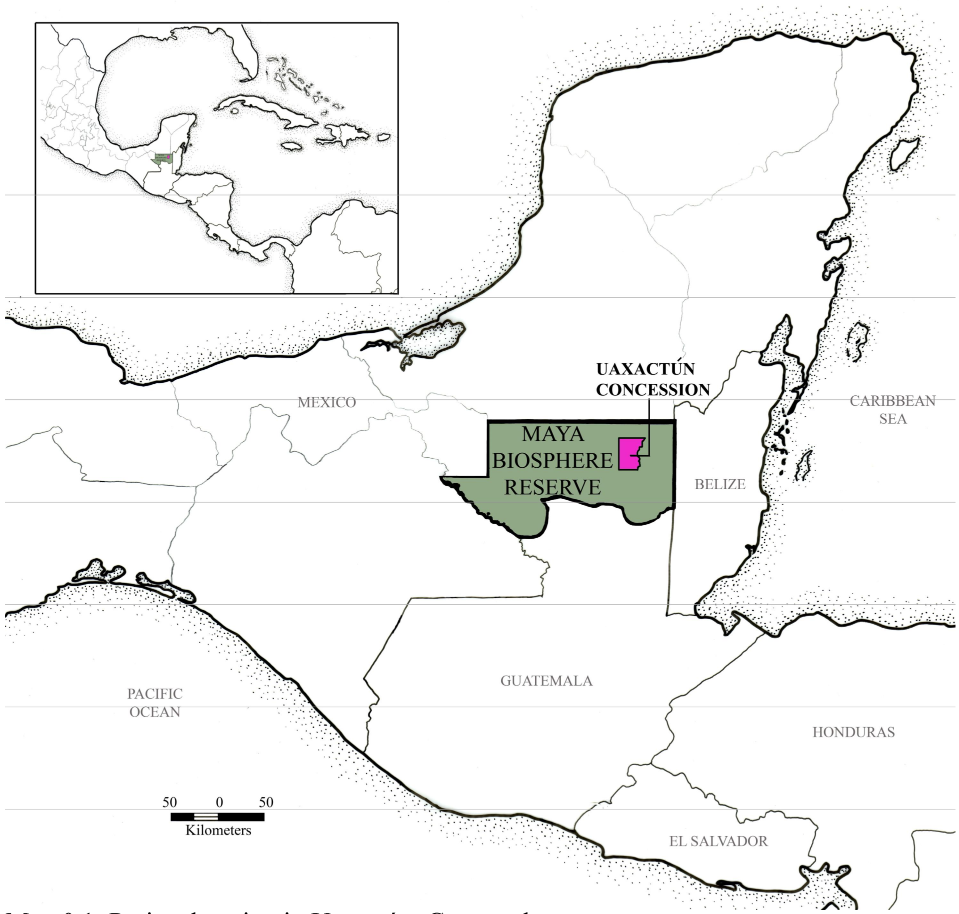
Introduction

Many of the world's greatest concentrations of biodiversity are located in developing countries where the struggle between preservation of natural resources and sustaining the livelihoods of local people who want to use those same resources creates significant challenges. In Guatemala the Maya Biosphere reserve was established to create a balance between protecting a large portion of intact continuous forest and allowing local communities to use the forest resources as a basis for subsistence and development. The success of this balance depends on the ability for communities and managers to plan for resource use at a landscape scale. It is at this scale that important spatial patterns can be preserved which allow landscape processes, such as wildlife migration and hydrological cycles, to continue to function.

Now, in the face of the emerging economy of ecotourism, Uaxactún, a community living in the reserve, wants to improve quality of life through ecotourism development. Ecotourism, in theory, could complement the community's conservation and development efforts. However, implementation without appropriate planning could lead to exploitation of forest resources and would undermine the advances the community has made towards achieving sustainable management of these resources. Our study provides Uaxactún and its support organizations with a model to plan for ecotourism at a large scale using principles of landscape ecology. This model aims to protect biodiversity and high habitat quality as well as incorporate tourist preferences to increase the success of tourism planning.

The village of Uaxactún is located in the Multiple-use zone of the Maya Biosphere Reserve (MBR) established in 1990 in northern Guatemala (Map 0.1). In 1999, this community was granted a 25-year concession from the government of Guatemala for the management of 206,476 acres of forest. This small community of mostly Ladinos (Spanish speaking people of mixed race) lives within the forest concession located 23 kilometers north of the famous Tikal National Park. The local community government of OMYC ("oh-meek") (Sociedad Civil Organización, Manejo y Conservación- *Civil Society of Organization, Management and Conservation*) is responsible for the management of the concession with the assistance of our client, the international non-profit organization of the Wildlife Conservation Society (WCS). In the application process for the concession, OMYC developed a comprehensive management plan for the entire concession to effectively develop sustainable land uses while protecting natural resources according to the requirements of the biosphere reserve model (UNESCO 1984). WCS also plays an important role in helping the community develop management strategies for sustainable resource use and the conservation of flora and fauna.

Recently the community has expressed interest in diversifying their economy to include sustainable ecotourism. Their interest in this venture has prompted OMYC to form the Ecoguías, a group of young community members training to become tourist guides. This intention to pursue ecotourism is also stated in their management plan created by the community in conjunction with the Wildlife Conservation Society. At this time their economy consists mainly of the extraction of non-timber forest products, along with limited timber extraction, tourism, and sales of local crafts. Tourism is addressed briefly in the Uaxactún Management Plan, but no comprehensive plan exists. Due to Uaxactún's proximity to the Tikal National Park and ruins, the presence of excavated ruins in the village of Uaxactún, and the growing interest in tourism development in the region, the potential for pursuing ecotourism in the concession is great - it is also highly precarious if the industry is unsustainable and threatens the natural resource base. Many other regional development pressures exist that threaten to compromise the sustainability of the concession's management practices and the integrity of the biosphere reserve model, which aims to allow humans to live in a mutually beneficial relationship with protected areas. If Uaxactún villagers cannot protect their values, traditions, and natural resources in the face of such development pressures, they risk losing their grant given to them by the government to manage the concession. In order to continue to protect their earned right to manage the concession resources and manage for environmental impacts, we feel the community must plan for sustainable ecotourism at a large scale and from an ecological perspective using principles of landscape ecology. There is a growing consensus among conservation biologists and practitioners that conservation strategies need to be implemented at a large scale in order to be most effective (With, in Wiens and Moss, 2005). It is important that



Map 0.1: Project location in Uaxactún, Guatemala.

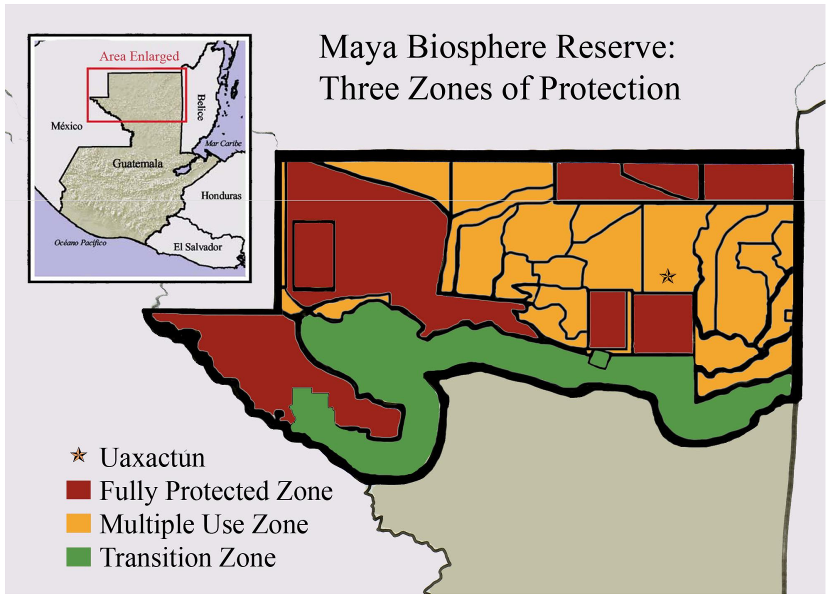
planning for any diversification of resource use, including ecotourism, is approached at a large scale, carefully, and purposefully.

Our Master's practicum, *Planning for Ecotourism in Uaxactún Guatemala*, provides a model for the community, OMYC, and WCS to use as a framework in planning for ecotourism. Uaxactún has already proven itself as a role model to other community concessions in the reserve by their organization and vigilance in preventing forest fires and deforestation. The community now has the opportunity to continue to set an example in the region with ecotourism planning. More importantly it has an opportunity to strengthen the success of the biosphere concession model by proving the effectiveness of allowing sustainable resource use by local communities to achieve conservation. Using geographic information systems (GIS) we have taken a broad scale approach to planning for ecotourism development that aims to protect rare and vulnerable habitats and preserve critical landscape patterns. By adapting the models to include tourism preferences surveys completed (Juska and Koenig 2006, Shoka 2006), our results and recommendations aim to provide an initial analysis of ecotourism suitability based on principles of landscape ecology.

CHAPTER ONE: CONTEXT

Context: Uaxactún, Guatemala

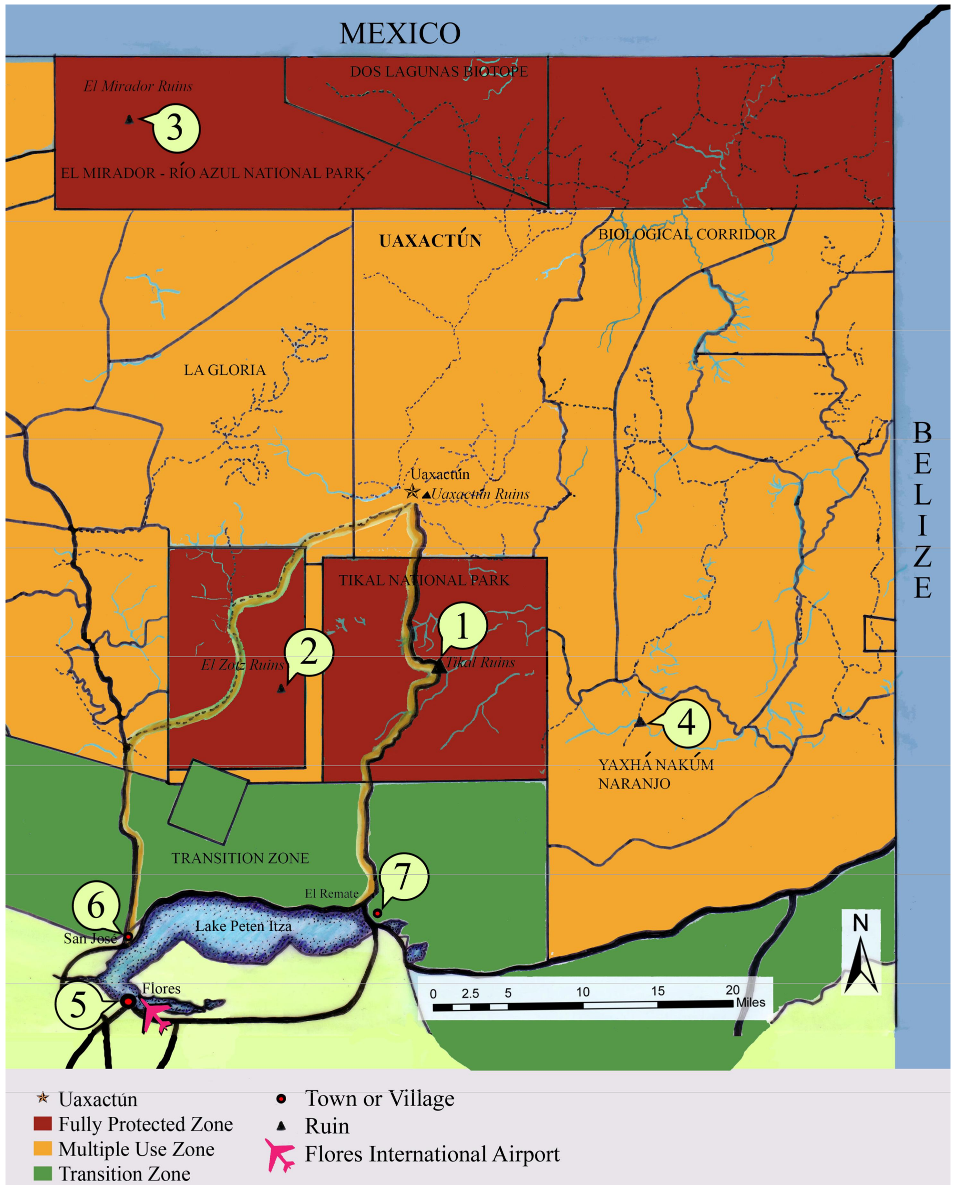
The community concession of Uaxactún includes 83,558 hectares (206,476 acres) of land within the Multiple-use zone of the Maya Biosphere Reserve (MBR). The village of Uaxactún located within the concession is located within the municipality of Flores, the capital city of the department of Petén. The MBR was created to maintain forest cover and biodiversity, while enabling local communities to benefit from sustainable resource use. With the reserve model, there are three zones of protection: the less protected transition zone buffering the reserve, the Multiple-use zone which allows sustainable resource use, and the fully protected national parks (Map 1.1). Even though Uaxactún's concession is located within the Multiple-use zone, it is adjacent to two fully protected areas; the national park of Tikal to the south, and Mirador-Río Azul National Park to the north. To the east of the concession also in the Multiple-use zone is the Biological Corridor La Danta-Tikal-Triángulo connecting Tikal National Park to the eastern portion of Mirador-Rio Azul National Park. To the west is the industrial concession[1] of La Gloria, which is a part of the municipality of San José, (OMYC 1999). Uaxactún's location between two fully restricted areas puts it in a unique position to act as a linkage for these areas. Uaxactún is also located on the more remote eastern side of the MBR which is adjacent to protected areas in both Mexico and Belize. The eastern side has so far been less vulnerable to colonization and development pressures when compared to the western side, thus increasing its' biological value as a less disturbed region of the forest.



Map 1.1: Three zones of biosphere reserve model in northern Guatemala.

[1] An industrial concession managed by the government and only allows limited timber extraction whereas a community concession is managed by the community and allows both timber and non-timber resource extraction.

Major regional tourist destinations include (Map 1.2) the Tikal ruins to the south (1), the El Zotz ruins and bat caves to the southwest (2), and the ruins of El Mirador to the north (3). The aforementioned ruins are currently being excavated and are the largest complex of preclassical ruins discovered to date. Also, more recently the site of Yaxhá Nakúm to the southeast (4) has become a popular destination due to its use as a filming location on the U.S. television series "Survivor". The city of Flores (5) is the central location for tourist operators and tourists due to its proximity to Tikal and the presence of a small international airport. Flores is located on a small island in the south west end of Lake Petén Itza. Other destinations around the lake include the city of San José on the north side (6), and the town of El Remate on the north east side of the lake (7) that was the most visited resort town in the region according to a tourist survey done in 2005 by Juska and Koenig (2006).

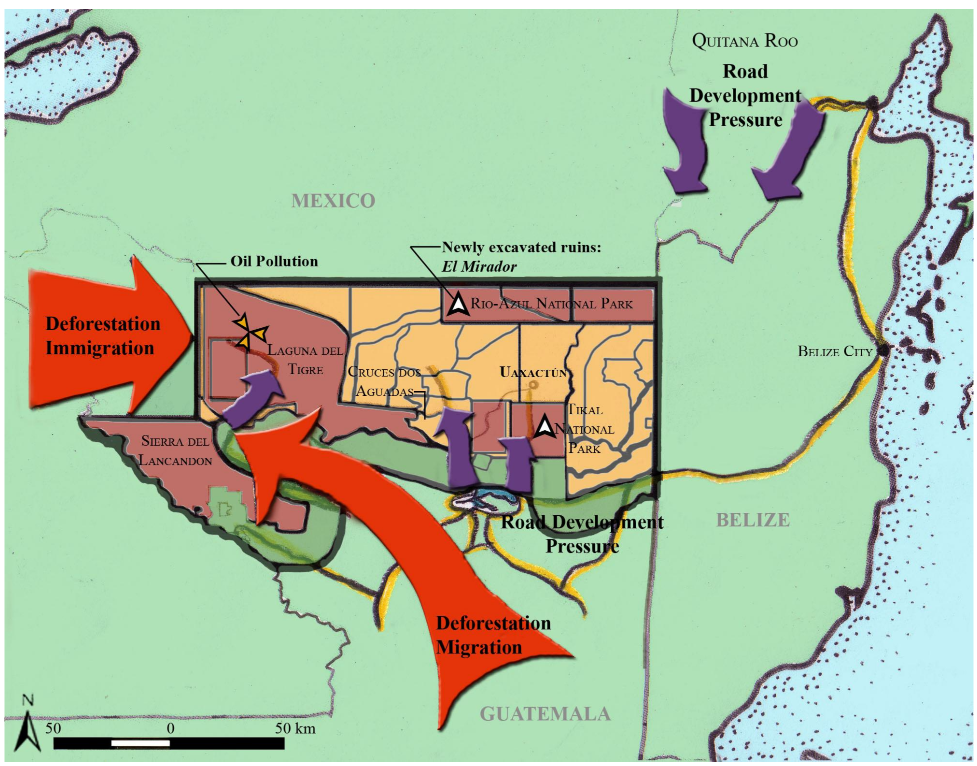


Map 1.2: Tourist destinations around Uaxactún

Threats to the MBR

Map 1.3: Location of the Maya Forest. Modified from Radachowsky (2002).

The MBR is located in the greater Northern Mesoamerican region referred to as the Maya Forest (Map 1.3). The Maya Forest contains a large portion of protected land and intact forested areas within, and is comprised of two countries (Guatemala and Belize) and five states in Mexico (Campeche, Chiapas, Quintana Roo, Tabasco and Yucatan). It functions as a wildlife corridor that provides habitat and allows movements of many wildlife species including many that are endemic to the area. This area is unique in that it contains some of the world's greatest biodiversity and has been identified by the Critical Ecosystem Partnership Fund as the second most important of 25 hotspots in the world for species diversity and endemism- only the Tropical Andes hotspot ranks higher (CI 2004). An ecological evaluation of the Mirador-Río Azul National Park in the northeast corner of the reserve found the presence of numerous endangered and endemic species, including many range extension of wildlife otherwise thought to be endemic to the Yucatan peninsula (WCS 2004). Another critical biological function is that the convergence of three of the Western Hemisphere's four migratory bird routes occurs in this region. Also, the Maya Forest (Map 1.3) is the "largest continuous expanse of tropical rainforest in the Americas after the Amazon" (CI 2004). The conservation of this continuity is one of the primary goals of the reserve managers. However, major factors such



Map 1.4: General areas of threats in the MBR relative to Uaxactún

as deforestation, pollution, and landscape fragmentation threaten the conservation goals of the MBR.

Understanding the types of activities that are threatening the conservation efforts in the MBR and their locations helps us understand the role Uaxactún can play in maintaining the overall health of the MBR region. While many of these threats occur throughout the region, others are concentrated in specific areas (Map 1.4). For example the western region of the MBR Laguna del Tigre has been especially affected by deforestation, immigration from Mexico, and migration from southern Guatemala (CI 2004). Also, recent development proposals indicate the newly excavated ruins in El Mirador to the east may now provide an incentive for developers to create more roads through the reserve for better access to the ruins (GHF 2004). The community of Uaxactún has the opportunity to provide intact forest cover that would allow for movement of wildlife throughout the greater landscape, and provide interior habitat to populations of species most sensitive to disturbance. At the same time any proliferation of threats to biodiversity within the concession would affect the entire region. Understanding the importance of this role emphasizes the need for Uaxactún to approach ecotourism in a manner that will maintain ecological integrity by optimizing levels of resource use and conservation of biodiversity.

The table below (Table 1.1) summarizes the threats to the MBR caused by multiple factors present in the region and briefly describes their impacts on the ecosystem and where they are located. While the majority of these threats occur to the west of Uaxactún in Laguna del Tigre and Sierra del Lacandón, or are concentrated in the transition zone from which Uaxactún is further removed, many of the impacts are experienced throughout the concession. The presence of an access road into Uaxactún from Flores, the capital of Petén, is especially noteworthy, as often roads can become vectors for an increase in human-access disturbances, an increase in pollution, and in the long range the blockage of routes for wildlife movement (Sader *et al.* 1998, Grunberg *et al.* unpublished).

Table 1.1: Threats to the MBR

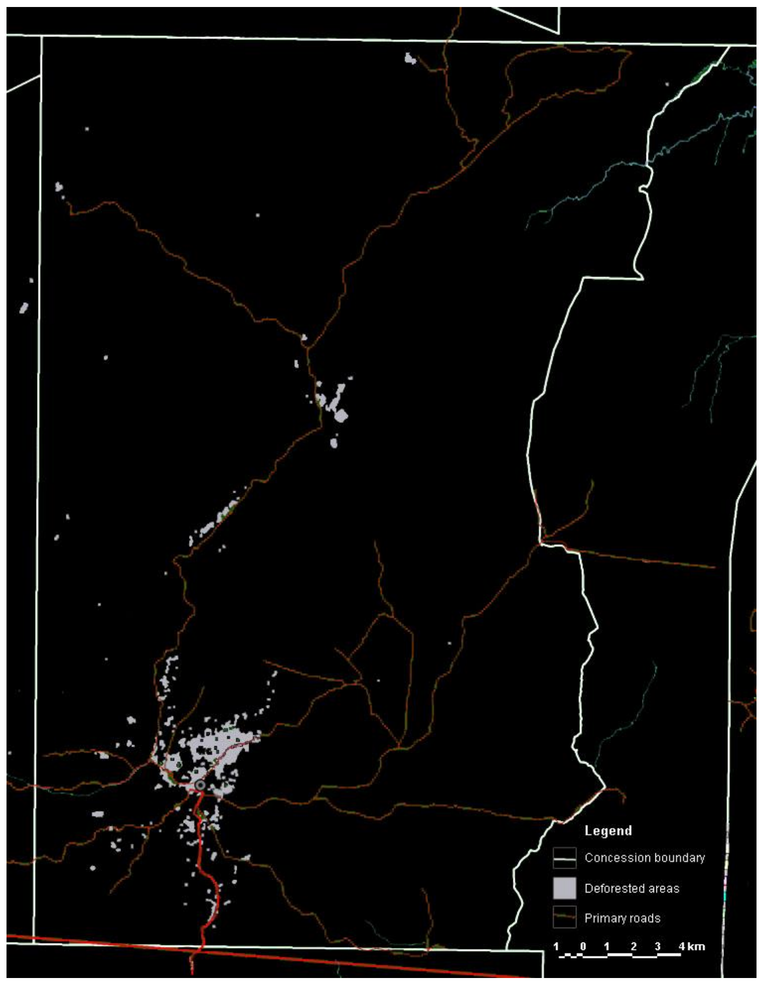
Factor	**Impact to ecosystem**	**Description**	**Areas of concentration within MBR (Map 1.4)**
Agriculture	Deforestation	-Soil compaction and erosion -Change in natural hydrological cycle -Decrease in water quality -Change in forest structure and plant communities -Loss of habitat -Fragmentation of wildlife corridors -Loss of carbon sequestration	-Laguna del Tigre -Sierra del Lacandón -Throughout transition zone
	Habitat fragmentation	-Destruction of core habitat -Habitat/patch isolation	
	Increased risk of fire	-Associated with slash and burn land clearing techniques -Loss of soil nutrients from leaching	
	Pollution	-Use of agrochemicals further degrades water quality	

Unsustainable logging	Deforestation	See above	Throughout the biosphere reserve
Road presence (Forman 2003)	Short range	-Particulate and aerosol materials deposited	Throughout the transition zone: -To Uaxactún -To Laguna del Tigre -Along NW boundary of Sierra del Lacandón -Through Cruces dos Aguadas
	Medium range	-Transfer of energy and materials that disrupt natural processes (ex. heavy metals deposition, mineral nutrients deposition, inhibiting seed germination etc)	
	Long range	-Human-access disturbances -Exotic species spread -Effects in streams -The blocking of wildlife movement routes	
Proposed and potential development	Deforestation	See above	-Mundo Maya Project -Quintana Roo Road -Plan Puebla Panama
	Road effects	See above	
	Habitat fragmentation	-Destruction of core habitat -Habitat/patch isolation	
Oil extraction	Pollution	-Pollution to groundwater and surface water including Polycyclic Aromatic Hydrocarbons (PAH's)	Laguna del Tigre
	Associated infrastructure	-Increase in human-access disturbances	
Unsustainable non-timber-resources extraction (hunting, xate harvesting)	Over-hunting and decrease of local wildlife populations	-Potential for extinction of endemic/ endangered species	Associated with settlements throughout MBR
	Loss of xate palm in understory	-Potential for local extinction of xate	
Lack of institutional support	Unregulated use and overexploitation of natural resources		Throughout MBR

CHAPTER TWO:
APPROACH, GOALS, AND OBJECTIVES

Approach

Our model creates a plan for ecotourism in Uaxactún that focuses on protecting natural resources from the impacts of tourism. Impacts of tourism are caused by multiple factors including the location of tourism activity, activity type, season of activity, equipment used, and specific plant or animal species responses to activity (Buckley 2000). There are therefore many approaches one can take to reduce these impacts. Our model focuses on how to manage for biodiversity by planning the location of activities that occur in the concession. We feel that in using a landscape approach to the placement of potential impacts, the regional spatial structure and ecological processes can be most effectively protected, therefore maximizing biodiversity.



Map 2.1: Overall forest cover of the Uaxactún concession. (Modified from WCS)

We approach protection using a regional landscape approach that stems from principles of landscape ecology. As described by Turner in her 1989 article *Landscape Ecology: the Effect of Pattern on Process*, "Landscape ecology emphasizes broad spatial scales and the ecological effects of the spatial patterning of ecosystems. Specifically, it considers (a) the development and dynamics of spatial heterogeneity, (b) interactions and exchanges across heterogenous landscapes, (c) the influence of spatial heterogeneity on biotic and abiotic processes, and (d) the management of spatial heterogeneity" (Turner 1989). Through protecting spatial patterns we aim to preserve the integrity of ecological processes. Ecological processes include: wildlife movement, seed dispersal, animal foraging patterns, groundwater flows, and stream flows (Forman and Alexander 1998). The spatial structure of Uaxactún is a continuous matrix of lowland tropical forest habitat with large areas of interior forest. Disruptions to this structure causing fragmentation include dissections by the road network and perforations by the village and cultivated fields (Map 2.1). Our approach would therefore seek to maintain the continuous matrix of Uaxactún's forest cover in order to best preserve the ecological processes in the region.

The proposed model provides an approach to ecotourism planning that takes into account the most conservative measures of wildlife sensitivity to ecotourism impacts, and the distance those impacts may extend. By focusing on how these sensitivities translate to broad landscape patterns, this approach would allow for the initiation of ecotourism activities before the desired biological and environmental surveys and inventories have been conducted, or in the case that it is not feasible to do so. A report by D'Eon and colleagues (2002) discusses how the maintenance of spatial patterns can act as a surrogate for more species-specific scientific approach. There is no true surrogate that could represent all biodiversity in all situations (Margules in Weins and Moss 2005). While this approach does not incorporate specific organism vagilities[2], we hope to achieve maximum biodiversity protection.

We viewed a landscape ecology approach as the most appropriate approach for accomplishing a comprehensive plan for ecotourism. This approach is suitable for achieving balance between resource use and resource protection in Uaxactún for numerous reasons:

1. Because Uaxactún is the link between two protected areas (Tikal and Mirador-Río Azul National Parks), maintaining landscape connectivity is an important and regional issue.
2. A highly intact forest cover already exists, therefore, maintaining interior habitat is a significant issue.
3. The large scale of the site requires the use of a landscape approach in order to effectively operate at such a broad scale.
4. A high incidence of endemic/endangered species warrants the protection of their habitats and movement through the landscape in order to insure that their populations continue to be healthy.
5. A landscape ecology approach may protect species and ecosystem components without the use of costly and time intensive biological surveys by offering a generalized spatial solution (Forman and Collinge, in Degraaf and Miller 1996).
6. This approach can be implemented immediately.

Uaxactún residents and specifically our clients OMYC and WCS have an interest in pursuing ecotourism to complement their economy if it has the potential to be compatible with their policy of sustainable resource use. While tourism already exists, it is at an undesirably low level, and is limited by a lack of organization within the community, and a lack of proper planning. OMYC and the Ecoguías (the Uaxactún guide organization) are interested in pursuing ecotourism activities that involve overnight guided tours into the forest. A snapshot tourist survey completed by Juska and Koenig (2006) concurrently with our study supported this desire by revealing that 84% of tourists' were interested in overnight tours as well. Our model reflects our clients' interests and tourist preferences by its focus on the regional scale. Our planning approach is to create a model that attempts to strike a balance between future tourism resource use and natural resource protection.

[2] Vagility refers to a species' dispersal ability. In the paper by D'Eon and colleagues "Landscape Connectivity as a Function of Scale and Organism Vagility in a Real Forested Landscape" (2002), the authors found that highly vagile old-growth associates perceived patches of harvest, old-growth, and recent wildfire patches as connected. Less vagile species in turn perceived the same landscape matrix as lacking connectivity because their interaction with the patches was at a different scale.

In many respects it is to the advantage of Uaxactún residents that ecotourism development in Uaxactún is still in its infancy. There is a need for further investigations and analysis of the landscape before managers and local entrepreneurs can make informed decisions about offering sustainable tours. Specifically, in creating the model we were limited by a lack of information concerning the karst geology of the region, and how resource use would impact the water resources in the area. As more information is gathered and surveys are conducted, objectives and conditions for ecotourism planning could change. These uncertain and changing conditions require a flexible planning tool. We have attempted to provide OMYC with a model that could adapt to changing scenarios.

Although in our project we address only ecotourism, we view the model as a tool that could be applied for other resource use decisions in the concession.

Guiding principles:

1. Maintain levels of landscape connectedness, forest cover intactness, and forest interior habitat.
2. Avoid any increase in the extent of existing disturbance associated with current resource use such as disturbance from roads or camps.
3. Use only existing camps and roads for ecotourism activities due to the increase in disturbance that would result from the creation of new infrastructure.

One overarching decision was not to consider the placement of any new camps, roads, or related infrastructure that would be used in the pursuit of ecotourism development. We decided to use established camp locations as the focus of our analysis. We felt it was important to minimize any increase in the level of disturbance or deforestation that could be associated with future ecotourism activities. This strategy would also minimize negative impacts on wildlife habitat.

In summary, our approach was shaped by the following:

Table 2.1: Description of approach

Observation	**Approach**
• High percent forest cover and relatively low levels of disturbance on the Uaxactún landscape • Important area for linkages between Tikal and Mirador-Rio Azul National Parks	Use landscape ecology principles
	Concentrate tourism infrastructure in areas already affected by resource use
	Designate existing infrastructure (roads/camps) to be used for ecotourism activities
• Client interest in ecotourism activities that involve overnight guided tours into the forest	Focus model on camps located throughout concession
• Gaps in information and data	Provide the Uaxactuñecos with a flexible model that can be adapted to incorporate changing tourist preferences, ecological data, and conservation priorities

Goals and Objectives

In order to create our model, we established objectives that represent our goal of adhering to principles of landscape ecology. Our goal was to maintain the spatial integrity and structure of the landscape in order to preserve the ecological integrity and function of the landscape. While structure and function are intrinsically related, they represent different dimensions of the landscape and are measured in different ways. Taking this into account, the objectives focus either on habitat quality or on connectivity and the probability of habitat isolation. For example, our objectives would identify sensitive or biologically valuable habitats based on their rarity, vulnerability, or remoteness. Our objectives would also identify habitat connectivity or isolation as distinguished by continuous forest cover, dissection by roads, or perforation by cultivated fields.

Our goal is represented by four objectives (Table 2.2), and descriptions of each objective will follow.

Table 2.2: Description of objectives

Goal	Objectives
Maintain spatial integrity and structure of the landscape in order to preserve the ecological integrity and function of the landscape.	Protect areas that contain rare or sensitive habitat types
	Protect areas vulnerable to erosion
	Maintain habitats that exhibit high degrees of connectivity
	Protect interior forest habitats from impacts of roads

Descriptions of Objectives

Protect areas that contain rare or sensitive habitat types:

In Uaxactún, wetlands, low forests, riparian forests and bodies of water are sensitive habitats because they provide regionally rare habitat to endangered and endemic species (Garcia and Radachowsky 2004, WCS 2004, Ramsar convention www.wetlands.org). In addition, wetlands, riparian forests, and bodies of water provide important habitat to many endemic species such as the bird species Yucatan jay (*Cyanocorax yucatanicus*), Black catbird (*Dumetella glabriostris*), Ocellated turkey (*Meleagris ocellata*) and amphibian species Yucatan Casque Headed Tree Frog (*Triprion petasatus*), Leprus or Mottled Chirping Frog (*Eleutherodactylus leprus*) which is also on the IUCN (Red List) status as Vulnerable (VU), and the Elegant Narrowmouthed Toad (*Gastrophryne elegans*) (Radachowsky 2002). These habitats are also important because they provide surface water to all wildlife including endangered species such as Baird's Tapir (*Tapirus bairdii*), large cats, and numerous other endangered bird, reptile and amphibian species (Garcia and Radachowsky 2004). For these reasons we recognize these habitats as having special value and deserving preservation.

In the temperate zones of the United States, wetland and riparian areas are protected from disturbance through the strict protection of the areas surrounding the habitat. Studies have shown that terrestrial ecosystems extending beyond these sensitive habitats are used in the life cycles of otherwise aquatic species. A review of biological criteria for protecting terrestrial habitat around wetlands and riparian habitat by Semlitsch and Bodie (2003) found that amphibians and reptiles required on average an approximately 250 meter area beyond the aquatic habitat to truly represent the extent of habitat they used. They argue that the protection of both these terrestrial and aquatic areas is critical to maintain the biodiversity of amphibians and reptiles associated with wetland and riparian habitats (Semlitsch and Bodie 2003). Studies also show that amphibian and reptile species have an extreme sensitivity to water pollution making them conservative bio-indicators of water quality impacts (Buckley 2000).

Protect areas vulnerable to erosion:

Disturbances such as roads, harvesting activities, or fires will lead to soil erosion (Elliot and Hall 1997). We would also associate similar disturbances with an increase in recreational activities. Vegetation helps stabilize forest slopes with their root strength and their lowering of soil moisture content (Ziemer 1981). The loss of this stabilization through deforestation or trampling results in a lower slope safety factor, and increases the chance of erosion. The relative stability of a slope also depends on the type of soil present.

In Uaxactún the soils are described as gray or brown clay soils, sometimes with limestone rocks protruding from the surface. They range from shallow to deep and well drained to poorly drained (Brokaw and Mallory 1992, Wright *et al*. 1959, Iremonger and Brokaw 1995, Cabrera and Sanchez 1994, Martínez-Tuna 1999). An electronic 1:200,000 Food and Agricultural Organization of the United Nations (FAO) soil series map provided by CONAP describes the soil series as Quinil-Yaxha-Chapayal-Uaxactún, and the soil orders as Rendzinals, Cambisoles and Vertisoles. When these karstic soils (with their high proportion of clay) are exposed to high levels of rainfall, the chance of erosion increases.

In order to prevent erosion and habitat degradation associated with erosion, activity can be either limited or excluded from areas with steep slopes, or special construction techniques can be implemented. It is important that areas with steep slopes remain forested and as undisturbed as possible by walking trails, roads, or camps. The Uaxactún management plan has limited activity in areas where the slope is above 24 percent (OMYC 1999). On the other hand, an eight percent or above slope is categorized as “steep” with regards to soil conservation, and a 15 percent slope is considered the maximum slope that allows for infiltration without erosion (BMP guidelines to the karst regions of Maryland, USA 2006, USDA Conservation Service 1975). We chose to designate areas of a slope of 15 percent or above as “steep” in order to insure maximum infiltration during the expected high levels of rainfall.

Maintain habitats that exhibit high degrees of connectivity:

For this objective, we focus on maintaining connectivity in habitats within Uaxactún that exhibit *high degrees of connectivity*. The degree of connectivity is defined by Forman as a measure of how connected or spatially continuous a corridor network or matrix is, and is an important indicator of ecological integrity and habitat quality (Forman 1995). The higher the degree of landscape connectivity is, the greater the capacity for the landscape to facilitate animal movement and other ecological processes (Forman *et al*. 2003).

Conversely, habitat fragmentation has serious impacts on plant and animal populations and is one of the most commonly cited threats to species extinction and an ensuing loss of biological diversity (Wiens 1996 as cited by D'Eon *et al*. 2002). Decreasing fragment size has been positively correlated with a decrease in species richness. In the Neotropics it is thought that forest fragments of <10,000 ha suffer a loss of an array of area-demanding species (Terborgh 1992; Chiarello 2000 as cited by Laidlaw 2000).

Connectivity, the inverse of fragmentation, is an essential element of the landscape structure because of its importance to population survival (D'Eon *et al*. 2002). The road network in Uaxactún has transformed the spatial structure of the landscape by reducing levels of connectivity, thus affecting the patch size and habitat quality. By analyzing the effects of the road network on the spatial structure of the landscape we can identify and maintain habitats that exhibit high levels of connectivity. When conducting our analysis of connectivity we found it necessary to expand the scale of the study site beyond the boundaries of the Uaxactún concession. The main reason for this was because the ecological processes that are affected by connectivity, such as wildlife movement patterns, operate at landscape scales that extend beyond the concession boundaries.

<u>Protect interior habitats from impacts of road:</u>

Dissection by roads can be differentiated from other cases of dissection because of the additional disturbances associated with vehicular traffic along road corridors. Road disturbances have negative impacts on the adjacent patches that are not always associated with other cases of dissection. These impacts include: road avoidance by wildlife due to traffic noise, changes to the hydrological cycle, and increased sedimentation and harmful chemical deposition to nearby habitats (Forman and Alexander 1998). The distance to which these different ecological effects extend outward from the road corridor has been described as the *road-effect zone* (Forman and Alexander 1998, Forman *et al*. 2003) and will be described in greater detail in the next chapter.

We applied this road-effect zone concept in order to analyze the impacts of roads on the habitats in Uaxactún. We also wanted to identify those habitats that are most impacted by roads from those that are interior enough from disturbance to provide habitat for interior wildlife species.

CHAPTER THREE:
BACKGROUND

As Uaxactún considers the expansion of their economy to include ecotourism, it is important to understand the context of tourism as a growing industry, and tourism's growing role in supporting conservation in protected areas. In one respect it seems that Uaxactún is poised to succeed as a tourist destination due to its location in a remote jungle of the internationally recognized MBR. It also seems to be the ideal candidate for ecotourism because of its location adjacent to one of the most popular tourist destinations in Guatemala, the Tikal ruins. However there exists a real risk of impacting or degrading the valued resources of the concession with the unplanned or unmanaged development of ecotourism activities, especially concerning impacts from roads. With careful planning and management, tourism can be compatible with resource protection.

Role of Tourism in Conservation

The United Nations World Tourism Organization (UNWTO) met on September 13, 2005 to make a declaration on the growing importance of tourism. They specifically recognized the growing role sustainable tourism contributes to environmental conservation, especially in developing countries.

The growth and volume of the tourism industry is an important component in conservation efforts. According to the UNWTO, in 2004 international tourist arrivals reached an all-time record of 763 million as compared to 532 million in 1994. In absolute figures worldwide earnings on international tourism reached a new record value of US $623 billion in 2004 as compared to US $337 billion in 1994. UNWTO's "Tourism 2020 Vision" forecasts that international arrivals are expected to reach over 1.56 billion by the year 2020. Just between 2000 and 2004, international tourist arrivals in Guatemala increased by a notable 34% as compared to an average of 11% throughout the Americas. Estimates of ecotourism officially represent only a fraction of these numbers for tourism, but there is still an expectation that non-ecotourists will increasingly visit national parks and protected areas.

There is no internationally accepted definition of "ecotourism". Ecotourism as an alternative to mass tourism is one of many options that include responsible tourism, science tourism, ethical tourism, soft-tourism, environmentally-friendly travel, green tourism, sustainable tourism, adventure travel, and low-impact tourism (Goodwin 1996). These alternatives are a result of the tourism industry's response to the impacts of mass tourism on the environment and the visitors' experience. Many of these alternatives could be considered a marketing tactic with no real meaning. Ecotourism on the other hand is one alternative for which there has been a push for a universal definition (Goodwin 1996).

Goodwin (1996) wrote a thorough review of the various definitions of ecotourism in his paper "In Pursuit of Ecotourism". In it he explains that part of the reason for the popularity of the term is that it has a number of different meanings, and it is therefore used often and indiscriminately. Also, the term has been exploited as a marketing tool because the tag '*eco-*' is associated with responsible consumerism. Other examples include ecotour, ecotravel, ecosafari, ecovacation, eco(ad)venture, ecocruise, and so on (Cater and Lowman 1994). The various definitions for ecotourism described in Goodwin's paper vary in the degree to which they encourage the growth of the local economy, the education or increased conservation awareness of ecotourists, and the environmentally responsible behavior or attitude expected of the ecotourists themselves. Goodwin and others (Buckley 2000) stress the importance of protected area managers, conservationists, and local people to agree on a definition that can be used analytically.

As a conclusion to his review, he created his own definition for ecotourism:

Low impact nature tourism which contributes to the maintenance of species and habitats either directly through a contribution to conservation and or indirectly by providing revenue to the local community sufficient for local people to value, and therefore protect, their wildlife heritage area as a source of income.

Specific to our study area, the Consejo Nacional de Áreas Protegidas (CONAP), the Guatemala national management body of the Maya Biosphere Reserve, created their own definition for ecotourism in their document "Master Plan for the Maya Biosphere Reserve 2001 – 2006", (SMARN/CONAP 2000).

***Ecoturismo**: Viaje o visita ambientalmente responsable a sitios naturalmente poco intervenidos, con la finalidad de disfrutar y apreciar la naturaleza y cualquier recurso de carácter cultural asociado del pasado o del presente. El ecoturismo tiene un bajo impacto ambiental, apoya la conservación de la naturaleza, provee beneficios socioeconómicos a las poblaciones locales y recursos financieros a las áreas protegidas.*

Ecotourism: Environmentally responsible travel or visits to relatively undisturbed areas, with the purpose of the enjoyment and appreciation of nature and any cultural resources of the past or present. Ecotourism has a low impact on the environment, supports the conservation of nature, provides socioeconomic benefits to the local populations and financial resources for the protected areas. (Translation by the authors)

If all ecotourism activities in the MBR adopt CONAP's definition for ecotourism, then steps can be taken for local communities to take ownership over the types of tourism ventures that are allowed to occur in their concessions to ensure that they contribute to conservation. A commitment to low impact activities and for funding to be directed toward common conservation goals would make more certain the sustained integrity of tourism management in response to tourism's growing pressure.

Impacts of Ecotourism

Numerous non-government organizations and international conservation organizations and governments perceive and endorse ecotourism as a sustainable solution to the conservation of natural resources, especially in protected areas (Stem *et al.* 2003, Wells and Brandon 1992, IUCN website, WCS website). Several case studies have since questioned this assumption to assess what the impacts of ecotourism are, and the results have been both positive and negative. The importance of these impacts is now widely recognized by management agencies, environmental non-government organizations, and researchers (listed in Buckley 2003, UNEP 2002), but it is also recognized that there is a significant lack of knowledge of visitor impacts (Grossberg *et al.* 2003, Leung and Farrell 2002). Impacts on wildlife and the physical environment as well as lessons learned need to be reviewed in order to better understand how ecotourism can be used as a tool for sustainable conservation of a protected area.

Impacts on Wildlife

Impacts on wildlife are assessed both directly through observations of behavior, and indirectly through measures of habitat degradation and the effects of new infrastructure. The wide range of sensitivities of animals and ecosystems makes it difficult to generalize the effects of any impact. Wildlife species have a range of responses to the presence of tourists and infrastructure. Vegetation types have a range of responses to trampling by tourists from increase in stress, loss of foliage, or slow population decline. They are also affected by fragmentation caused by new infrastructure causing changes such as plant composition. Also influential is the type of activity, the type of equipment used, and the season during which the activity occurs. It is extremely difficult to predict exactly what effects any impact may cause in a highly complex and functioning ecosystem. Add to this the observation by Buckley (2000) that research focusing on the more inadvertent ecological impacts of tourism and recreation is rare.

More detailed studies are available which focus more on directly observable impacts on wildlife. The impact of ecotourism on animal population densities, species composition, and community structure was investigated in a study conducted by Hidinger (1999) in Tikal National Park, Guatemala located 23 kilometers south of the village of Uaxactún. She compared measurements of select animal populations near the Tikal ruins site where tourists are concentrated, with a more remote control site without tourist traffic. She found certain species such as the agouti, coatimundi, deppes squirrel, and ocellated turkey had greater densities around the more highly trafficked ruins area. This was attributed to the specie's ability to adapt to human presence as well as the lack of predators when tourists were present. On the other hand species such as the crested guan, great curassow, and tinamou were found in greater densities at the remote control site. The two explanations offered were that the crested guan and great curassow are large game birds hunted for food and therefore have a healthy fear of humans, whereas the tinamou is a timid species with a preference for more interior habitat. Finally, the peccary, howler monkeys, and spider monkeys were found to be equally occurring in both the ruins and the control site. However, behaviorally the monkeys were found to respond more sensitively to humans in the control site by shaking branches etc, as compared to the absence of a reaction at the ruins. This study concluded that a management strategy of concentrating tourists in already disturbed areas would minimize negative impacts on animals.

Another study done by Grossberg *et al.* (2003) nearby in Belize addressed the impacts of ecotourism specifically on the endangered black howler monkey, *Alouatta pigra*. Through surveys of tour guides and visitors, as well as observations of tour group interactions with howler monkeys, impacts to monkeys and perceptions of impacts were analyzed. Grossberg found interactions to range from silent observation of the monkeys, to more intense shaking of branches, offering of food, and roaring at the monkeys in an attempt to elicit a roar. The study found that larger tour groups had the most intense interactions with the howler monkeys. Of 108 tourists surveyed who experienced a more intense interaction as described, only 18% perceived the actions as potentially harmful to the monkeys. The reality is that observations suggest that tourist presence has a detrimental effect on the howler monkey. When howlers respond to tourist presence by increased vigilance, coming to the ground, or roaring, they are prevented from engaging in their normal activities of foraging and resting. Also, any increase in the chance of a physical confrontation between the monkeys and humans (or their dogs) increases the chance of spreading disease to the howlers. Unpublished data further suggests that long-term changes in reproductive success and intergroup relations would also be a potential result of tourist presence (A. Treves, R. Grossberg and L. Bar-Sagi unpublished data 2000, as cited in Grossberg *et al.* 2003). The study suggests that managers can reduce these negative impacts through increased education of tourists, restrictions on group size, the addition of educational signage, and further training of guides (recognizing that often tourists model their behavior after their guides).

A thorough review of case studies and research on the environmental impacts of ecotourism on wildlife was completed by Buckley (2000) and included both direct and obvious impacts (such as road kill) as well as less obvious impacts (such as long-term population decline) (Table 3.1). Buckley (2000) stresses the inability to predict with certainty what impact a specific action will have on the environment due to the range of sensitivities of wildlife in different types of ecosystems. He gives the example that trampling damage from a hiker is greater in an alpine meadow than a rainforest due to the resilience of the vegetation types to re-grow. On the other hand, a weed seed or soil pathogen carried in mud on a hiker's boot would have a greater chance of impacting the rainforest than the harsher alpine environment. Also, small bodies of water are more likely to be polluted than the ocean, and noise from human voices is more disturbing in a woodland than a bare mountain-top. The following is a summary of some of the impacts of ecotourism on wildlife:

Table 3.1: Summary of studies of ecotourism impacts on wildlife (modified from Buckley 2000)

Wildlife	Impact study
Invertebrates (limited data)	• Assemblages of terrestrial insect species are modified by the introduction of exotic plants as a result of tourism
Reptiles and amphibians	• Off-road vehicles in the Mojave Desert have been shown to cause major or complete hearing loss in the fringe-lizard (Brattstrom and Bondello 1983) • Disturbance by tourists caused nest abandonment and subsequent egg predation (Crawshaw and Schaller 1980, Jacobsen and Kushlan 1986)
Birds	• Bird species assemblages, populations and behavior changed in areas used recreationally, for hunting, or by recreational vehicles (Blakesley and Reese 1988, Bell and Austin 1985, Keller 1989, Belanger and Bedard 1989) • Repeated disturbance by tourists caused reduction of breeding success (brown pelican and Herman's gull: Anderson and Keith 1980; ground nesting bird species: de Roos 1981, Yalden and Yalden 1990; bald eagles and ospreys: Bangs *et al.* 1982, Buehler *et al.* 1991; imperial eagles: Gonzalez *et al.* 1992; golden eagles and peregrines: Bocker and Ray 1971, Watson 1976; various species in the Netherlands: Saris 1976)
Mammals	• In the Sierra Nevada bears abandon winter dens if heavily disturbed by skiers (Goodrich and Berger 1994) • Deer disturbed by orienteering in Scandinavia died from stress (Sennstam and Stalfelt 1976, Jeppesen 1987) • Dall sheep in Canada heart rates increased by up to 20 beats per minute when hikers approached (MacArthur *et al.* 1982)
Aquatic biota	• Small numbers of recreational swimmers may increase the concentrations of bacteria in small, pristine streams (Warnken 1996) • Backcountry hikers distribute certain waterborne pathogenic bacteria and protozoa (Buckley 1998, W. Warnken and R.C. Buckley, unpublished as cited in Buckley 2000) • Recreational fishing tramples banksides and wading in streams damages fish eggs (Roberts and White 1992)

Buckley (2000) concludes that essentially all forms of tourism will have a negative impact on the natural environment, and ecotourism especially will tend to impact areas of high conservation value. His review suggests that environmental management practices at all levels (from tour operators to management agencies) can reduce impacts, and the ecotourism industry has the responsibility to do this.

Direct Impacts on the Physical Environment

Both vegetation and soils are affected by trail, road, and recreation site impacts. These impacts can lead to habitat destruction and in the long term potentially impact wildlife populations. In addition, the introduction of infrastructure such as buildings or roads can alter or degrade habitat and introduce pollutants or invasive species. Not only do these impacts adversely affect the environment, but it may have a negative effect on a tourist's experience. While some of the literature reviewed recommended concentrating tourist impact to reduce impacts on wildlife, the effect of this concentration would be further environmental degradation in the areas of concentration (Farrell and Marion 2001). The degree of impact may be avoided or minimized through the proper location, construction, and maintenance of infrastructure (Cole *et al.* 1987; Leung and Marion 2000, as cited in Farrell and Marion 2001).

Trails and roads are essential components of any ecotourism venture in order to accommodate tourist travel. The establishment of primary trails and roads can aid conservation by concentrating negative impacts if they are properly located, constructed, and maintained. The actual construction of infrastructure has a high potential to degrade the environment. In tropical ecosystems the erosive effects of trail and road construction are more extreme than in temperate regions (Kuss 1986). The high rainfall, wet tropic soils, and shallow root systems create a more sensitive environment. Research suggests that low levels of trampling on trails can rapidly impact tropical rainforests (Talbot *et al.* 2003), for that reason the effects of vehicles driving on roads can be inferred to be greater. Some of the most extensive and quantitative studies assessing the impacts of ecotourism have focused on the physical effects of trampling on vegetation and found variation to depend on climate and intensity (Bhuju and Ohsawa 1998, Buckley 2000, Burden and Randerson 1972, Cole 1978, Kuss 1986, Lynn and Brown 2003, Turton *et al.* 2000, Weaver and Dale 1978).

A study of visitor impacts at eight protected areas in Costa Rica and Belize compared recreation site and trail use, and found impacts to be most evident along trails (Farrell and Marion 2001). The most common types of trail impacts were trail proliferation, erosion, widening, and exposed roots. In recreation sites they found the most common impacts to be vegetation and leaf litter loss, and soil exposure. Other impacts included physical and biological pollution of water resources, disturbance and feeding of wildlife, littering, artifact collection, and graffiti. They also found that many of these impacts could be avoided if infrastructure was both properly located and properly designed. Consistently, the under-designed trails with no structural reinforcement experienced greater levels of degradation (Hesselbarth and Vachowski 1997; Birchard and Proudman 2000, as cited in Farrell and Marion 2001). Also, many trails were located in areas prone to flooding and other impacts therefore making them more vulnerable to degradation. The best solution in these cases may not be to reinforce the trail with more structure, but to instead relocate the trail to a location that has better drainage and is less prone to damage by treading.

In addition to negative effects of visitor impacts on the physical environment, research has also shown that physical impacts adversely affect the visitor experience (Buckley and Pannell 1990, as cited by Chin *et al.* 2000). A study by Chin and colleagues (2000) in Malaysia found that tourists are sensitive to signs of degradation, particularly those that are visually prominent, and these signs can negatively impact their experience. The impacts with the greatest influence included presence of litter, soil erosion, and vegetation damage. An intolerance of litter was explained by the possibility that littering violates deeply held norms of Western culture (constituting the majority of the visitors in this study) where littering is seen as abuse rather than normal use of natural areas (Lucas 1990, as cited in Chin *et al.* 2000). These results may have management implications when considering the acceptability of certain impacts, and how to monitor them.

Although tourism is a growing industry which holds promise to contribute to conservation, in practice there are many risks of negatively impacting protected resources. Particularly related to site specific designation of the location of infrastructure, managers can be made aware of the extensive literature that exists on road and trail design, construction, and maintenance. The initial location of an impact can be critical in managing for the least degradation. Careful management and planning are key to ensuring the success of a sustainable ecotourism effort that resists negative impacts, while ensuring visitor satisfaction.

Impacts of Roads

It is worthwhile to focus on roads and their impacts on surrounding habitats. Road ecology is a new focus within landscape ecology, and more studies are beginning to focus on the ecological effects of roads. The field of road ecology promises to be challenging yet necessary for consideration in planning, conservation, management, design and policy (Forman and Alexander 1998). The following section will summarize the possible effects of roads related to planning for ecotourism in Uaxactún.

Road networks dissect forest patches, inhibit movement of important interior species, and increase the amount of edge habitat along the road corridor (Forman and Alexander 1998). The presence of roads results in a range of negative ecological impacts including changes in hydrological cycles, sedimentation, and harmful chemical effects. Studies indicate that the impacts of roads in remote natural areas is most pronounced since, from an ecological perspective, those areas have the most to lose: "…roads not only increase access to previously isolated natural resources, they also fragment landscapes into small, disconnected patches where edge habitats predominate. As a result, biomass declines, community structure changes, pest invasions increase, and the rate of species loss skyrockets" (Wilkie *et al*. 2000).

Loss of Connectivity

The reason we should be concerned about roads having an affect on connectivity is because high levels of landscape connectivity are important to sustain habitat quality for two primary reasons. First, it allows for multi-habitat species to move freely across the landscape and utilize the varied habitat types that they depend on for their daily or lifetime needs. For instance, some amphibians shift habitats depending on seasonality. Research on the North American leopard frog describes how it migrates seasonally from breeding ponds in the spring to meadows during the summer, on to different over-wintering sites in the fall. Barriers that impede these organisms' movements, such as roads, result in higher mortality, and lower population viability (Forman *et al*. 2003).

The second reason high landscape connectivity is important is because it allows for populations that have suffered local extinction or decline to repopulate other suitable habitats within the region. Reduced movement through the landscape due to barriers or filters could create a situation where habitats are underutilized and less populated than they could otherwise support. A low local population of species increases the chance of species extinction in that area (Forman *et al*. 2003).

In the case of Uaxactún, a previously continuous matrix of lowland tropical forest has been dissected into smaller patches by a road network used for resource extraction by the Uaxactún community. Dissection is defined as a spatial process that the landscape undergoes when areas have been carved up and subdivided by the use of equal-width lines, such as a road network (Forman 1995). Dissection can be viewed as a special case of fragmentation, but the two spatial processes are differentiated because their separating elements are typically so different (roads, powerlines, railroads, windbreaks for dissected landscapes vs. logged clearings, cultivated fields, housing blocks, pastures, etc. for fragmented landscapes) (Forman 1995). Depending on the species, the ecological effects of dissection and fragmentation can either be identical or very different. For the purpose of this project, we will use the term *dissection* when referring to habitat fragmentation by roads.

The presence of roads in a previously continuous interior patch dissects the patch into two smaller fragments and reduces the interior habitats by introducing edge conditions on either side of the road corridor (Reed *et al.* 1996). These edge conditions can extend into the forest fragment far beyond the extent of the actual road corridor. In a study done in temperate forests, edge effects were so prevalent, that circular reserves of <100 ha were described as containing no true interior habitat (Wilcove *et at.* 1986 as cited in Laidlaw 2000). Because of the increase in edge conditions along the road corridor, the interior habitat loss is many times greater than the total area of the road. This means that for interior wildlife species, the width of habitat fragmentation is much wider than the actual width of the road corridor and this creates a barrier or a partial barrier to movement across the landscape. Also included with those species most affected by roads are those species which have multi-habitat requirements, and those that are highly mobile and cover large distances (Forman *et al*. 2003).

Impacts on wildlife

Roads affect wildlife movement in several different ways. One of the more evident effects is road mortality, made obvious by the presence of road kill that is often found scattered along highways and interstates. Even on less trafficked roads road mortality can occur. On the road from Tikal to Uaxactún, a Jaguar was stuck and killed by a vehicle in 2003 and an ocelot in 2005 (WCS-Petén, Personal communication). Although death from car impact is the main cause of mortality, it rarely affects population viability. More importantly, road avoidance, caused primarily by traffic noise, has a greater ecological impact. The most serious effect of road avoidance is that the road becomes a barrier that acts to subdivide and threaten the viability of entire populations (Forman and Alexander 1998).

In general, the possibility for roads to act as conduits for wildlife movement is seldom the case (Forman and Alexander 1998). Some exceptions have been observed: foraging animals may travel parallel to road corridors for short distances, nocturnal predators may move along roads that have low traffic volumes, and carrion feeders may move along roads in search of road kill. In the area around Uaxactún, Jaguars and puma often use roads, including the road that connects Uaxactún with Tikal, making them susceptible to hunters and on some occasions, vehicles (WCS-Petén, Personal communication).

Road avoidance

According to findings of Forman and Alexander (1998), most wildlife is very sensitive to the presence of roads, and their reaction is to avoid them. Road avoidance is attributed mainly to the traffic noise of passing vehicles. Alternative hypotheses also credit visual disturbance, pollutants, and presence of predators moving along road corridors as causes. Studies have identified songbirds as animals particularly sensitive to traffic noises. Research on ecological effects of highways in the Netherlands revealed some important patterns: 60% of bird species present had lower densities near highways. In the zone affected by roads, the total number of bird species progressively decreased with proximity to roads. The distance of this effect was most attributed to the level of traffic density which is highly correlated to traffic noise. On highways in woodlands with cars driving an average speed of 120 km per hour (75 mph), the effect distance for the most sensitive species on a road with traffic density of 10,000 vehicles/day was 305 meters (1,000 feet), and on a road with 50,000 vehicles/day it was 810 meters (2,657 feet) (Forman and Alexander 1998). Although jaguars and pumas have been known to use the less trafficked roads around Uaxactún as corridors for movement, a recent jaguar study in Quitana Roo has shown that jaguars in that area of Mexico selectively avoid roads, staying on average four kilometers away, and six kilometers away from villages. These data are not published (WCS-Petén, Personal communication).

Undoubtedly, the roads in Uaxactún experience considerably less traffic density at speeds much slower than 120 km per hour. Officials in Tikal control traffic, with average speeds being approximately 50 km per hour (despite the 20 km per hour limit). The average speed on the current Tikal-Uaxactún road is roughly 30 km per hour (WCS-Petén, Personal communication). Forman and Alexander (1998) speculate that on roads with little traffic, effects on wildlife may resemble behavioral responses to acute disturbances when individual vehicles periodically pass by, rather than chronic disturbances of heavy trafficked roads. For these less trafficked roads, they suggest that visual disturbance and predators moving along remote road corridors may be more significant for road avoidance than the effects of noise disturbance.

A more comparable study done on the effects of tropical rainforest roads in Queensland, Australia, which experienced practically no traffic noise effects, may help provide some insight on potential effects of roads in Uaxactún. Where several studies documented the biotic and abiotic changes of rainforest roads, this study focused on how these changes impact small mammal composition along the road edges *versus* the forest interior. The results concluded that these narrow roads acting as strips of alien habitat had caused shifts in small mammal communities in favor of generalist species, such as *Melomys cervinipes*, over edge-avoiding species. The distance of penetration of edge effects on small mammal community structure could be estimated conservatively at 50 meters (164 feet) (Goosem 2000).

It seems apparent that traffic noise is only one source of a broader trend of road avoidance by wildlife. The study cited above seems to indicate that changes to habitat structure and composition as well as increased colonization of generalist species along the edge can lead to displacement or loss of habitat for interior species. Another example of this was seen in the Amazonian rain forest when light-loving butterflies penetrated the rainforest up to 250-300 meters from the edge, competing for food and space with forest interior species (Lovejoy *et al*. 1986; Brown and Hutching 1997, as cited by Goosem 2000). Other causes of road avoidance are visual disturbances and pollutants, although studies done in the Netherlands found that these effects extended outward only for short distances from the edge compared with traffic noise effects (Forman and Alexander 1998).

The numerous possible effects of a road-avoidance zone can extend outward from tens to hundreds and even thousands of meters from the road corridor, depending on multiple factors including the sensitivity of the animal, the ecological process in question, the slope and suitability of adjacent habitats and wind direction. For instance, the road-avoidance zone for caribou extends outward up to five kilometers (Forman and Alexander 1998). In general, these road-avoidance zones exhibit lower breeding densities and reduced species richness. What is more, these zones serve to functionally fragment and further isolate habitats for the populations of interior species, greatly increasing the barrier effect of roads. When considering the total area of road-avoidance zones, and their contribution to habitat isolation, the ecological impact of road avoidance must be much greater than that of road mortality or habitat loss due to road construction (Forman and Alexander 1998).

Besides road avoidance and changes in wildlife behavior, roads are responsible for other changes to ecological processes and flows on the landscape that, although more indirect, still have serious impacts on wildlife habitat. These include water runoff, sedimentation, and chemical transport.

Water run-off

The presence of roads can result in changes to the hydrological cycles, especially when located on upper hillsides. They have the potential of concentrating surface run-off by channeling the run-off along the roads and accelerating flows into first-order streams, which in turn increases peak flows of streams and rivers. This impact is magnified when these roads are located in hilly mountainous terrain where cut-banks made in the hillside converts slow-moving groundwater flow (subsurface run-off) to fast-moving surface run-off. The increased run-off that is associated with roads may increase rates of erosion, reduce the rate of percolation and aquifer recharge, alter channel morphology and increase stream discharge rates (Forman *et al*. 2003). These changes to the hydrological cycle can destroy aquatic habitats as well as restructure riparian forest habitat along stream and river corridors.

Sedimentation

The sediment yield (the quantity of sediment arriving at a specific location) of a road to a nearby aquatic habitat depends on the sediment supply of the road (higher supply for dirt roads and lower supply for paved roads) and transport capacity of a storm event (heavy rainfall yields a greater capacity). With roads, soil surfaces exposed to increased hydrological flows lead to higher erosion rates and sedimentation yields (Forman and Alexander 1998).

Sedimentation by wind is another concern of roads to habitat and ecosystem health. Road dust can damage vegetation between ten and 20 meters out on either side of the road, but in downwind situations, the effect-zone can extend up to 200 meters. Other ecological issues caused by wind include weed migration, change in waterfowl and shorebird habitat, and altered movement of large mammals (Forman and Alexander 1998).

Chemical transport

The ability for a road to transport chemicals can have a drastic impact on habitat quality, although this impact tends to be primarily localized near the road. Transportation of chemicals occurs primarily by storm water run-off through or over soil adjacent to roads. Pollutants, such as heavy metals, alter soil chemistry and may be absorbed by plants, and can severely damage adjacent habitats (Forman *et al*. 2003).

In Uaxactún, the transport of heavy metals, especially lead, could be a major issue due to the fact that the use of leaded gasoline in quite common. These heavy metals are relatively immobile- soils within five to eight meters from the road contain the greatest concentrations of heavy metals, but high concentrations of lead have been found in soils 25 meters out from the road. Another potential concern for chemical transport associated with roads is nitrogen from NOX emissions from vehicle tailpipes. In a study in Britain, vegetation up to 100-200 meters from the highway roadside was effected (Forman and Alexander 1998).

Road network

The overall impacts of roads on the adjacent habitats are significant. Cumulative effects of a road network on a landscape scale should be understood. At this scale, the major ecological impacts are the disruption of landscape processes and loss of biodiversity. Roads networks alter the way a landscape functions by interrupting horizontal flows of ecological processes such as stream flow, groundwater flow, and natural disturbance regimes such as fire spread, foraging, and dispersal and impacting the species dependent on them. Road networks also disturb interior habitats, impacting interior species, species with large home ranges, stream and wetland species, and rare native species (Forman and Alexander 1998).

In areas comprised of natural forests, such as Uaxactún, it is important to analyze the impacts of road networks and consider the possibility of removing segments of the road network that are located in sensitive areas or dissect an otherwise continuous patch of forest. The other alternative would be to temporarily close road segments during important times of the year such as seasonal migration of amphibians or breeding seasons of certain sensitive animals.

Road-effect zone

Road-effect zone is defined by Richard Forman in his book Road Ecology; Science and Solutions as the zone of influence along a road over which significant ecological effects extend. Furthermore, he identifies three processes that help determine the distance that road-effects extend: wind, water, and behavioral movements. Wind carries dust, nitrogen from tailpipes, and noise; water carries sediment and dissolved chemicals, while the behavioral attractions to suitable habitats and avoidance of less suitable habitats of different animals result in a variable range of effects (Forman *et al*. 2003).

Depending on the mechanism and the particular interaction between roads and adjacent habitats, the extent to which the road effect extends outward can vary from short to long. Generally, many of the effects that are limited to short-distances from the roads are due to particulate and aerosol materials deposited from local air movement. The effects that extend to medium-distances are those that affect species and transfer of energy and materials. Finally, effects that extend out long-distances from roads include the blocking of wildlife movement routes, exotic species spread, effects in streams, and human access disturbance such as logging and hunting (Forman *et al*. 2003). The cumulative effect of these different road-distance effect zones for the example road network (in Figure 3.1) greatly decreases the remote areas (interior habitat) and increases population isolation for those wildlife species that demonstrate road avoidance.

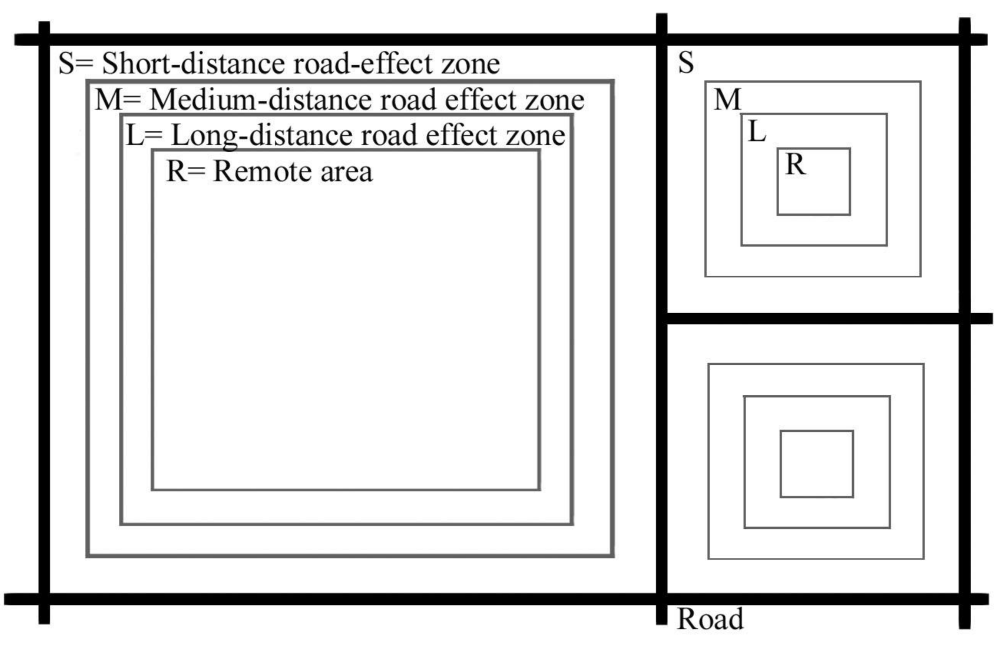


Figure 3.1: Zones of ecological effects in a road network (Adapted from: Forman *et al*. 2003)

While it is possible for ecotourism to play a role in sustaining Uaxactún's resources, research has shown that it will require careful planning and management. Our literature review has specified the risks of impacting or degrading the valued resources of the concession with the unplanned or unmanaged development of ecotourism activities and associated infrastructure. In order for tourism to be compatible with resource protection in Uaxactún, residents must be aware of the impacts on wildlife, impacts on the physical environment, and impacts from roads.

CHAPTER FOUR:
DESCRIPTION OF STUDY AREA

Livelihoods and economics

The people of Uaxactún refer to themselves, very aptly, as a "forest community". This is due to their dependence on resources from the surrounding forests to provide them with a living. This relationship is also why the community has such a strong commitment to sustainability and to maintaining the ecological health of the forest. For the most part, this understanding of sustainability has guided their methods and rates of resource extraction. However, it should be recognized that these norms for sustainable extraction are not always followed. Increases in the population of Uaxactún, as well as the fluctuations in the markets, has led to the current pressure on non timber forest resources.

Their forest use includes both non timber extraction and timber extraction; agriculture is secondary (OMYC 1999). Although extractive resource use typically affects habitat quality and levels of disturbance, resource use was not incorporated into the suitability analysis for planning for ecotourism, with the exception of agriculture, for the following reasons:

Non timber extraction:
This resource use primarily refers to harvests of xate, chicle, allspice, bayal vine (*Desmoncus sp.*) for furniture, various branches, mosses and mushrooms for local crafts, and hunting (OMYC 1999). Non timber resource extraction is permitted everywhere in the concession, except for the strictly protected areas, which include flooded areas and in zones of archeological resources (ancient Maya sites). Extraction has modestly low impacts, since it is primarily small numbers of collectors traveling on foot, dispersed across the concession on small footpaths.

Undoubtedly, the extraction of these non timber forest products has the potential to affect the ecological processes at many levels, from individual and population to community and ecosystem (Ticktin 2004). The disturbance caused by the extraction of NTFP was not incorporated into our model because of limitations in data that made it difficult to map, with any certainty, the locations of these impacts or to differentiate a more impacted area from a less impacted area within the concession. This uncertainty stems from the fact that non timber extraction is permitted throughout the concession and the level of harvesting, and areas of concentration of these resources, are hard to predict. They respond to the changing market demands and success of the community to adopt sustainable norms of extraction (WCS-Petén, personal communication).

Timber extraction:
This resource use was not included in the analysis because not enough was known about the region's ecosystems and the specific harvesting techniques utilized by the Uaxactún foresters to predict how these selective harvesting techniques would affect habitat quality and ecological processes. In a literature review conducted by Hill and Hamer, they found that studies investigating the impacts of selective harvesting on tropical forests fauna, when done at large spatial scales, were more likely to report increased diversity following disturbance (Hill and Hamer 2004). Besides the acute but infrequent disturbances caused by the extraction process, the effects could result in a more diverse habitat mosaic. Because of these uncertainties, we decided to exclude timber extraction from the suitability analysis.

The forest resources and harvesting norms are described briefly in the following table:

Chicle (Manilkara [Achuras] zapota)

Chicle's preferred habitat is tropical dry and wet forest (Hartshorn 1983), growing well in the limestone soils. It is also highly shade tolerant (Record and Hess 1943, as cited in Schlesinger 2001, p. 144). The chicle season is between August and December based on the peak flow of sap from the tree, and a six year rotation cycle (OMYC 1999). This means that the chicleros concentrate their efforts in smaller areas over a longer time period. The season of this intense use does not compete with, or overlap, the peak tourism season in the dry season.

Xate (Chamaedorea spp.)

The preferred habitat of xate is primary and mature secondary forests in the shade of well-drained upland tall forest (Reining *et al.* 1992 as cited in Schlesinger 2001, p. 142). The xate collection season runs year round with a six month rotation cycle, and xateros are constantly moving throughout large areas of the concession for short periods of time. Due to unsustainable harvesting techniques there has been an observed difficulty in regeneration thus initiating replanting efforts using nurseries.

Allspice trunk

Allspice berries

Allspice (Pimenta dioica)

The preferred habitat of allspice is primary and mature secondary forests in shade of well-drained upland tall forest (Reining *et al.* 1992 as cited in Schlesinger 2001, p. 142). Harvesters of allspice work between July and September, partially overlap the chicle season, but in theory utilize a five year rotation cycle harvesting secondary growth branches.

Ocellated turkey (*Meleagris ocellata*)
(www.phasianus.homestead.com/junglesafari.html)

Hunting

Locals hunt wild game to gain an important source of protein. In addition, the community gains income by allowing limited numbers of tourists to hunt the ocellated turkey (at right) which are endangered worldwide but locally abundant (OMYC 1999). For the locals the most commonly hunted species are deer (*Mazama americana*), tepezcuintle/paca (*Agouti paca*) and great curassow (*Crax rubra*). Within the community, hunting wild game for protein is currently considerably cheaper than buying chicken (OMYC 1999). Both xateros and chicleros constantly hunt and gather food while they are in the forest. A survey of the amount of wildlife hunted found that chicleros hunted and consumed a significantly larger quantity of wildlife than xateros (McNab 1998). Despite the shorter harvest period that chicleros work, the fact that they work in larger groups would further increase their consumption. Recently however, the market for chicle is much weaker, less is harvested, and this may no longer be true (WCS-Petén, personal communication).

Sustainable Logging

The Uaxactún management plan describes a strict rotation plan for eight zones in the east side of the concession. It presently does not allow timber extraction in the west side of the concession due to the documented higher biodiversity, sensitivity, and habitat quality of the high canopy upland forests. They have not completely ruled it out however, but will consider it only once a more thorough environmental impact assessment can be made, and more funding is available that would allow proper roads to be built to minimize habitat degradation from timber extraction.

Subsistence Farming

At the time of the development of Uaxactún's management plan, approximately 50 percent of the 138 families of Uaxactún were allotted farms, and engaged in subsistence farming over a total area of approximately 1,600 ha (3,940 acres), 1.90% of the total area of the Uaxactún concession. Primary crops include corn, beans, bananas, and plantains. Designated areas for agriculture are permanent and managed by CONAP. According to the Uaxactún management plan, approximately 40 percent of the fields are actively cultivated at one time while the remaining 60 percent are left fallow. An example cited in the Uaxactún Management Plan describes the rotation cycle for the commonly grown corn as two years of cultivation followed by four years of rest (Soria and Bamaca 1999, as cited by OMYC 1999). OMYC feels these fields pose no threat of expansion due to the fact that they are cleared for subsistence farming and are not used for commercial purposes because the soils are poor

A pattern of small-scale agriculture such as that found in Uaxactún, where fields are left fallow for several years or more, could create a patchwork of areas at different stages of forest succession. This pattern could result in an increase the habitat diversity and species richness, much like the effect of small-scale natural disturbances (Andrade and Rubio-Torgler 1994). The limitations in our data did not allow for us to differentiate the areas of cultivation from those that were left fallow. There was no way to know for how long these fields had been left fallow, or at what stage of succession they were in, and what potential habitat function they served. Although these fallow fields have the potential to serve these ecological functions, for the purpose of our model we stayed consistent with our conservative approach and designated this land use as a source of disturbance caused by human activity on the landscape.

Physical Analysis

Karst Geology

Uaxactún and the Petén region sit upon a limestone plateau of karst. Karst landscapes in general are characterized by a lack of surface water, as evident in the root of the word "karst" from the Slavic *kras* or *krs* and Italian *carso* meaning "a bleak waterless place" (Monroe 1970). Karst landscapes typically have a poorly developed surface network of streams but in contrast will have a well developed underground circulation of water. Karst regions often contain aquifers that are capable of providing large supplies of water. In the United States 40% of groundwater used for drinking comes from karst aquifers (USGS website 5/29/05).

Perhaps one of the most interesting and potentially sensitive issues regarding the ecology of Uaxactún is its karst geology. Very limited data exists in the Petén region and specifically Uaxactún concerning this issue. Gaps in information limit regional planning for ecotourism. This was a major concern as we were conducting the suitability analysis, since research elsewhere has shown the importance of understanding the nature of karst processes and landforms in order to make informed decisions about land use and management. The potential environmental implications for karst land management concern the prevention of contamination of groundwater, and the danger of sinkhole collapse. It is in the best interest of the community to understand their groundwater system in order to plan for the prevention of these dangers. More specifically, it would be useful to delineate the boundaries of recharge areas, the directions of groundwater flow, and the springs where groundwater may surface throughout the landscape.

Karst landforms are typified by closed depressions ranging in size from tiny holes to those covering wide areas. When observing these depressions on a topographical map there generally appears to be an absence of surface drainage, and a series of small basins surrounding each depression. In tropical karst areas sinkholes and hills dominate the landscape giving it a mottled appearance. Sinkholes function as funnels, directing surface runoff from the ground surface into karst aquifers (Zhou and Beck 2005). One of the threats to groundwater quality in karst landscapes is this potential for pollutants or contaminants to directly enter the groundwater. Meanwhile, sub-surface erosion and weathering by water can create and enlarge cavities within the rocks to form a complex network of underwater streams, channels, and caves. Because of this unique interaction of surface and groundwater in karst landscapes, it is important to first understand the specific network layout of groundwater paths when assessing the suitability of locations for increased development.

Karst landscapes are sensitive to groundwater contamination because of the chance for polluted or contaminated water to enter the groundwater through cracks and sinkholes without any filtration. Also, many of these underground streams flow extremely quickly, thus enabling contamination to spread quickly. Pollutant travel time in a karst aquifer can be rapid, on the order of kilometers per day in contrast to meters per year in most non-karst aquifers (Mull *et al.* 1988). Once the pollutant has entered the groundwater system it is nearly impossible to guess where it will go unless the flow has been mapped. It is not uncommon to find that underground water currents move uphill with respect to surface topography, or even criss-cross, implying the presence of multiple layers of channels (White 1988).

What these findings could indicate for Uaxactún is that the location of human or animal waste discharge, or the use of chemicals in land cultivation, may put the local water supply at risk. Villagers in Uaxactún are at risk primarily because a portion of their water supply comes from karst-derived sinkholes whose bottoms have been sealed by clay and silt sediment, which allows for surface water to be retained. These sinkholes, called *aguadas*, are located at the bottom of a karst ridge where groundwater seepage would probably surface. On the other hand, there is a functioning water distribution system in Uaxactún, and the potential exists to operate it year round. With government support, villagers can potentially be less dependent on the *aguadas* in the future (WCS-Petén, personal communication).

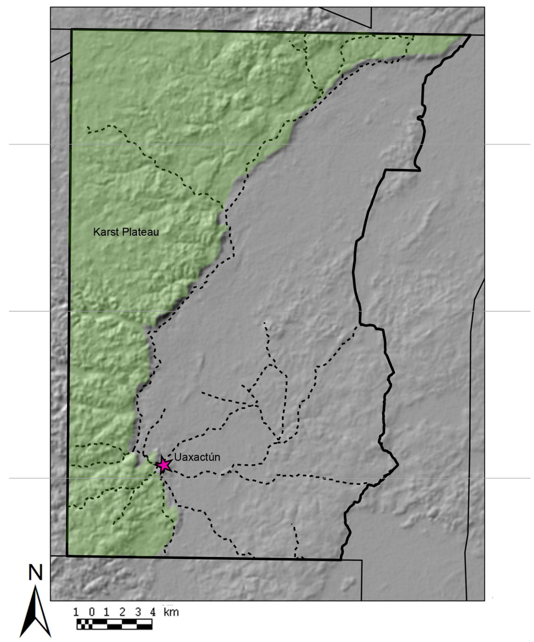
Another issue in karst landscapes is that caverns, caves, or eroded sinkholes that form below the surface can periodically collapse. Many studies have found that this collapse process can be facilitated by human interactions with the water table level, diversions of surface water, or by the misplacement of roads (Zhou and Beck 2005). Sinkholes do exist regionally in the MBR area, including Uaxactún, and it is important to understand how and where these collapses may occur.

Clearly, any environmental impact study for construction of tourism infrastructure should address both the issues of land stability and managing of waste water and stormwater in a karst landscape in order to fully account for the risks associated with human and animal use.

Preliminary Investigation of Groundwater Flow based on Uaxactún Topography

Through the use of GIS, we conducted some analysis in order to investigate the character of the surface of Uaxactún in order to confirm whether or not the topography of the study area conformed to characteristics described in the studies and literature on karst landscapes. Although these analyses are intended as preliminary, and were conducted without prior or subsequent ground-truthing, the results matched the mottled pattern of the surface that typifies such landscapes which furthered our conviction that potential contamination was indeed a concern for both current and future locations of land use and development

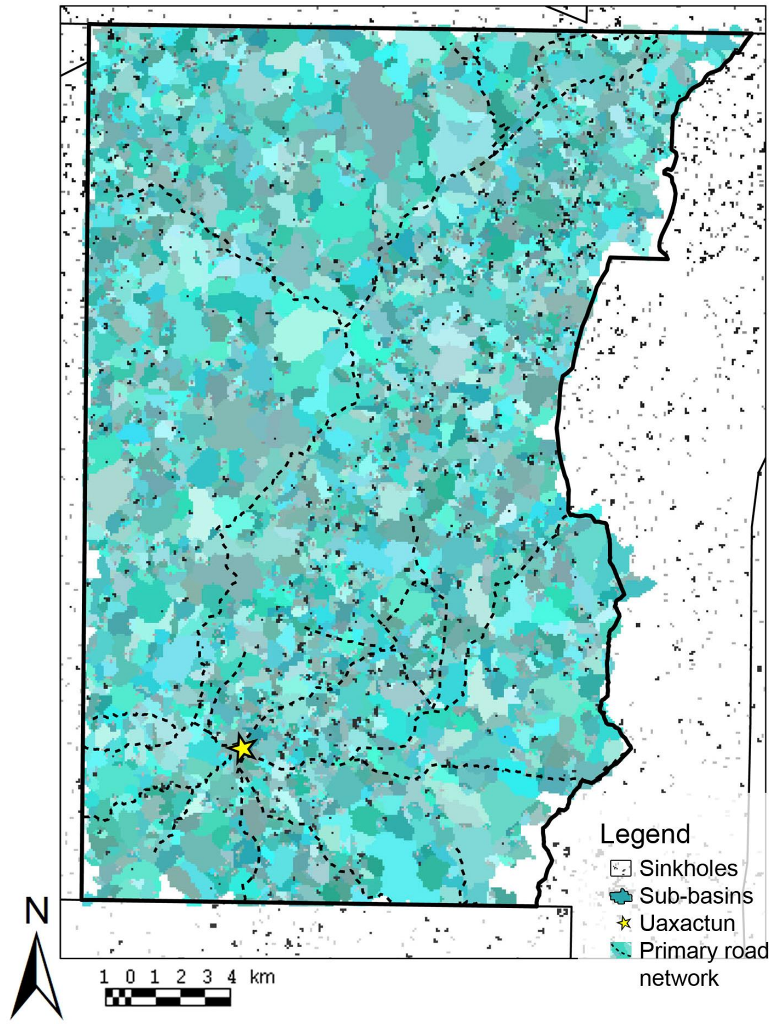
First, based on our observations of topography alone, there is a distinct ridge at the edge of what potentially could be a karst plateau with signature sinkhole and hill landforms on the west side of the concession (Map 4.1). A primary road runs through the concession at the base of this ridge.



Map 4.1: Surface topography: Green area indicates higher elevation plateau defined by a distinct ridge running through the concession.

To investigate the presence of sinkhole and hill landforms, we mapped the locations of sinks using GIS. A sink is a local low elevation point on the surface, around which all other points are at a higher elevation. By using a map of the surface topography we were able to produce a map of surface water flow direction and surface water accumulation, and to delineate the sub-watershed boundaries that exist within the Uaxactún concession. A sub-watershed would be defined as the area draining exclusively to each sink point. It was important to use fine scale topographic data for this analysis (for example a resolution of one contour every 6.10 meters (twenty feet) instead of one contour every 30.48 meters (one hundred feet)), so that the map of sub watersheds that we produced would include the small-scales differences in elevation at which these sinkholes exist. This analysis produced a map of multiple disconnected small basins. Map 4.2 shows these basins overlaid with the sinks, which represent the lowest point in each basin or sub-watershed.

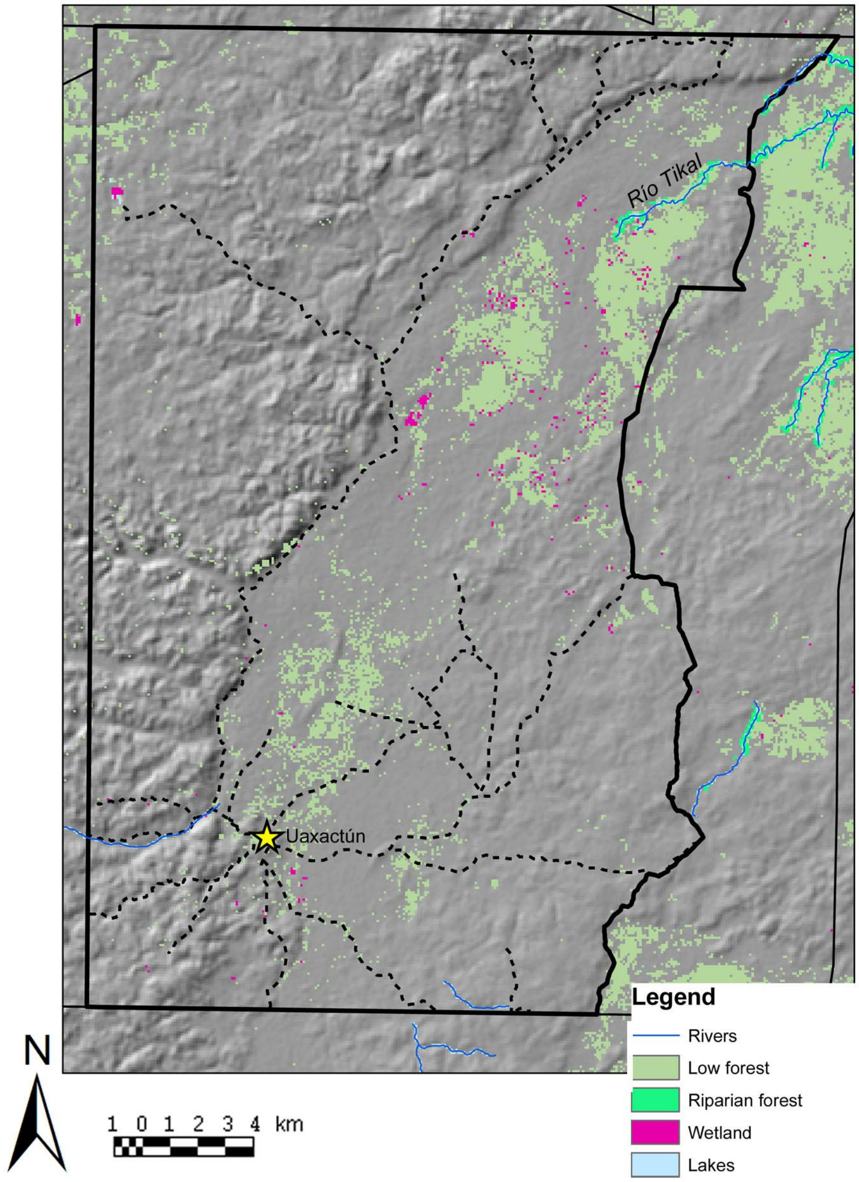
The presence of these widespread surface depressions indicates the potential that they are connected to an underground conduit system in which water is free to flow to a spring outlet at a lower level (Palmer 1984, Ford and Williams 1988). This combined with the known presence of one spring at Manantial in the northeast corner of the concession suggests that possibly groundwater reemergence through seeps or springs below the ridge could be more common, especially considering the widespread presence of wetlands and low forests on the eastern half of the concession (Map 4.3). However, even in the low areas of the river in the northeast corner of the concession, Río Tikal, locals have seen the water flowing into sinkholes. Also, the springs at Manantial are at a higher elevation than the areas where the Río Tikal plunges into the earth. This may suggest that there are multiple aquifer layers (WCS-Petén, personal communication).



Map 4.2: Computer generated sub-basins (as indicated by different shades of blue) and sinkholes (as black dots) throughout the concession.

Again, because groundwater flows are controlled by the orientation of fractures and interconnected cavities below the ground surface, it is insufficient to use observable surface topography to predict groundwater flow, and these are simple observations and conjectures. It is unknown whether water flows to the Río Tikal, or if water flows south towards Lake Petén Itza. Either way, in considering the general implications of groundwater contamination, we can say that surface water contamination from sedimentation, agrochemicals from cultivated fields, and other migrations of nutrients and heavy metals would negatively affect habitat quality and potable water supplies if it quickly travels through karst geology back to the surface.

Our analysis of surface character here is unfortunately insufficient to accurately incorporate into an overall environmental sensitivity analysis of the concession. The unpredictability of underground karst water flows makes it necessary to conduct site-specific mapping in order to make site-specific recommendations (Gillieson 1997). However, it is our hope that an awareness of karst geology and water issues may encourage the community to conduct further research that may aid in the planning of future impact assessments conducted by the community, and the beginnings of a water quality monitoring program.



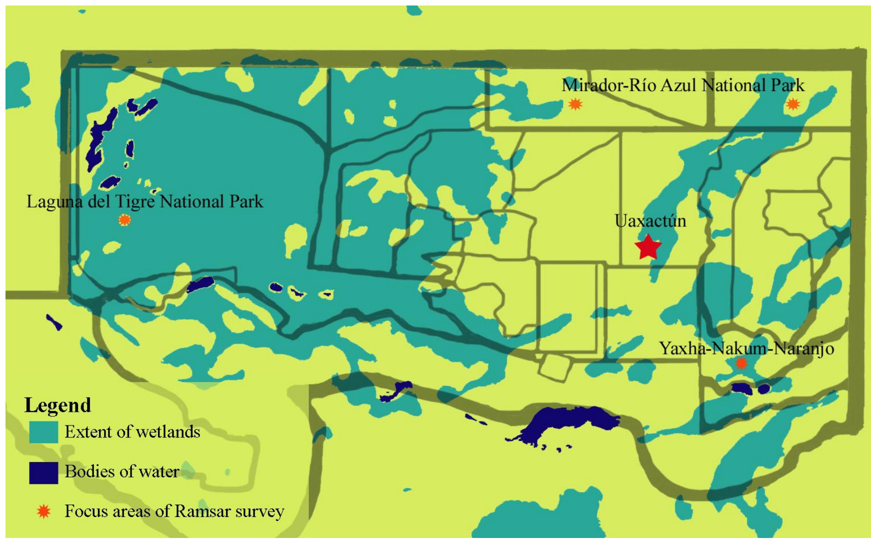
Map 4.3: Presence of wetlands and low forest in the concession.

Landcover Classes

In the MBR, research has only recently begun to emerge that attempts to identify the different ecologies and characteristics of the different habitat types present. Meanwhile, the websites of conservation organizations such as WCS, The Nature Conservancy, and the World Wildlife Fund all describe the region as full of rare and endemic species of flora and fauna, and in need of protection. However, more site-specific surveys of these endemic populations or their habitats seem to be lacking, or remain unpublished. For this reason we drew our conclusions using studies conducted within the region and in close proximity to our site.

We were supplied general landcover data and class descriptions. However, when compared to other studies conducted in the region we often found the descriptions of the same landcovers to use different terminology. Also, descriptions were frequently either in Spanish, or translated from Spanish, so variations of translations became another factor. In order to assemble data from these other studies, we re-named and re-defined our landcover classes by compiling the information we were provided with by WCS together with data available from biodiversity surveys that were completed in the same region.

More specifically, we developed a landcover classification scheme using biodiversity surveys from two locations within the MBR: Yaxha-Nakum-Naranjo and Mirador-Río Azul National Park. Map 4.4 indicates these park locations in relation to Uaxactún. The map also shows the locations of Ramsar recognized wetlands (in light blue), and large water bodies (in dark blue). In addition we referred to a survey and description of karst wetlands in the United States. When appropriate, survey data that described habitat function of comparable landcover classes was used to extrapolate the habitat function of our landcover classes. These comparable landcover classes were assumed to be either a more specific subset of our landcover class, or a more general term which encompassed our landcover class due to their proximity to our study site and similar geomorphology and climate. For example in a survey of Yaxha-Nakum-Naranjo there are habitats described as shrub swamps or seasonally flooded forests. These habitats were considered to be a more specific subset of what we called low forest because both habitats were described as seasonally flooded forests with low canopy vegetation. Therefore, if a specific endangered animal was found in a shrub swamp of Yaxha-Nakum-Naranjo, we would assume that it was possible for that animal to exist in the low forests of Uaxactún as well. The following descriptions of landcover classes include descriptions we considered equivalent to ours from other studies, when applicable.



Map 4.4: Locations of wetlands (in light blue) surveyed around Uaxactún region (adopted from the Ramsar sites information website)

Landcover Data

Landcover data layers along with all other GIS data layers were provided to us by CEMEC (Centro de Monitoreo y Evaluación de CONAP- WCS). We re-classified the landcover data layers into the following landcover classes: cultivated fields, tall forest, low forest, wetlands, riparian forest, and bodies of water. Other layers included road network; rivers and seasonal streams; villages; major ancient Maya sites; campsites; and surface topography. Sources for each layer varied, and are further described in the methods section. Limitations of our data included a lack of discernment between secondary forest and primary forest, as well as cultivated fields and fallow fields. The refinement of these data layers in future studies would be an improvement to the model since they indicate different expected levels of biodiversity and habitat quality.

Cultivated Fields

This landcover class was termed *Agropecuario*, (translated to "farming" or "agricultural") in the original GIS landcover data layer. The area included in this landcover class corresponds closely with the class described in the Uaxactún Management Plan as *Suelo Desnudo* (translates to "bare soil") which represents 1.92% (1,603.73 ha) of the Uaxactún concession and consists of the land cleared for the village center, active cultivated fields known as *milpas*, or fallow fields known as *guamiles* (OMYC 1999). We have accepted this inability to discern fallow from cultivated fields as a limitation of our model and generalized this landcover class as a source of human disturbance within the natural areas of the Uaxactún concession. We did not consider this landcover class as providing sensitive or rare wildlife habitat value.

Tall Forest

This landcover class was originally two separate landcover classes in the GIS data layer, and together they represent 97.82% of the Uaxactún concession (OMYC 1999). Their descriptions were as follows:

- *Bosque alto y medio intercolinar o en planacie*: Tall and medium forest in valleys and on alluvial flats on soils with good drainage, found at elevations between 200-300 MSL with a canopy height between six and 40 meters (CONAP 2001).
- *Bosque alto y medio en serrania*: Tall and medium broadleaf evergreen forests growing on rocky, mountainous terrain with good drainage, found at elevations between 300- 636 MSL (meters above sea level) with a canopy height between six and 20 meters (CONAP 2001).

These classes were combined in our analysis because they were designated as having similar habitat values and were not distinguished as separate classes in descriptions of habitat requirements for interior or otherwise sensitive wildlife species found in natural history guide books (Schlesinger 2001, Krichner 1997). This does not mean they aren't valuable as habitats. On the contrary, these habitats are recognized as containing the highest level of biodiversity in Uaxactún as well as endangered and endemic species (OMYC 1999).

We designated the remaining landcover classes as rare habitats that exhibit a high occurrence of endemic and sensitive species, and were incorporated into our rare and sensitive habitats analysis.

Low forest

This term was adopted from the WSC Rapid Evaluation of the Mirador-Río Azul National Park (WCS 2004), and was originally the data class called *Bosque Bajo.* In the GIS landcover layer it represents about 9% of the total landcover in Uaxactún. The general description of the class in the metadata was as follows:

- *Bosque Bajo*: Broadleaf forest with dense foliage comprised of grasses, shrubs and trees with canopy heights to six meters, localized to alluvial flats and subject to seasonal flooding. They are found at elevations between 100-200 MSL (CONAP 2001).

This definition was further expanded to include habitat function by extrapolating from the habitat descriptions in the table we created below (Table 4.1):

Table 4.1: Low forest inferred habitat value

Habitat name	**Location of survey (and source)**	**Comparable habitats descriptions**	**Inferred habitat value of landcover (from same source)**
Shrub-dominated wetlands	Yaxha-Nakum-Naranjo (Ramsar convention: www.wetlands.org)	Shrub swamps, shrub-dominated freshwater marsh, shrub carr, alder thickets on inorganic soils	The following are general descriptions that applied to all wetlands associated habitats in the Yaxha-Nakum-Naranjo concession. Therefore only the *most applicable habitat values* are indicated here: • Supports rare/endangered mammal species • Supports rare/endangered reptile species • Supports rare/endangered bird species
Freshwater, tree dominated wetlands	Yaxha-Nakum-Naranjo (Ramsar convention: www.wetlands.org)	Freshwater swamp forest, seasonally flooded forest, wooded swamps on inorganic soils	
Sinkhole wetlands	Throughout the United States (Tiner 2003)	Marshes, aquatic beds, shrub swamps, forested wetlands and ponds	• Rare plant species • Key habitat for feeding and breeding for amphibians and reptiles
Low forest	Mirador-Río Azul National Park (WCS 2004)	Same as our description	• Endemic bird species and individuals • High rodent diversity • Distinct butterfly communities in great numbers • Distinct communities of dung beetles

Wetlands

This landcover class was termed *Humedales* in the original GIS landcover layer, and the general description was as follows:

- Humedales: Herbaceous vegetation characterized by a lack of woody plants (OMYC 1999). The surface is covered by freshwater (in Uaxactún), with depths varying, but not exceeding six meters (CONAP 2001).

The above description was not explicit as to whether-or-not it was inundated year-round or only during the rainy season. This definition was further expanded to include habitat function by inferring from the habitat descriptions in the table we created below (Table 4.2):

Table 4.2: Wetland inferred habitat value

Habitat name	**Location of survey** **(and source)**	**Comparable habitats descriptions**	**Inferred habitat value of landcover** **(from same source)**
Seasonal/intermittent freshwater marshes/pools on inorganic soil	Yaxha-Nakum-Naranjo (Ramsar convention: www.wetlands.org)	Includes sloughs, potholes, seasonally flooded meadows and sedge marshes	The following are general descriptions that applied to all wetlands associated habitats in the Yaxha-Nakum-Naranjo concession. Therefore only the *most applicable habitat values* are indicated here: • Important for amphibians • Supports rare/endangered bird species • Staging area for migratory waterbird species • Supports rare/endangered mammal species
Permanent freshwater marshes/pools	Yaxha-Nakum-Naranjo (Ramsar convention: www.wetlands.org)	Ponds (below eight ha) marshes and swamps on inorganic soil; with emergent vegetation water logged for at least most of the growing season	
Sinkhole wetlands	Throughout the United States (Tiner 2003)	Marshes, aquatic beds, shrub swamps, forested wetlands and ponds	• Rare plant species • Key habitat for feeding and breeding for amphibians and reptiles
Wetlands	Mirador-Río Azul National Park (WCS 2004)	Seasonal forest ponds. The most widely distributed wetland in the park, locally referred to as *aguadas*, form in isolated depressions throughout the landscape	• *Tapirus bairdii* (endangered) • *Tayassu pecari* (endangered) • Large cats (endangered) • *Sceloporus chrysostictus (endemic to Yucatan)* • *Mazama Pandora (endemic to the Yucatan peninsula)*

Bodies of water

Originally named *Cuerpos de agua* in the GIS data layer, this landcover represents only 0.11% of the Uaxactún concession. No further description for this landcover class was found, but we adopted the definition for *Lagunetas* from the WCS survey of Mirador-Río Azul, and applied it to our landcover class because of it similarity in size and character of the layer *Cuerpos de agua*:

- *Lagunetas*: Systems or bodies of water extending less that 0.1 km² that have formed from small collapses in the limestone bedrock, known as "*aguadas*". Because of the shortage of permanent rivers, these *lagunetas* are the only year-round source of water for the animal, as well as human, populations (CONAP 2001).

There is some overlap between the two landcover classes of *bodies of water* and *wetlands* in regards to their extrapolated descriptions and habitat function (Table 4.3). This is because the Yaxha-Nakum-Naranjo and Mirador-Río Azul surveys often grouped them together as marshes/pools and permanent/seasonal. We found it difficult to separate these two landcover classes (bodies of water and wetlands) but believe that they are differentiated primarily by the depth of their basins.

Table 4.3: Bodies of water inferred habitat value

Habitat name	**Location of survey (and source)**	**Comparable habitats descriptions**	**Inferred habitat value of landcover (from same source)**
Permanent freshwater marshes/pools	Yaxha-Nakum-Naranjo (Ramsar convention: www.wetlands.org)	Ponds (below eight ha) marshes and swamps on inorganic soil; with emergent vegetation water logged for at least most of the growing season	The following are general descriptions that applied to all wetland associated habitats in the Yaxha-Nakum-Naranjo concession. Therefore only the *most applicable habitat values* are listed here: • Important for amphibians • Supports rare/endangered bird species • Staging area for migratory waterbird species • Supports rare/endangered mammal species • Possibly supports rare/endangered and endemic fish species
Sinkhole wetlands	Throughout the United States (Tiner 2003)	Marshes, aquatic beds, shrub swamps, forested wetlands and ponds	• Rare plant species • Key habitat for feeding and breeding for amphibians and reptiles
Wetlands	Mirador-Río Azul National Park (WCS 2004)	Seasonal forest ponds. The most widely distributed wetland in the park, locally referred to as *aguadas*, form in isolated depressions throughout the landscape	• *Tapirus bairdii* (endangered) • *Tayassu pecari* (endangered) • Large cats (endangered) • *Sceloporus chrysostictus (endemic to Yucatan)*
Temporary and permanent ponds	Mirador-Río Azul National Park (WCS 2004)	Refered to as *pozas* and form in basins along river channels	• Similar to Wetlands

Riparian forest

This landcover class was originally called *Bosque ripario* and the following description was given:

- Bosque ripario: Forests that develop on the edges of rivers and their tributaries. Their canopies reach heights up to 30 meters (Table 4.4).

Table 4.4: Riparian forest inferred habitat value

Habitat name	**Location of survey (and source)**	**Comparable habitats descriptions**	**Inferred habitat value of landcover (from same source)**
Intermittent creeks and riparian forests	Mirador- Río Azul National Park	An extensive network exists locally (In Uaxactún located in the Northeast corner of the concession) referred to as arroyos, only sporadically contain sufficient water to maintain current	• Distinct butterfly communities in great numbers • Distinct communities of dung beetles • Bird edge specialists • *Peromyscus yucatanicus* (endemic) • *Heteromys gaumeri* (endemic)

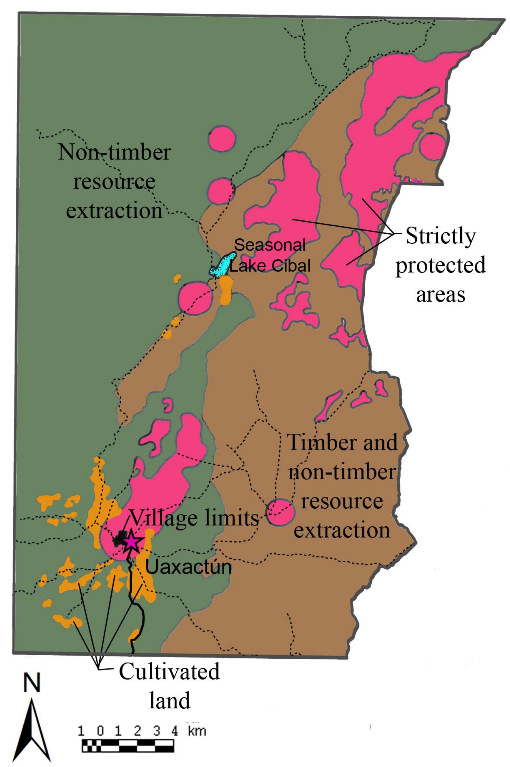
In summary, we were able to infer habitat types from landcover. This was necessary in order to incorporate the landcover information into our overall suitability analysis. Although this was useful, our analysis would have benefited greatly from a more detailed ecosystem map of Uaxactún. This information would help make better land use and management decisions. Hopefully WCS and OMYC will work toward refining their landcover data through ecological studies.

Camps and Resource Use

Land Use Plan

The overall natural resource management plan found in the OMYC management plan (Map 4.5), differentiates between timber and non-timber extraction areas, areas of limited timber extraction, and strictly protected areas (around low forests and ancient Maya sites). Resource use is the driving force in infrastructure and spatial patterns. The resource use in the concession also reflects the community of Uaxactún's commitment to the ideals of sustainability, as can be seen by generous areas of non-timber harvesting and the zones of strict protection in the seasonally flooded areas in the Land Use map to the right. Our approach to ecotourism planning will expand on this land use plan through the designation of areas or camps as appropriate for or protected from ecotourism use.

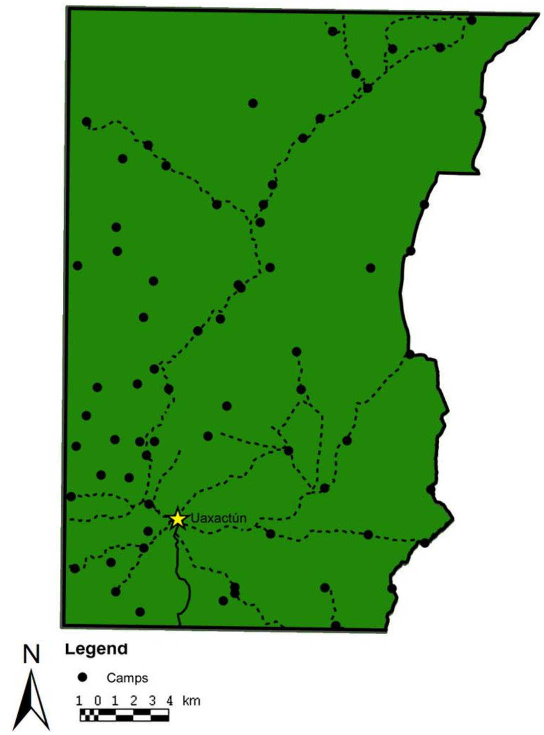
Land Use: Uaxactún Concession



Map 4.5: OMYC land use management plan

Camps

Non-timber resource extraction is, and has been in the past, the predominant source of income for the majority of Uaxactuñecos. Associated with these harvests is an extensive network of campsites throughout the concession of Uaxactún (Map 4.6). While often temporary camps are built for a single use by a single party throughout the concession, a number of established campsites are repeatedly rebuilt or maintained year after year. Camp construction is a common skill known among the Uaxactúnecos, and residents on hunting excursions or members of the fire patrol may use them throughout the year as accommodation. The majority of camp users however are collectors. Both collectors of xate ("xateros") and chicle ("chicleros") use the camps during their treks into the jungle, which can sometimes last for multiple days. Collectors of allspice use the camps as well, but we did not research them. Also, more recently a local ecotourism venture was created to bring foreign hunters into the concession to hunt the ocellated turkey (*Meleagris ocellata*), forming a new camp user group.



Map 4.6: Locations of camps in Uaxactún

We collected information on camp life and construction techniques of camps through informal interviews and two guided tours with up to ten local villagers during the month of August, 2005. Most of these villagers were xateros and chicleros, and had a range of associations with OMYC, from *socios* to representatives. Informants were introduced to us by WCS. The locations of the permanent camps were mapped by CEMEC-CONAP/WCS, and were made available to us as a GIS layer.

Overall there are differences in the ways the camps are used by each user group and in resource consumption associated with the use of these camps, but the camp structure and construction can be generalized for all users.

Xateros vs. Chicleros

Based on the thesis work of McNab (1998) and reaffirmed by conversations with four local harvesters, we found that xateros tended to use the camps less often because the nature of their work allowed them to return home on the same day, rather than working in the forest for multiple days. The chicleros on the other hand, would work for multiple weeks at a time in the forest, spending nights at jungle camps. Also, xateros tended to work in pairs or smaller groups, sometimes even alone (despite potential dangers), whereas chicleros tended to work together in larger groups. Therefore, the number of campsite users at one time would be far greater at a camp of chicleros versus a camp of xateros.

The tourist turkey hunters stay in the jungle for multiple days and use camp sites between March and May (to harvest males during the latter part of the reproductive season, after they have bred

(OMYC 1999)). The camps they use tend to differ from other camps in that there is more care spent on creating more elaborate structures (such as elevated bed frames) with higher quality materials, and construction methods.

Campsite Structure and Construction

Both xateros and chicleros use similar techniques and materials in the construction of campsites. One informant commented on camp structures, “Everyone knows how to make them. You can do it anywhere”. With some exceptions, all materials used can be found within the forest without having to search far from the camp location. We investigated construction techniques and material use through an informal interview of informants introduced to us by WCS, followed by a guided trip into the concession forests and camps with the following results:

A well-constructed camp using local techniques and materials provided by the forest can last one to three years, even if they are only used two to three months a year. Material quality depends on the species of tree or palm that is used in construction. For example “guano macho” palm has coarser and thicker fronds than “guano hembra” (see photo), therefore, guano hembra is considered more valuable and of higher quality for a roof because it forms a tighter and longer lasting weave.


Guano macho (left) and guano hembra (right)

Palms and young trees are collected to make rainproof lean-to structures either for sleeping or cooking. It is also common to see a central structure with a fire pit that would be used by all campers who could sit around a fire together. In the cooking lean-to, shelves can be made to hold food, and a vine can be hung over a fire and used to tie and hang kettles or pots over the fire to cook (see photo). In sleeping areas, roofs are made with either woven palms or tarps. Within these sleeping structures, campers have the option to make raised sleeping platforms from poles, vines, palm leaves and strips of bark. This is done as a safety measure to reduce the risk of being bitten by snakes or bothered by other potentially harmful wildlife. During the rainy season, both tourists and locals use mosquito nets when they sleep, carrying them from camp to camp.

Camp sheltered cooking area (left), and sleeping area (right), August 2005.

Resource Consumption Associated with Camps

The impacts associated with the camps are caused both through resource consumption and through an increase in waste. On the one hand the camps use almost entirely natural and renewable materials, and very limited clearing of vegetation is necessary to create space for a new camp. On the other hand, while everyone may know how to build a camp, materials may be used with varying degrees of conservation. For example, when gathering palm fronds, a careless chiclero might cut down the entire palm, while others more conscientious might only take what they need. Also, fuel for the cooking fires is collected within close proximity of camps to have fires, impacting the area around the camp through thinning and trampling. Of equal importance to resource consumption is waste disposal. Any trash produced by campers is either buried or burned on site.

Apart from materials used, the hunting of animals by camp users has an impact on the surrounding area. Research has shown a difference in the consumption amount and preferences of xateros versus chicleros (McNab 1998). Not only have chicleros been shown to consume more pounds of animal overall, they also show more discretion in their choice of animal. For example they will target certain species, whereas xateros will eat a wider variety of animals.

Our field observations made from a visit to one of the main camps confirmed what sources had informed us: that their existed a network of major camps whose locations are permanent. The areas around these camps are also disturbed due to repetition of camp use, the trampling of vegetation and soil compaction, hunting, clearing and fuel gathering, and trash accumulation associated with their use. Norms associated with camp use have considerable impacts on the habitat in which they are located such as: noise effects and hunting which negatively impact wildlife diversity, trampling and selective harvesting for construction materials and fire wood which negatively impact plant composition and structure and soil compaction, and sewage and trash disposal which increase nutrient inputs to the environment. For these reasons we view camps as nodes of human disturbance within the natural areas of the Uaxactún concession.

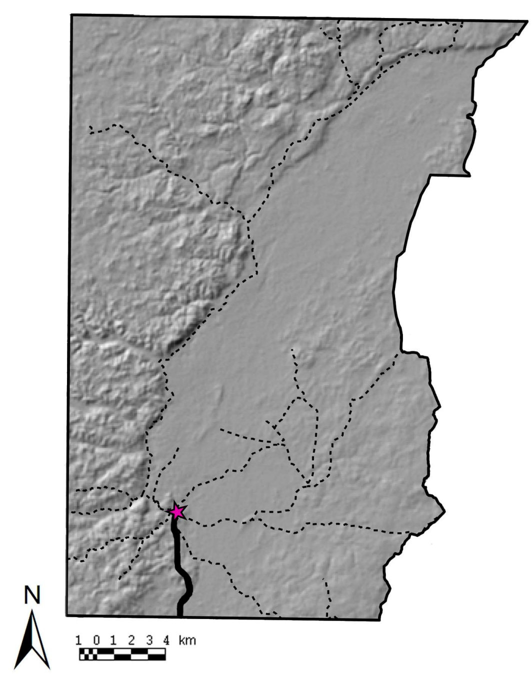
Water Use and Sewage Disposal

Water is the most limiting factor for campers in the concession. It is usually necessary to bring water out to the camps. Campers carry their own water on their person or with mules or horses, or they can arrange for a vehicle to drop it off. In one camp we visited we observed a large trough dug into the ground (46.15 cm or 18 in deep) that was lined with palm leaves. We were told that a tarp would be laid on top of the leaves to line the trough that would then be filled with water carried in by a truck. This miniature pool could then supply water for a few weeks, depending on how many campers used it, and how conservatively they used the water.

Although surface water is scarce, many camps are purposefully located near water when possible Often these water sources are seasonally filled *aguadas*, which could be wetlands or seasonal ponds. Because of the potential for these water sources to be directly connected to the groundwater system, a camps close proximity to them could have serious implications for health hazards. Surface runoff carrying waste from the camp into the water source would pollute the drinking source for the campers and potentially the groundwater supply as well. In light of the karst geology, the sites chosen for sewage disposal may have serious implications. With regards to waste disposal, it is necessary to consider more permanent and environmentally friendly technologies for sewage disposal (such as composting toilets) at camps that are considered most suitable for increased use.

Roads

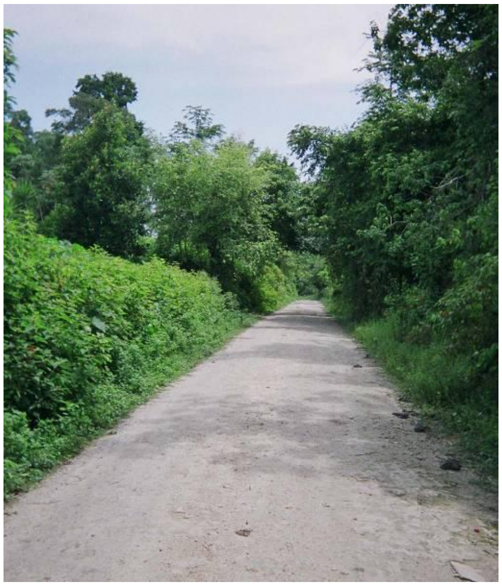
There is one main access road into the concession that connects to Tikal 23 kilometers to the south. It has a stabilized gravel road bed although it is poorly maintained and rutted in parts and seldom re-graded. The other access road connects to El Zotz to the west. Although referenced as permanent, the primary rutted roads used for extraction of resources, were not installed with aggregate road bed and are therefore subject to erosion, poor drainage and flooding (Map 4.7). Many are inaccessible in the rainy season, or, if they are used, have suffered from road widening due to attempts to avoid mud. The potential benefit of informal road construction is that it does not obstruct hydrological flows to the same degree as a raised road bed would, although it still has adverse impacts on adjacent habitats through compaction, sedimentation, and increased surface run-off. This is especially pertinent in Uaxactún as the central road runs along the base of a karst



Map 4.7: Uaxactún road network

plateau where groundwater seepage from the base may form areas of inundation in the alluvial flats to the east.

Primary paved Access Road (to Tikal)



Primary Unpaved Road (for resource extraction)

Ancient Maya Sites

Ancient Maya sites are strictly protected by a law set forth by the government agency (IDAEH), in charge of all cultural and archeological resources of Guatemala. Apart from the main excavated ancient Maya sites just outside the village, there are ten "large" ancient Maya sites located throughout the concession that are indicated in the management plan as most suitable for tourism out of a total of 59 ancient Maya sites reported throughout the concession. The ancient Maya sites in the forest are unexcavated and of various sizes. However, most have been raided, leaving gaping tunnels in their sides. On our visit to the ancient Maya sites of Ramonalito, we observed Mayan carved stones called or "stellas" (English term used by archaeologists), trenches created by looters, and a look-out platform built in the tree canopy atop the ruin that was used for fire management.


Figure 4.1: Excavated ruins of Uaxactún with sheltered Mayan carved stone in front.

Because these archeological sites are strictly protected, there is no permanent collecting or camping allowed within a set distance from each ruin. Because the areas around each ruin are protected from harvesting and do not allow permanent camp sites, we can assume that these ancient Maya sites will not be disturbed to the same degree as an established campsite would. Although they would receive a certain level of impact from ecotourism activities, they would not be subject to disturbances associated with camp activities such as cooking, sleeping, producing waste, and spending greater lengths of time in a concentrated area sustaining a higher noise level. Instead, ancient Maya sites would receive short visitations by ecotourists whose main activity would be observation. Due to the low levels of disturbance expected at the ancient Maya sites sites, we did not analyze them for their suitability apart from their tourism suitability based on their proximity to camp sites and proximity to the village.

CHAPTER FIVE:
METHODS

Methods for GIS Analysis and Data Assessment

We created an analytical model that could assess locations for their different levels of suitability for ecotourism. This required the synthesis of what we learned from our study of Uaxactún, and understanding of the implications of resource use dynamics for landscape processes. The analysis was conducted in two phases:

- *Phase One: Camp Suitability Analysis*
- *Phase Two: Integration of Tourist Preferences*

In the first phase existing camps where analyzed based on their physical location within the concession. Their suitability for use in tourism development was ranked according to their potential overall ecological impact. In the second phase data from a study surveying tourist preferences in Tikal (Juska and Koenig 2006) was applied to the model to demonstrate how this model can be tailored to incorporate tourism preferences to further refine the Camp Suitability Analysis. The methodology for the first phase will be described in the following sections.

***Phase One*- Camp Suitability Analysis**

Step 1- Develop spatial factors to represent the project objectives
Step 2- Assign ranking or binomial classification to spatial factors
Step 3- Identify and map spatial factors using GIS
Step 4- Create Suitability Decision Matrix

Step 1- *Develop the spatial factors based on the project Goals and Objectives.*

In order to incorporate the project's goals and objectives into the GIS model, we selected elements that could be mapped, identified and analyzed in the camp suitability model. The spatial factors were selected to represent the project objectives, given the GIS layers available (Table 5.1).

The objective "to identify and protect areas vulnerable to erosion" is an example. The team selected *slopes* as the appropriate spatial factor. Although this is an important measure of susceptibility to erosion, there may have been addition data that would be useful in assessing vulnerability in a more comprehensive manner, such as *soil type*. This GIS data layer was not available to the group and therefore, could not be incorporated into the analysis.

Table 5.1: Description of spatial factors

Goals	Objectives	Spatial factors
Preserve the ecological integrity and function of the landscape	Protect areas that contain rare or sensitive habitats	Wetlands, riparian forests, bodies of water
		Low forest
	Protect areas vulnerable to erosion	Slopes
	Protect interior forest habitats from impacts of roads	Roads
		Cultivated fields
Maintain spatial integrity and structure of the landscape	Protect habitats that exhibit high degrees of connectivity	Patches enclosed by road network

Step 2- *Assign rank to spatial factors*

Based on these goals and objectives, we developed spatial suitability classifications for each spatial factor (Table 5.2). Each suitability ranking or binomial classification is explained by our analysis approach.

Table 5.2: Description of rankings

Spatial factor	Analysis approach	Ranking designation
Wetlands, riparian forests, bodies of water	Applied a 300 meter buffer around perennial wetlands, bodies of water and riparian zones	*Within 300m buffer of wetlands, riparian forests, and bodies of water:* Unsuitable
Low forest	Within low forest (seasonally inundated)	*Within low forest:* Unsuitable
Slopes	Used topographic data layers to identify areas vulnerable to erosion (with slopes equal to or exceeding 15%)	*High vulnerability (slopes >15%):* Unsuitable *Acceptable vulnerability (slopes 0-15%):* Suitable
Roads	Applied three buffers of differing sizes to primary roads: 50 meters, 300 meters, and 1000 meters in order to measure the disturbance zone for different species with a range from low to high sensitivity to human disturbance	*50m (species with low sensitivity):* Most suitable *300m (moderate sensitivity):* Moderately suitable *1000m (high sensitivity):* Least suitable *>1000m (highest sensitivity):* Unsuitable
Cultivated fields	Applied three buffers of differing sizes to areas cultivated fields: 50 meters, 300 meters, and 1000 meters in order to measure the disturbance zone for different species with a range from low to high sensitivity to human disturbance	*50m (species with low sensitivity):* Most suitable *300m (moderate sensitivity):* Moderately suitable *1000m (high sensitivity):* Least suitable *>1000m (highest sensitivity):* Unsuitable
Patch enclosed by roads	Analyzing the existing primary road network, identified patches of land that were completely enclosed by a road circuit. Ranking based on patch size. Bigger patch = more interior habitat	*Small patches (0-300 acres):* Most suitable *Med. patches (300.01-10,000 acres):* Moderately suitable *Large patches (>10,000 acres):* Least suitable

<u>Wetlands, riparian forest, bodies of water</u>

Factor justification:

This factor is a direct spatial representation of the team's objective to protect those areas of rare or sensitive habitats. Because of the rareness of these habitats in the region and their value as habitats for rare and endemic species, and their importance for drinking water, the landcover layers of wetlands, riparian forests, and bodies of water (Table 5.3) have been selected by the team for protection from ecotourism activities. Using the binomial classification of either suitable or unsuitable, these areas are protected.

Approach to analysis:

The team felt that it was important to protect these sensitive habitats as well as closely associated terrestrial habitats. To protect habitats in Uaxactún against a potential increase in human disturbance associated with increased ecotourism (such as sewage, waste, trampling and noise), buffers representing areas of strict protection can be designated around each rare habitat type.

In practice, the widths of these buffers vary according to landcover criteria or wildlife habitat requirements. To determine the appropriate widths of the buffers, the team used the precedent of Semlitsch and Bodie (2003) to respond to the most sensitive species needs and represent the most conservative estimate. For wetlands, riparian forests, and bodies of water a 250 meter buffer should be applied in order to account for the terrestrial habitat required by amphibian and reptile species for feeding and breeding. An additional 50 meter buffer around all rare habitats would protect them against human disturbance and render the area within 50 meters of both their aquatic and terrestrial habitat as unsuitable for ecotourism. As a result these habitats require a 300 meter buffer in total. In keeping with this conclusion we viewed the areas within these buffers as unsuitable for consideration in ecotourism.

Data source:

Table 5.3: Landcover data source

Data set	**Description**	**Year published**	**Format**	**Source**	**Original projection**
Sisnat	Landcover types	2000	ESRI® grid	CONAP/TNC	UTM 16, NAD27 Central America

<u>Low forest</u>

Factor justification:

Similar to the *Wetland, riparian forest and bodies of water* spatial factor, this factor is a direct spatial representation of the team's objective to protect habitats based on the landcover layers that are regionally rare or sensitive to human disturbance (Table 5.3). Like the other rare or sensitive landcover classes, low forests serve as valuable habitat to an array of endemic and rare wildlife species (see Table 4.1). The low forest landcover class is distinct, however, in that it only floods during the wet season while the other sensitive landcover classes have water present year-round. Because of this hydrological distinction, we decided to analyze the low forest using a different approach than the previous spatial factors, as described below.

Approach to analysis:

Because low forests experience seasonal flooding during the wet season, we assumed that the composition of the wildlife species associated with the landcover would fluctuate seasonally as well, as the habitat dynamics changed from wet to dry forest. The loss of the wet habitat during the dry season led us to assume that a 250 meter associated terrestrial habitat buffer (used in the analysis of the habitats with year round presence of water) would no longer apply. This decision was based on the assumption that the seasonal character of the flooded habitat would change the wildlife species present and/or any dependency on the adjacent landcover as terrestrial habitat for breeding or other life stages. Therefore we applied only a 50 meter buffer in order to protect from human disturbance.

Because we found a lack of information and data researching the dynamics of the low forest ecosystem, this analysis is speculative and therefore we encourage that more research and understanding is achieved before either excluding or implementing tourism activities in proximity to low forests. For this reason we have ranked camps found within the 50 meter buffer around low forests in a special category of "research needed". This ranking would require that site specific field investigations be carried out before making any decision to implement ecotourism activities.

Slopes

Factor justification:

Slope was identified as an appropriate spatial factor that would represent the team's objective to protect areas vulnerable to erosion. As discussed in the previous section, the risk of environmental degradation increases as slope increases beyond the point of allowing for infiltration. Similar to the rare habitat analysis, binomial classifications were used to classify areas as having acceptable or unacceptable percent slope.

Approach to analysis:

Using a Digital Elevation Model (DEM) (Table 5.4), the team used a slope analysis function in GIS to calculate the percent slope within the Uaxactún concession and identify areas of steep slopes. The team chose to designate areas above 15% as steep. We chose to use this measure as a conservative estimate that was consistent with the best management practice standard of another karstic region (BMP Maryland, USA 2006). Camps located in areas with a slope equal to or exceeding 15% will be classified as unsuitable for ecotourism development, while those located in areas with a slope below 15% will be identified as suitable.

Data source:

Table 5.4: Elevation data source

Data set	**Description**	**Year published**	**Format**	**Source**	**Original projection**
srtm16	Elevation in meters	2003	Raster grid	NASA/DLR	UTM 16, NAD27 Central America

Patch enclosed by road

Factor justification:

Patch enclosed by road was the spatial factor used by the team to address the objective of maintaining areas that exhibit high degrees of connectivity. Roads were used to define the boundaries of patches for two main reasons:

1. Road networks play a major role in landscape transformation by dissecting previously continuous large patches into smaller patches. Ecological flows and processes become limited between these smaller patches and the adjacent patches, as roads either act as barriers or filters to movement across the landscape, particularly in regards to more sensitive wildlife species.
2. There is no other development or land use present in the concession that contributes to the fragmentation of the landscape.

Approach to analysis:

It is important to note that roads were used in two separate analyses in order to incorporate different effects of roads on habitat. For this patch size analysis, the team focused on the potential for roads to contribute to habitat isolation by examining the layout of the road network. This analysis does not take into account the effects of roads on habitat quality. Instead, it considers whether or not the road completely encloses a patch of forest, and therefore decreases its connectivity with adjacent patches. In certain instances, two roads came within close proximity of each other, pinching the forest between the roads in a narrow aperture. We decided that roads within 500 meters or less of each other would be interpreted as an ecological barrier even though the road technically does not enclose the forest (Figure 5.1).

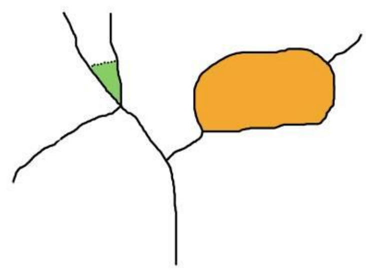


Figure 5.1: A road network fork that creates a small patch is shown in green, while a larger patch that is completely enclosed by a road is shown in orange.

The team believes that the best way to avoid further dissection of the landscape and maximize landscape connectivity is to distinguish those patches experiencing the greatest degree of dissection from those that exhibit the greatest degree of connectivity. Therefore, small patches enclosed by the road network were differentiated from larger patches with borders that often continued far outside the concession boundary. Because many of these patches extended beyond the Uaxactún border, the team increased the geographic extent of the analysis, since most political lines do not impose any barriers to movement for wildlife (in the case of Uaxactún). The only border that was used as a barrier was the southern border of the concession due to the management regime of limit demarcation and maintenance on that particular border. Because it borders Tikal National Park, vegetation is cleared to create a fire break, and the break is frequently patrolled by trucks looking for poachers and trespassers. For those actions we consider this border equivalent to a road.

The patches that had the greatest degree of connectivity were those patches that were uninterrupted by the road network (Table 5.5) and therefore exhibited the least amount of dissection. These patches were large and often extended beyond the boundaries of the concession (Table 5.5). Therefore, the larger the patches are, the greater their value is in regards to landscape processes.

The smaller patches were viewed by the team as the areas most compromised by dissection, and therefore ranked most suitable for tourism activities. Medium-sized patches were ranked moderately suitable while the larger patches were ranked as least suitable. Therefore camps located in smaller, more isolated patches will be ranked as more suitable locations for ecotourism development while those in larger, well connected patches will be identifying as least suitable.

Data source:

Table 5.5: Road and concession data sources

Data set	Description	Year published	Format	Source	Original projection
caminos	Backroads and access roads with surface type attributes	2005	ESRI® shapefile	CEMEC-CONAP/WCS, WCS	UTM 16, NAD27 Central America
aprotegida-concesiones	Protected areas of the Multi-Use Zone with name and management categories	2005	ESRI® shapefile	CEMEC/CONAP	UTM 16, NAD27 Central America

Roads and cultivated fields

Factor justification:

In this analysis the team focuses on the disturbance and degradation of habitat caused by *roads and cultivated fields* (Tables 5.5 and 5.3). These human disturbances have been identified by the team as the two greatest sources of impact on the landscape. Through the spatial processes described as perforation (by cultivated fields) and dissection (by roads) of the forest matrix, the result is a loss of interior habitat. We used the mapped entities of these spatial factors to analyze the extent of their impact, and to delineate interior habitats from human created edges.

Approach to analysis:

This approach of delineating areas of interior habitat was based on Forman's concept of a road-effect zone (Forman 2003), where effects of disturbances extend outward from the road corridor into adjacent habitats. We have adopted this road-effect zone and applied it to both roads and cultivated fields because the team felt that many effects described for roads on habitats could be applied to cultivated fields. Cultivated fields have been identified as nodes of human disturbance where surrounding habitats experience impacts similar to those caused by roads such as: acute noise disturbances that effect animal movements and species composition, changes in plant composition and reduction of plant diversity, increased sedimentation from exposed soils and chemical transportation from agrochemical applications. It is likely the approach we have taken for analyzing the impacts of cultivated fields is an oversimplification and an exaggeration of what the impacts of the agricultural practices in Uaxactún actually are. Because we were unable to discern cultivated fields from fallow fields, the results are based on a generalization that all the area designated for agriculture is in cultivation.

Based on Forman, we identified three different effect zones: short, medium and long-distance effect zones. According to Forman, the extents of the effect zones are asymmetrical with convoluted boundaries, reflecting the unequal effect-distances due to variable slope, wind, and habitat suitability on opposite sides of the roads (Forman 2003). For our approach, we fixed the distances of outward extent for the three zones at 50 meters for the short distance effect, 300 meters for the medium distance effect, and 1000 meters for the long distance effect. These distances were set using the more conservative estimates of the range of distances encountered in our literature reviews.

In using the most conservative estimates for the different effect zones, the team was able to ensure that effect zones on adjacent habitats were fully represented. This allowed us to identify and protect ecological processes of interior habitat from the perspective of the most sensitive wildlife species. Therefore, using camp locations (Table 5.6) camp suitability was ranked as follows: camps located in the short-distance effect zone were ranked as *most suitable*, since they would be under the influence of all three effect zones; camps in the medium-effect zone were ranked as *moderately suitable*, since they were only under the influence of the medium and long-distance effect zones; and camps in the long-distance effect zone were ranked as *least suitable* since they were only influenced by long-distance effect zones. Areas outside the effect zones were ranked as *unsuitable*, since they were remote enough to be defined as interior habitat from the perspective of the most sensitive interior species.

Data source:

Table 5.6: Camp data source

Data set	Description	Year published	Format	Source	Original projection
Camp-amentos	Camps used for non-timber extraction, with camp names	2005	ESRI® shapefile	CEMEC-CONAP/WCS, WCS	UTM 16, NAD27 Central America

Step 3- *Identify and map spatial factors using GIS*

During this step we conducted GIS Analysis to create a suitability map for each spatial factor.

Step 4- *Decision matrix*

Ranked spatial factors were combined to generate a suitability map. In order to combine those rankings the team created a suitability decision matrix using the method of logical combination. As explained in Hopkins (1977), in this method we are able to assign suitabilities to sets of combinations of factors. Also, we can express this using verbal logic rather than numbers and arithmetic. An important aspect of this process of determining suitabilities is that it is explicit, and can deal with interdependence. For example, when combining three factors, there are eight possible combinations. Using rules of combination each combination of factors could have a different suitability (Kiefer 1965 as cited by Hopkins 1977). On the other hand, rules of combination can assign suitabilities without having to deal with every possible combination. For example a general rule could be that the rating of the worst factor overrides the ratings of all other factors. In the hierarchical combination method the approach is more structured, and allows subsets of factors to be considered for interdependence (Alexander 1964 as cited in Hopkins 1977).

Matrix justification:

The decision matrix (Table 5.7) is a representation of the structure of rules we applied to each camp for its relationship to each spatial factor. We prioritized certain spatial factors by using a binary classification system of yes or no questions, in order to eliminate certain camps by making this ranking override all other factor suitabilities. Thereafter we generated rules of combination to determine camp suitabilities.

The most explicit spatial factors were habitat type and slope because we used binomial classifications rather than rankings for their suitabilities. If a camp intersected rare or sensitive habitat (buffered wetland, riparian forest, or body of water and unbuffered low forest), then the camp was ranked as unsuitable overall. Because of uncertainties about the dynamics of low forest ecology, we allowed the consideration of camps that were within 50 meters (164.04 ft) of a low forest, but labeled them as worth exploring with the clause that more research would be needed to make management decisions. With regards to slope, in order to be conservative with our lack of knowledge of soil types we assumed that any camp located on a steep slope would potentially cause erosion and habitat degradation to an unsustainable degree. For that reason, any camp intersecting an area with a slope greater than 15% was considered unsuitable overall.

Of the spatial factors that were assigned rankings, proximity to road was the only factor that could possibly yield a ranking of unsuitable. Our most conservative estimate of the distance from a road in which animal behavior or movement would be affected due to human disturbance was within 1000 meters (3,280.83 ft) from each side. Beyond that 1000 meters the forest is considered undisturbed by the road and in interior forest. Therefore any camp that was located beyond 1000 meters of a road was ranked unsuitable overall. The only other camps ranked as unsuitable were the result of the combination of two factor suitabilities: distance from road and fragment size. For camps located in the least suitable fragment size (large), if they were also located between 300 and 1000 meters (984.25 and 3,280.83 ft) away from a road, they were considered unsuitable because we considered larger patches more sensitive to road disturbance.

The remaining camps were explicitly assigned rankings based on the combination of their suitabilities for each factor. Suitabilities in the matrix are organized from highest to lowest in the table from top to bottom and from left to right. For example patch size is written from left to right as small, medium, and large. From a suitability stand point a small patch is the most highly suitable on to a large patch which is considered the least suitable. Cultivated field effect is organized similarly from top to bottom with the most highly suitable rankings at the top. The overall effect is the pattern of the most highly ranked camps at the top left and the least suitable camps at the bottom right.

In summary:

The decision matrix can be translated in three main questions that will determine whether or not a camp is suitable or unsuitable. They are as follows:

1. Does the camp intersect rare or sensitive habitat?
    a. Buffered Wetland, Riparian Forest, or Body of Water? *If yes, camp is unsuitable.*
    b. Low Forest? *If yes, camp is unsuitable.*
    c. Within 50 meter buffer around Low Forest? *If yes, consider camp with more research.*
2. Is there an acceptable vulnerability to erosion where the camp is located? *If no, camp is unsuitable.*
3. Is the camp located beyond 1000 meters from a road? *If yes, camp is unsuitable.*

For the camps that the above listed questions do not pertain to, the decision matrix (Table 5.7) can be expressed in words by the following list of rules of combination for camp suitabilities:

- Camps located within 50 meters of the road regardless of proximity to a cultivated field are considered most suitable if located within a small or medium sized patch, and suitable if located in a large patch.

- Camps located between 50 and 300 meters of the road, within 0 to 300 meters of a cultivated field, and in a small patch are considered most suitable, in a medium or large patch are considered suitable.

- Camps located between 50 and 300 meters of the road, 300 meters or beyond from a cultivated field, and in a small patch are considered suitable, in a medium or large patch are considered least suitable.

- Camps located between 300 and 1000 meters of the road, within 0 to 300 meters of a cultivated field, and in a small patch are considered suitable, in a medium patch are considered least suitable, and in a large patch are considered unsuitable.

- Camps located between 300 and 1000 meters of the road, 300 meters or beyond from a cultivated field and in a small or medium patch are considered least suitable, and in a large patch are considered unsuitable.

Table 5.7: Suitability matrix

Landcover				Tall forest				Low forest					Buffered wetland, riparian forest, or body of water		
								Within 50m buffer around low forest				Within low forest			
Intersects rare or sensitive habitat?				No- Suitable				Worth Exploring- more research needed				Yes- Unsuitable	Yes- Unsuitable		
Acceptable vulnerability to erosion?				No	Yes			No	Yes			U	U		
Patch size (small to large)				U	Small	Medium	Large	U	Small	Medium	Large	U	Small	Medium	Large
Primary road effects	Within 50m- most disturbed	**Cultivated field effects**	Within 50m	U	MS	MS	S	U	MWE	MWE	WE	U	U	U	U
			Between 50 and 300m	U	MS	MS	S	U	MWE	MWE	WE				
			Between 300 and 1000m	U	MS	MS	S	U	MWE	MWE	WE				
			Beyond 1000m	U	MS	MS	S	U	MWE	MWE	WE				
	Between 50 and 300m	**Cultivated field effects**	Within 50m	U	MS	S	S	U	MWE	WE	WE	U	U	U	U
			Between 50 and 300m	U	MS	S	S	U	MWE	WE	WE				
			Between 300 and 1000m	U	S	LS	LS	U	WE	LWE	LWE				
			Beyond 1000m	U	S	LS	LS	U	WE	LWE	LWE				
	Between 300 and 1000m	**Cultivated field effects**	Within 50m	U	S	LS	U	U	WE	LWE	U	U	U	U	U
			Between 50 and 300m	U	S	LS	U	U	WE	LWE	U				
			Between 300 and 1000m	U	LS	LS	U	U	LWE	LWE	U				
			Beyond 1000m	U	LS	LS	U	U	LWE	LWE	U				
	Beyond 1000m- least disturbed	**Cultivated field effects**	Within 50m	U	U	U	U	U	U	U	U	U	U	U	U
			Between 50 and 300m												
			Between 300 and 1000m												
			Beyond 1000m												

Key:

MS- Most Suitable for further exploration	S- Suitable for further exploration	LS- Least Suitable for further exploration	U- Unsuitable for further exploration
MWE- Most Worth Exploring	WE- Worth Exploring	LWE- Least Worth Exploring	

***Phase Two*: Integration of Tourist Preferences**

For the second phase of our analysis we used the findings of a tourism survey of tourist preferences by Juska and Koenig (2006) completed in Tikal concurrently with our project research to demonstrate how this model can be tailored to incorporate tourist preferences. Using the most highly ranked results from the survey, the team created three hypothetical tours to analyze which camps would be suitable for each tour. Travel time was chosen as the spatial factor to evaluate camp suitability for hypothetical tours.

No suitability rankings were applied to individual camps or ancient Maya sites based on whether or not they would be more or less suitable for tourists.. Because of the limited information we had with regards to ranking the camps and ancient Maya sites from a tourism perspective (aesthetics, views, size, archeological importance or sensitivity, etc) we made the assumption that all camps and ancient Maya sites were equal. We instead classified the camps and ancient Maya sites as more or less suitable based on geographic distances in response to criteria generated from the tourist preferences survey results. For example, assuming the village is the starting point, if tourists prefer to visit an ancient Maya site during a half-day hike, we would classify all ancient Maya sites close enough to the village to be reached in a half-day hike as suitable.

Also, we have not incorporated any issues dealing with tourist safety in any of the tourism analysis. These issues, such as presence of venomous snake, availability of drinking water, and other risks associated with camping in remote locations, were viewed as outside of the project's scope.

The methodology for this second phase will be described in the following sections:

Step 1- Develop hypothetical tours
Step 2- Develop spatial factors to evaluate tours
Step 3- Identify and map spatial factors using GIS

Step 1- *Develop hypothetical tours*

The survey conducted by Juska and Koenig (2006) during the summer of 2005 surveyed nearly 100 respondents in Tikal National Park for their tourism activity preferences (Table 5.8). Their survey found the most popular results for tourism activities were the following:

- Interest in a guided, overnight visit to remote ancient Maya sites in the jungle.
- Interest in experiencing culture such as ancient Maya sites, farms, and use of forest products.
- Interest in a night tour of ancient Maya sites.
- Majority only wanted half-day of physical activity; less wanted a full-day.
- Most respondents do not spend a long time in the region.

Summary of the most highly rated responses from tourist preference survey:

Table 5.8: Selected survey results of tourist preferences

Preferences indicated:	Percent response
Activities offered in Uaxactún	
Experience Culture	56%
Night tour of ancient Maya sites	55%
Hiking/Trekking to ancient Maya sites	40%
Horseback tour to ancient Maya sites	32%
Tour of plant usage	30%
Interested in what Cultural Activities:	
Cultivated Field	31.5%
Forest	22.2%
Hiking/Horseback riding- Duration of physical activity:	
Half-day	53.3%
Full day	33.3%
Interest in guided, overnight visits to remote ancient Maya sites in jungle:	
Yes	84%
No	16%
How long do you plan on staying in Petén:	
Average	3 days

Using the tourist preferences data, we created three hypothetical tours that Uaxactún could offer to visitors that would include the different preferred tourist activities. With that information we further identified the camps most appropriate for each tour based on their distance classification. In all, camps would be evaluated by the following criteria:

- Rank from the environmental suitability analysis
- Distance from the village of Uaxactún
- Proximity to remote ancient Maya sites

Descriptions of hypothetical tours:

Tour 1*: Half day hike into the jungle to learn about forest culture including: use of plants and other forest resources, lunch in a jungle camp while learning about life as a xatero/chiclero, and a visit to a cultivated field to learn about local agricultural practices.*

This tour description equates to the following criteria: round trip distance between the village and the camp should be completed in half a day. Because cultivated fields are so abundant in close proximity to the village, the team assumed this would be achieved with any camp choice.

Tour 2: *Full day hike into the forest penetrates deeper into the Mayan jungles to learn about forest culture, cultivated fields, and remote archeological ancient Maya sites.*

This second tour description equates to: round trip distance between the village and a camp should be completed in a full day. Also, the presence of a ruin either within close proximity to a camp, or passable on the way in a full day would be the most suitable. Again, cultivated fields were assumed to be easily visited.

Tour 3: *Overnight hike into the jungle includes learning about forest culture, a visit to a cultivated field, and a visit to an archeological ruin. In addition, watch the sunset from the peak of an ancient Mayan temple and spend the night in a jungle camp to experience the night life of the Mayan jungle.*

This final tour description equates to: round trip distance between the village and a camp should be completed in an overnight visit. In order to watch the sunset from a ruin and return to a camp to sleep, the ruin must be located within a very close distance from the camp.

Step 2- *Develop spatial factors to evaluate hypothetical tours (Table 5.9)*

Table 5.9: Description of travel time spatial factor

Spatial factor	Analysis approach	Distance classification
Travel time	Applied buffers around the village and ancient Maya sites to estimate travel time	*Within 5,000 meters of the village: reachable in half to full day;* *Within 10,000 meters of the village: reachable in full day to overnight trip;* *Within 20,000 meters of the village: reachable in overnight trip or greater;* *Beyond 20,000 meters of the village: reachable in greater than overnight trip;* *Within 1,209.68 meters (0.75 miles) of a ruin: reachable in a short period of time*

<u>Travel time</u>

Factor justification:

Because the team lacked information regarding specific camp or road conditions such as level of difficulty, seasonality, or any measure of aesthetics or comfort, distances and travel time became the most important measures of tourism suitability. Because the team was limited by a lack of knowledge of local estimates of travel times, conservative estimates were used based on Euclidean distances, or map distances “as the bird flies”, rather than overland distance.

The camp's distance from the village of Uaxactún is important for planning trips in a specific time frame due to the short trips desired by many tourists. Also, because only one daily bus service is available to the village, timing is even more critical for a tourist interested in a short visit. However, estimates of travel time to and from specific camps or between a camp and a ruin are largely dependent on a guide's knowledge of trails, the speed or fitness of the tourists themselves, weather conditions, the amount of stoppage time allowed to take photographs or if wildlife is sighted etc. This evaluation is meant as a demonstration of how information from tourist surveys could be applied to tourism planning at a large scale.

Approach to analysis:

In order to make a conservative estimate of travel time, the team surveyed travel literature and websites for their estimates and time and distance. Using those estimates we converted their distances to Euclidean distances, and mimicked this conversion in creating our own distances.

Three distance zones of proximity to village:

- Half day to full day trip
- Full day to Overnight trip
- Overnight trip or greater
- Greater than an overnight trip

For proximity of camps to ancient Maya sites, buffers of a 1,209.68 meter *(*0.75 mile) radius were put around ancient Maya sites to observe whether any camps were located within these buffers. Again, using the GIS data (Table 5.10) these estimates of distance are conservative, and assume that the tourist is beginning his tour at the village, and hiking. The use of mules or horses for portions of the hike, and more intimate knowledge of foot trails by local guides would change these estimates.

*Data source***:**

Table 5.10: Ruin and village data sources

Data set	**Description**	**Year published**	**Format**	**Source**	**Original projection**
sitios-arqueologicos	Ancient Maya sites with names	2005	ESRI® shapefile	IDAEH, CEMEC-CONAP/WCS, WCS	UTM 16, NAD27 Central America
Asenta-mientos	Villages with names and population numbers	2005	ESRI® shapefile	CEMEC-CONAP/WCS	UTM 16, NAD27 Central America

CHAPTER SIX:
RESULTS

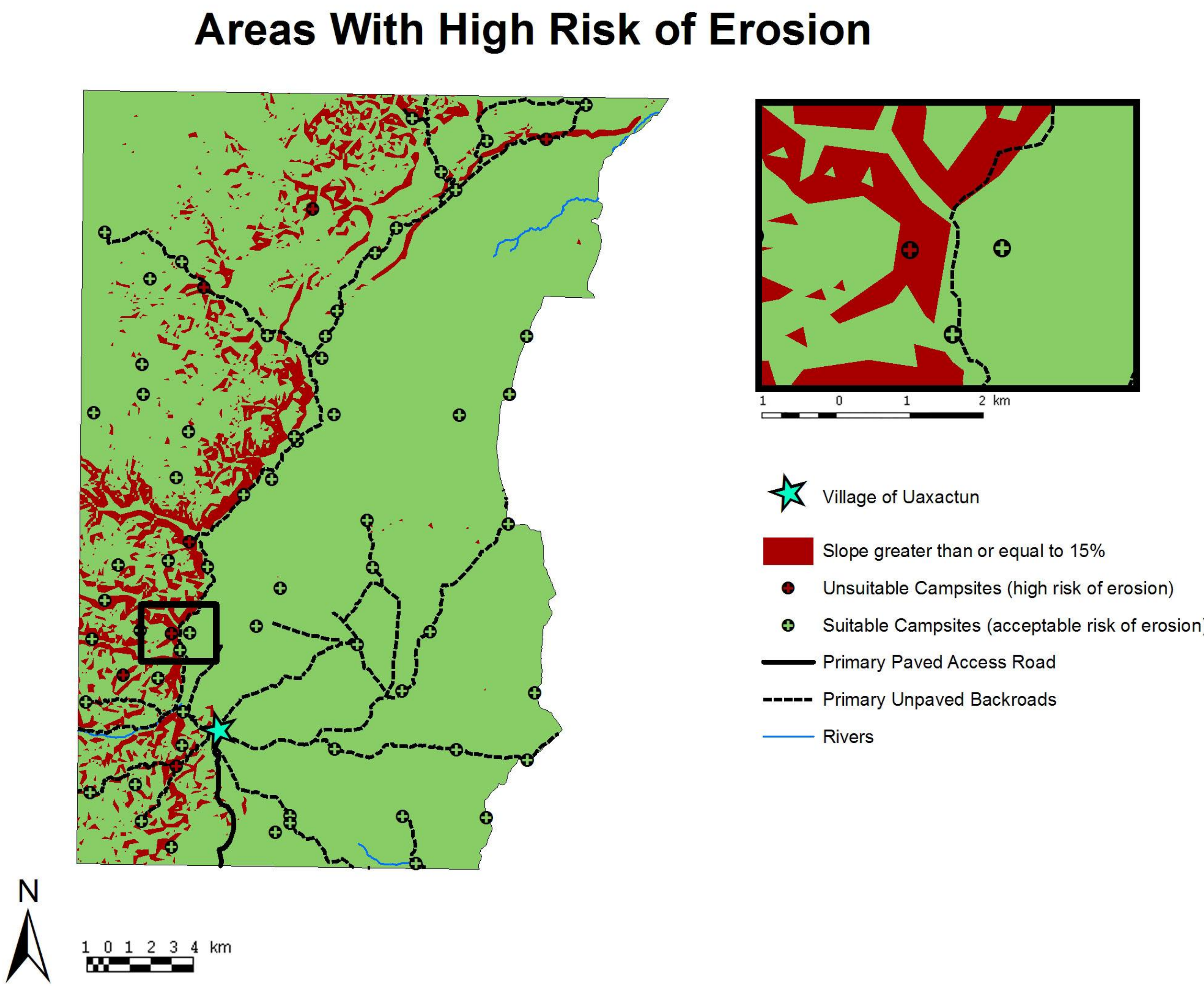
Results for Camp Suitability Analysis:

Spatial factors

Spatial factors were selected to create an overall camp suitability decision matrix. These factors were designed to be highly selective in yielding suitable camps. Our results identified only two out of 69 camps were ranked as overall most suitable, and 12 out of 69 camps were ranked suitable. The results for the special categories of low forest analysis found one camp out of 69 was considered most worth exploring or worth a field investigation, and four out of 69 camps were considered suitable for exploring, as they were all located within 50 meters of a low forest. Overall, 45 out of 69 camps (65.2%) were considered entirely unsuitable. The most important limiting factors were steep slopes and rare or sensitive habitats. The intersection of camps with these factors eliminated seven and five camps respectively as unsuitable. The second most important factor, and most selective, was proximity to roads. Eighteen camps were located beyond 1000 meters from a road and were rendered unsuitable (26%). Thereafter the most important factors were size of fragment and proximity to a cultivated field.

Steep slope, vulnerability to erosion:

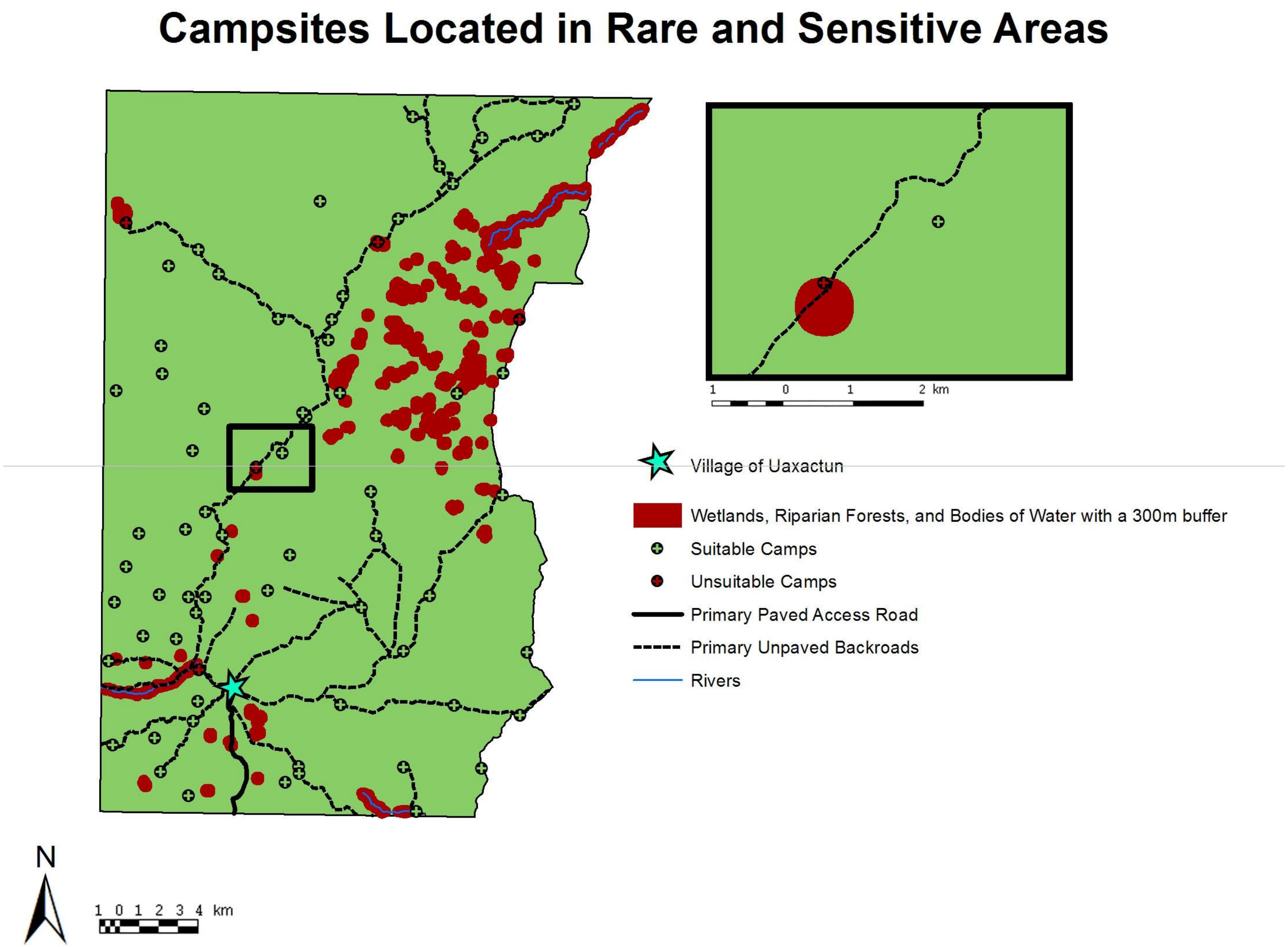
The areas with slopes exceeding 15% were concentrated along the ridge running through the middle of the concession, and to the west. Seven camps intersected the areas with steeps slope making them unsuitable (Map 6.1).



Map 6.1: Camps in areas with a high risk of erosion

Wetlands, riparian forests, and bodies of water:

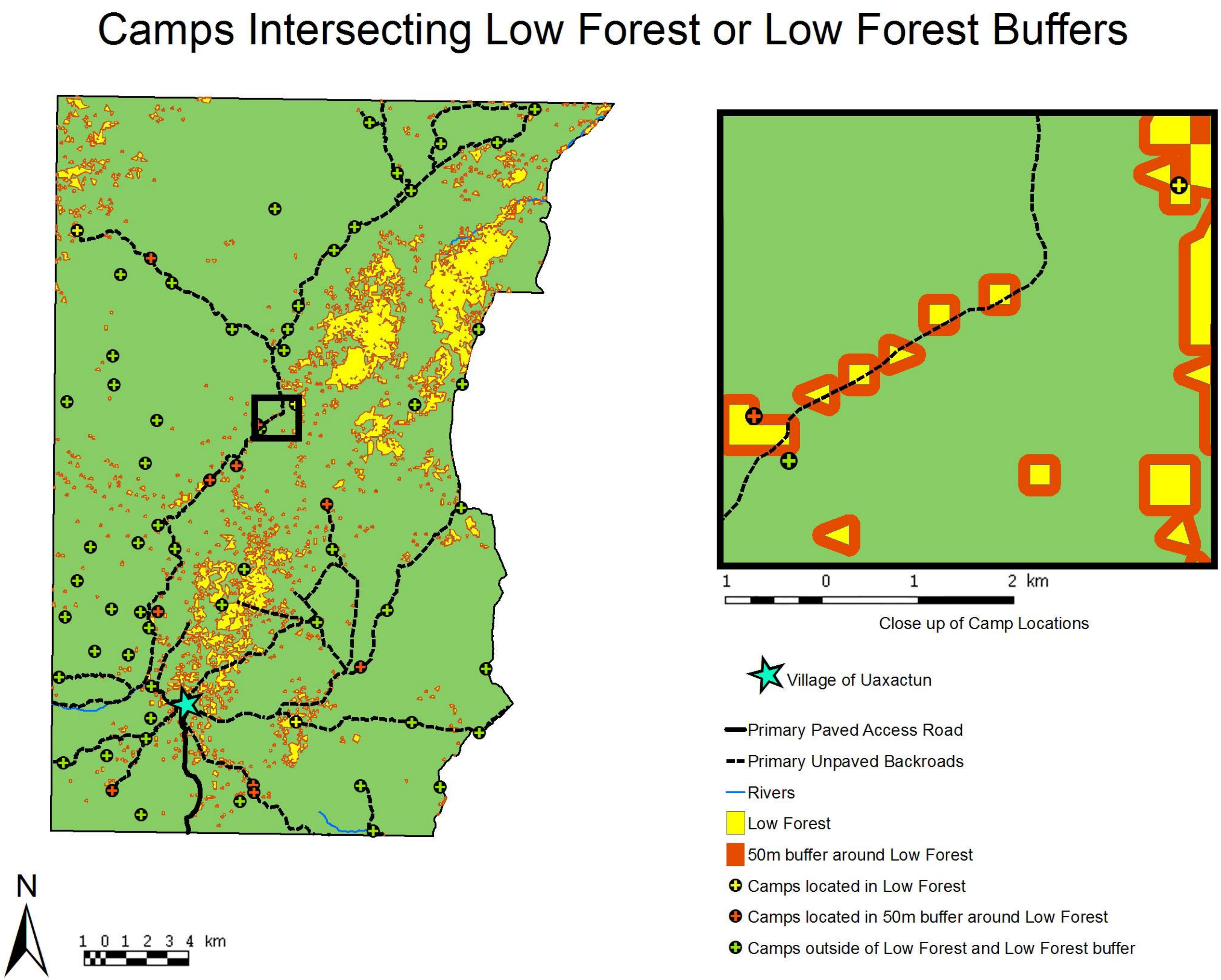
Wetlands, riparian forests and bodies of water were located primarily along river channels and concentrated in the north-east corner of the concession. The largest river in the concession is a section of the Río Tikal which begins in the northeast corner of the concession. Buffers around bodies of water overlapped the riparian forest buffers as would be expected. These buffers existed along the Río Tikal and along an unnamed segment of a river channel to the southwest of the village of Uaxactún. Five out of 69 camps were located within the buffered area of rare and sensitive habitats and classified unsuitable. No camps intersected the actual habitat extents as defined by the GIS layer in the absence of a buffer (Map 6.2).



Map 6.2: Camps located in rare and sensitive areas

Low forest:

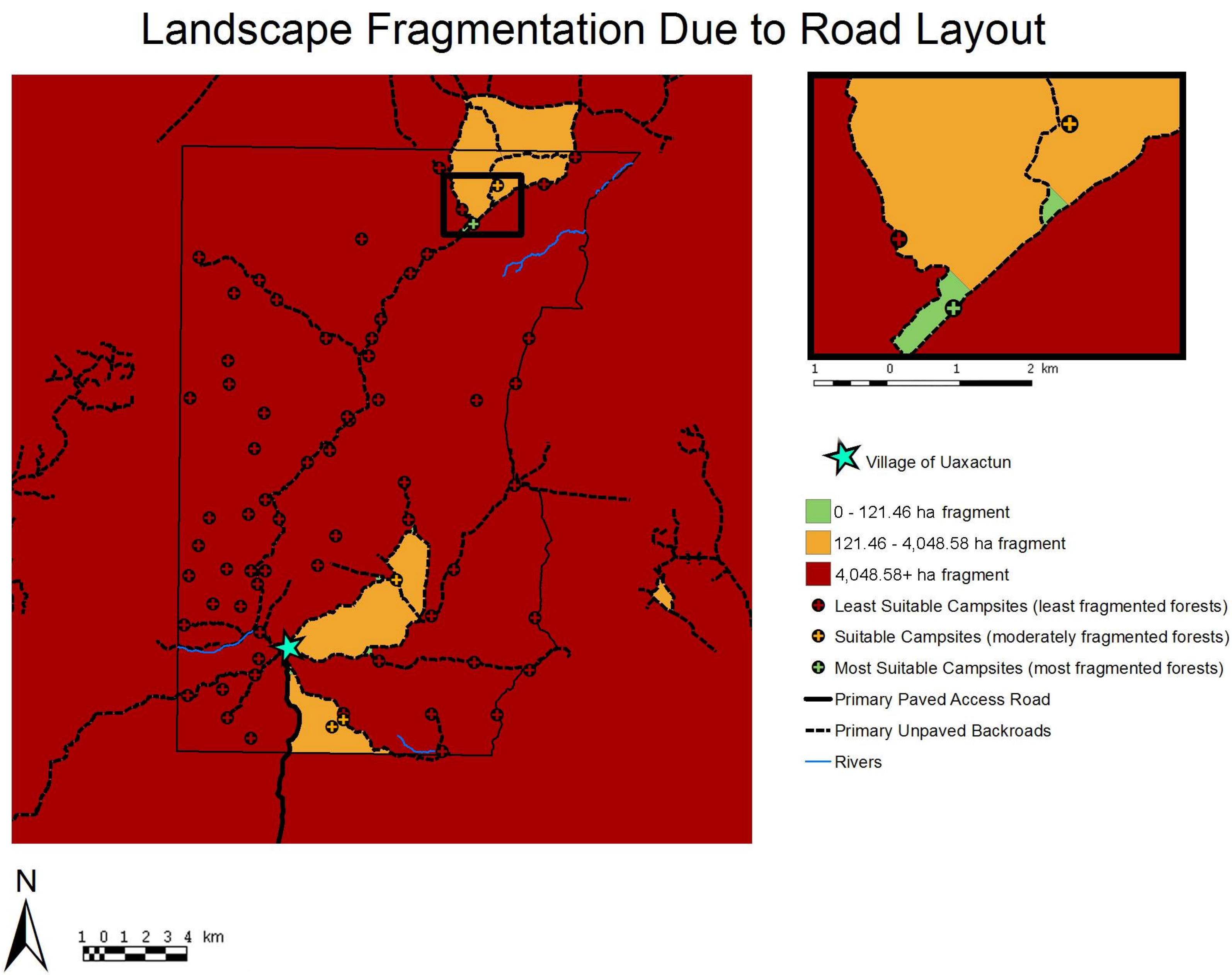
Low forest was concentrated to the east side of the concession where the elevation flattens out beyond the central ridge. This area of concentration coincided with that of wetlands, riparian forests, and bodies of water. Larger continuous patches of low forest of 850.2 to 1133.6 ha (2,100 to 2,800 acres) emerge in the northeast corner of the concession with increasing proximity to the Río Tikal. Three camps are located in low forests 0.81 to 21.05 ha (2 to 52 acres) in size and ten camps are located within 50 meters (164.04 ft) of a low forest patch between 0.53 and 4.86 ha (1.3 and 12 acres) in size. The low forests these camps are associated with are not the larger continuous patches but rather smaller areas dispersed among other forest patches (Map 6.3).



Map 6.3: Camps located in low forest or low forest buffers

Patches enclosed by roads:

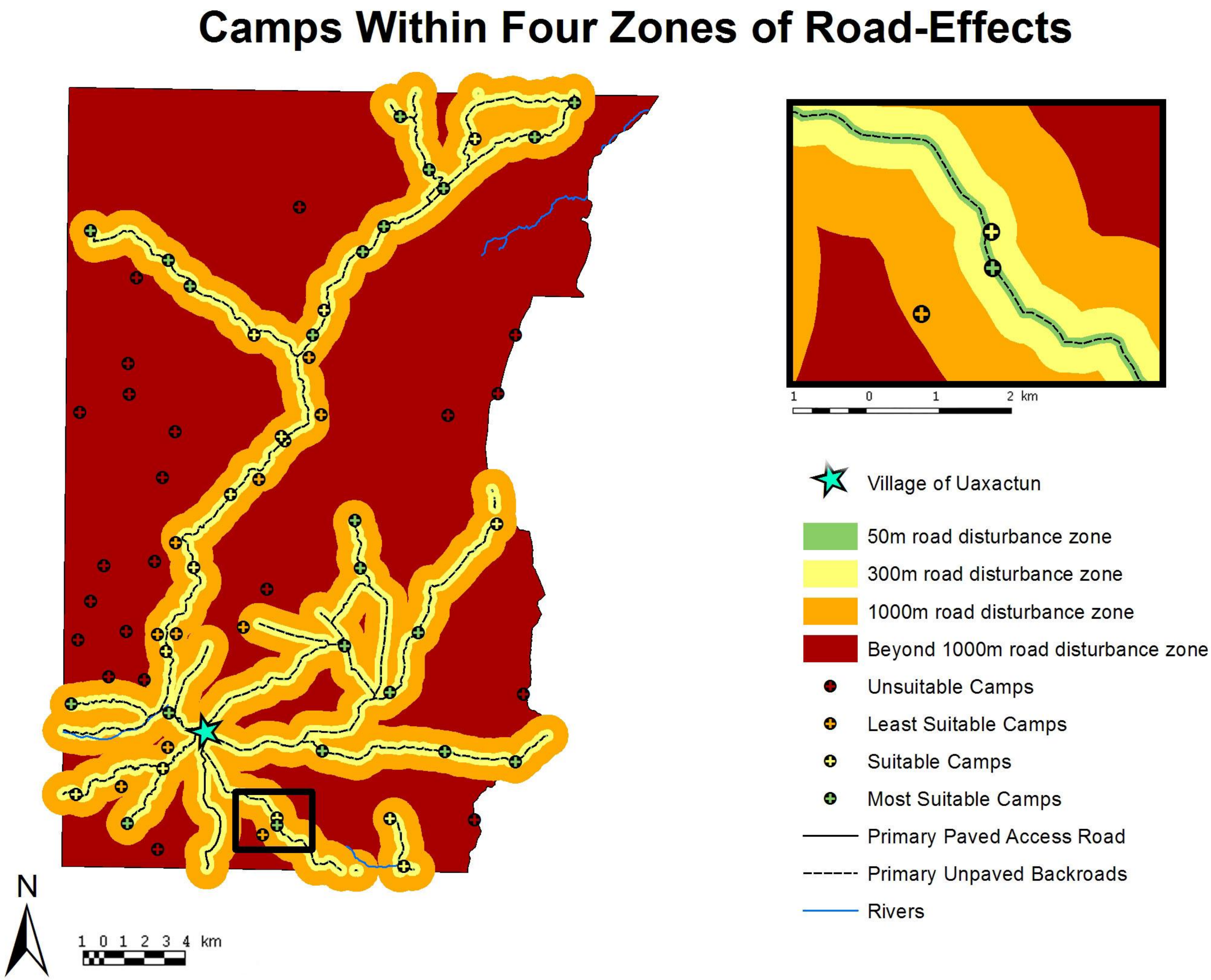
In measuring fragmentation due to road dissection throughout Uaxactún, the majority of the concession was composed of large patches (greater than 4,048.58 ha (10,000 acres)) and therefore with the potential to sustain populations of large-home-range wildlife. This result corresponded with our research regarding the relative intactness of forest cover and lack of infrastructure in the area. Five medium-sized fragments, located mostly within the concession boundary, were created by road encirclement (when considering the southern border a road). Four camps were located in these medium sized dissected forest fragments of 809.72 to 2,024.29 ha (2,000 to 5,500 acres). Nine small fragments were created when roads forked and the pinches between them were 500 meters (1,640.42 feet) apart. Only one camp was located in a highly compromised small fragment of 38.46 ha (95 acres) (Map 6.4).



Map 6.4: Fragmentation due to road layout

Roads:

The network of roads throughout the Uaxactún concession is concentrated in its southern half, especially around the village of Uaxactún. Otherwise, one primary backroad runs north along the central topographic ridge and leads to Mirador- Río Azúl National Park. More than half of the camps are located within 300 meters (984.25 ft) of a road, which was considered desirable to our team. That is because camps were located in areas we considered already impacted by roads, thus concentrating any further impacts. 23 out of 69 camps (33.3%) were located within 50 meters (164.04 ft) of a primary access road or backroad, and were considered the most suitable with regards to this spatial factor. 15 camps (22%) were located between 50 and 300 meters from the road, ten camps (14%) were located between 300 and 1000 meters (3,280.83 ft) from the road, and 21 camps (30%) were located beyond 1000 meters from the road, and were ranked as unsuitable (Map 6.5).

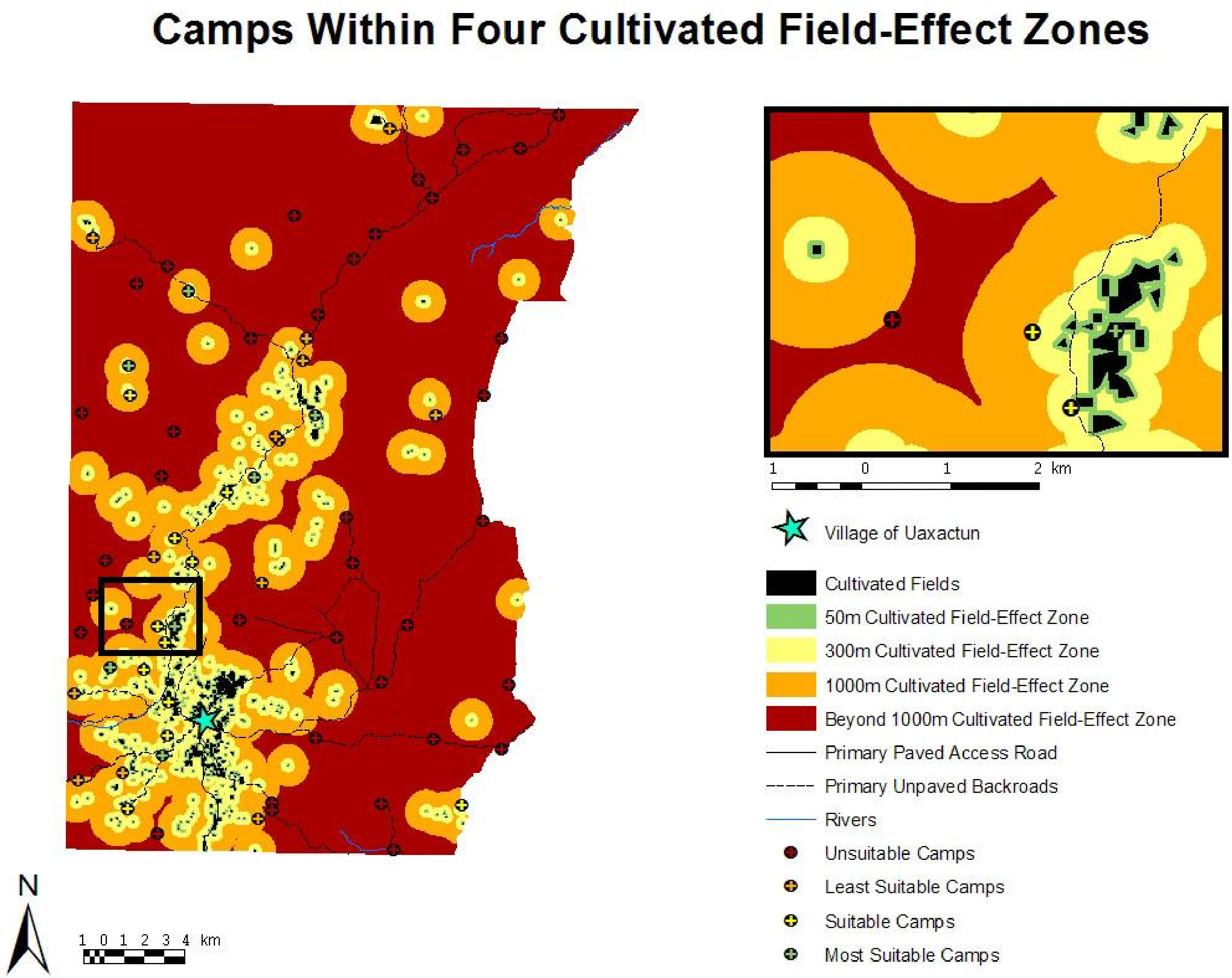


Map 6.5: Four zones of road-effects

Cultivated fields:

Cultivated fields (which also include abandoned or fallow fields) are concentrated around the village of Uaxactún and along primary backroads in the southwest corner of the concession. There are also many fields along the primary backroad to the north of the village. A small number of fields are scattered throughout what our team would consider interior forest. Fields are often associated with wetlands or low areas. 210 cultivated fields out of 360 (58%) either intersected the buffered low forest or the buffered wetlands, riparian forests, and bodies of water. This may be an indication that some areas that have been identified as cultivated fields via satellite image may in fact be seasonally flooded grasslands, and future studies would benefit from their further discernment (WCS-Petén, personal communication). We could also speculate that in these locations it is possible that water and nutrients collect and increase the productivity of the field. 16 out of 360 (4%) of cultivated fields directly intersect a wetland, and one field intersects a body of water (indicating it must be seasonal).

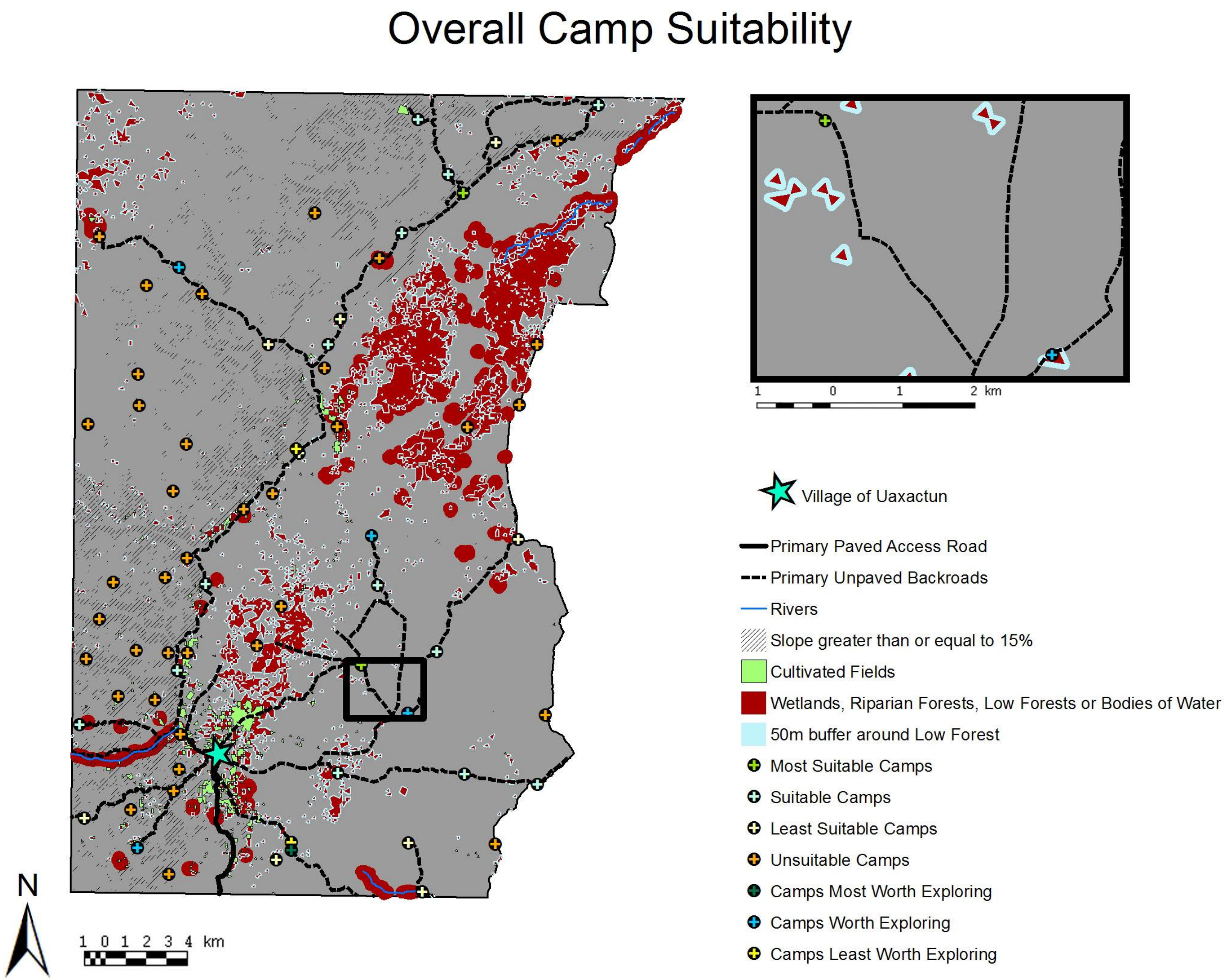
Seven out of 69 camps (10%) were ranked as most suitable by their location within 50 meters of a cultivated field. Eleven out of 69 camps were located between 50 and 300 meters from a cultivated field, 13 out of 69 camps were located between 300 and 1000 meters from a cultivated field, and 38 camps (55%) were located beyond 1000 meters from a cultivated field and ranked unsuitable. Camps at all rankings were distributed throughout the concession (Map 6.6).



Map 6.6: Four cultivated field-effect zones

Overall camp suitability

In order to analyze the cumulative results of each of these spatial factor measures, the team created a decision matrix. Using rules of combination method (Table 5.7), the worst and most important factor overrides all other factors. For example, our team has deemed areas vulnerable to erosion, areas of rare or sensitive habitat, and areas beyond 1000 meters from a road to be most important in determining overall camp suitability. Therefore, any camp that intersects these vulnerable areas will be considered unsuitable despite its suitability ranking for any other factor. The remaining camps that are considered suitable are ranked using rules of combination (Map 6.7). The categories of suitability attempted to recognize the limitations of our model by creating a range of certainty with which we would recommend the use of each camp (Table 6.1).



Map 6.7: Overall camp suitability

Table 6.1: Characteristics of most suitable camps

Camp name	Intersects area of rare or sensitive habitat?	Intersects 50m buffer around low forest?	High risk of erosion?	Degree of fragmentation/ patch size			Proximity to road?	Proximity to cultivated field?	Overall suitability rating
				High/ Small	Mod/ Med	Low/ Large			
Crusc Tablero	No	No	No	X			Within 50m	Beyond 1000m	**Most Suitable**
Bardales	No	No	No		X		Within 50m	Beyond 1000m	**Most Suitable**
La Palma	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
El Horcado	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
La Milpa Cedro	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
El Manantial	No	No	No			X	Within 50m	Between 300 and 1000m	**Suitable**
La Serteneja	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
El Kaibil	No	No	No			X	Within 50m	Between 300 and 1000m	**Suitable**
Rancho Dona Chona	No	No	No			X	Within 50m	Between 300 and 1000m	**Suitable**
La Esperanzita	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
La Trampa	No	No	No			X	Between 50 and 300m	Between 50 and 300m	**Suitable**
Bajo del Venado	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
Ruinitas	No	No	No			X	Within 50m	Beyond 1000m	**Suitable**
Enamorados	No	No	No			X	Between 50 and 300m	Between 50 and 300m	**Suitable**
El Corchal	No	Yes	No		X		Within 50m	Beyond 1000m	**Most Worth Exploring**
San Blas	No	Yes	No			X	Within 50m	Beyond 1000m	**Worth Exploring**
La Llorona	No	Yes	No			X	Within 50m	Between 50 and 300m	**Worth Exploring**
La Cariba	No	Yes	No			X	Within 50m	Beyond 1000m	**Worth Exploring**
El Ramonalito	No	Yes	No			X	Within 50m	Beyond 1000m	**Worth Exploring**

Results for Integration of Tourism Preferences:

Evaluations for hypothetical tours:

Tour 1*: Half day hike into the jungle to learn about forest culture including: use of plants and other forest resources, lunch in a jungle camp while learning about life as a xatero/chiclero, and a visit to a cultivated field to learn about local agricultural practices.*

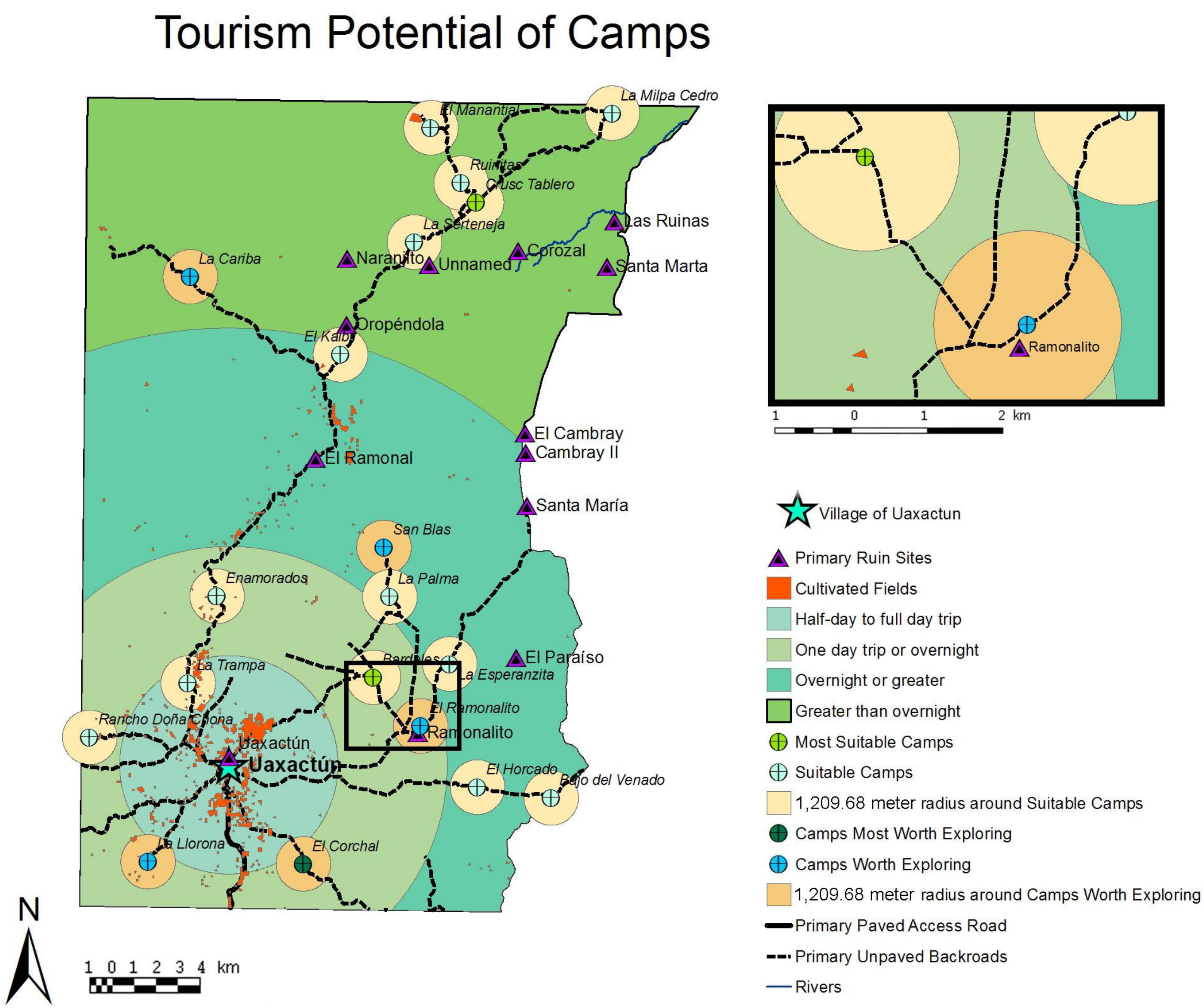
Referring to the camp tourism suitability table (Table 5.7), and the Tourism Potential of Camps map (Map 6.8), the camp that would potentially be most appropriate for this tour would be La Trampa. This camp is ranked environmentally suitable, and it is conservatively estimated to be reachable in a half day. Because of the proximity to the village of Uaxactún, there are many cultivated fields in the area that might potentially be included in the tour.

Tour 2: *Full day hike into the forest penetrates deeper into the Mayan jungles to learn about forest culture, cultivated fields, and remote ancient Maya sites.*

Referring to the camp tourism suitability table, and the Tourism Potential of Camps map, the camps that would potentially be most appropriate for this tour would be Bardales and El Ramonalito. Bardales is ranked as ecologically most suitable, while El Ramonalito is classified as worth exploring because it is within 50 meters of a low forest. Both camps are conservatively estimated to be reachable in a full day. On the other hand the camp El Ramonalito is essentially adjacent to the ruin of Ramonalito. The closest ruin to Bardales is also Ramonalito, but appears to be a couple of miles away.

Tour 3: *Overnight hike into the jungle includes learning about forest culture, a visit to a cultivated field, and a visit to an archeological ruin. In addition, watch the sunset from the peak of an ancient Mayan temple and spend the night in a jungle camp to experience the night life of the Mayan jungle.*

Referring to the camp tourism suitability table, and the Tourism Potential of Camps map, the camps that would potentially be most appropriate for this tour would be again Bardales, El Ramonalito, El Kailib, and La Esperanzita. Bardales is ranked ecologically most suitable, El Kailib and La Esperanzita are ranked suitable, and El Ramonalito is ranked worth exploring. Both El Ramonalito and El Kaibil are located within a conservative estimate of close proximity to an ancient Maya site. Again El Ramonalito is adjacent to the ruin Ramonalito, while El Kaibil is near the ruin of Oropéndola. Next in proximity is the ruin of El Paraíso with the camp of La Esperanzita that at a conservative estimate appears a few miles away and likely too far to have a night tour and come back in a short distance.



Map 6.8: Camp tourism potential

CHAPTER SEVEN: RECOMMENDATIONS

Recommendations:

This model has provided a landscape ecology approach using land suitability analysis to identify camps that may be suitable for further development in planning for ecotourism. From this model and our research, we have formulated recommendations for the community of Uaxactún and our client WCS with respect to planning, monitoring, and evaluating ecotourism. In planning for ecotourism our primary recommendation is for the local community to instigate or conduct further research on the more specific sensitivities of each habitat type in order to have a better understanding of potentially sensitive or rare ecosystems. In addition to research it is important in planning to simultaneously consider management techniques that could minimize visitor activity impacts. Before, during, and after any further ecotourism development has been implemented, it is extremely important to monitor and evaluate the impacts of the activities.

Planning for ecotourism

FURTHER RESEARCH

Ecosystem Mapping: To ensure more effective protection and conservation of biodiversity of ecosystem health, it would be best to produce a more detailed ecosystem map that delineates more subtle differences between landcover and landforms. For example it would be useful to analyze time-series data in order to map locations of secondary forest. This could also be interesting from a tourism perspective by enabling tourists to visit cultivated fields that are active as well as those that have reverted to forest. Most importantly, this refinement in data will allow for a deeper understanding of ecosystem functioning and relative importance by understanding ecosystem rareness or other unique characteristics, which would enable a more accurate vulnerability analysis and camp suitability model to be conducted.

Groundwater Surveys: A more thorough understanding of the karst geology and the movement of groundwater is extremely important. The karst geology that dominates the substrate in and around Uaxactún complicates the predictability of groundwater flow and may have potentially serious implications on groundwater contamination as discussed in chapter four. Surveys that track the flows of groundwater can be preformed to map the direction of water flow and pin point the areas at risk of pollution from waste, increased nutrients from fertilizers, or other pollutants that would be associated with an increase in tourism development. Results from an investigation like this will better inform the community and our client of the best locations for tourism activities to take place by avoiding areas that are most sensitive. The increase of camp use may necessitate more formalized facilities. It may be that a camp that is most suitable becomes a primary candidate for the construction of a composting toilet or other more permanent solution to accommodate an increase in use and waste from camp users. In order to best protect the health of the local wildlife and the community through the protection of the ground water supply in the area, it is imperative to understand where the inputs and outputs of groundwater are.

Tourist Preferences: In order to tailor tourism activities and offerings to reflect tourist preferences, greater research must be done to understand which types of tours would most likely be successful. Tours offered in Uaxactún should reflect the findings of these tourist preference investigations. It is also possible to target specific tourist groups that the community may wish to cater to. For example if the community wishes to accommodate or host more young backpackers, then a survey can weigh the preferences of that user when analyzing the survey results.

MANAGEMENT TECHNIQUES

Tourist Code of Conduct: Before carrying out tours that bring visitors into the concession or even tourist activities that take place in the village, it is necessary to develop a "tourist conduct code" which clearly states what types of tourist behavior are acceptable and appropriate for the community of Uaxactún. These behavioral norms should set an example of overall respect for the community's natural resources.

This code or these norms should reflect the conservation and environmental goals that are established by the community beforehand. The conduct code should address issues such as interactions with animals; adhering to established trail systems; behavior within and around ancient Maya sites; behavior within and around camps, safety, and waste management. It is extremely important that this code is enforced and adhered to by all community members and especially tour guides to ensure that visitors and tourists will respect the rules. Further, these norms can adhere to more broadly recognized or regionally established norms, such as those of certified tourism established by the Rainforest Alliance organization (Buckley 2002).

Resource Users Conduct Code: Additionally, the community should address issues that relate to use of resources and camps by different groups by creation of a "conduct code" or some preceding agreement. If camps used by chicleros and xateros are also planned to be used by tourists and guides, conflicts should be avoided before they arise.

Best Management Practices: Along with a conduct code for tourists, a list of Best Management Practices (BMP's) should be established that would guide tour practices and ensure that measures were in place to protect the environmental integrity of the forest. These BMP's would provide norms for aspects of tourism such as transportation and access to the forest; seasonality of tour offerings; camp establishment, construction and amount of materials to be used; food and water provisions (brought in rather than hunted, harvested or collected); fire management within camps; trash management, (packed out rather than burnt or buried), and waste and sewage management. Again, we would highly recommend in the case of a highly used camp that the community seriously consider the installation of a permanent toilet facility. A thesis by students at the University of Michigan in Belize discusses this issue and provides examples of some sustainable alternatives that could be referenced (Buckley *et al*. 2005).

Monitoring and evaluating ecotourism

An important step in tourism development and implementation is the monitoring and continued evaluation of effects and impacts of the tourism activities on the environment. It is essential that the community members monitor for degradation to water quality, erosion, changes in wildlife behavior, declining wildlife population numbers, trash accumulation, and any other indicators. Any observed changes should press the community to investigate whether or not the BMP's are effective, the camps and ancient Maya sites have been appropriately designated, or the number of visitations has become too excessive.

Collect Base-line Data: It is important to gather information which will serve as based-line data in future monitoring and evaluation initiatives. These surveys should include: wildlife abundance and diversity within the concession, water quality within wetlands and areas of surface water, existing conditions of roads, ancient Maya sites and camps including condition of vegetation in and around them, and degree of soil compaction and erosion.

Acceptable number of visitations: With the introduction of any new resource use, there will inevitably be some degree of change to the forest and ecosystems within. The community will need to decide at what level is that change unacceptable. Several strategies exist for this purpose but the two our team found most prevalent in scientific literature were Carrying Capacity and Limits of Acceptable Change.

Carrying capacity uses various environmental measures to determine the number of visitors that should be allowed per day or per year. Limits of Acceptable Change integrate public and community participation with management of protected areas to determine the limits of acceptable change for chosen physical indicators. This strategy may be more appropriate for Uaxactún. First, indicators are selected which represent the conditions that have been deemed appropriate and acceptable by the community and land managers. These indicators for example could focus on providing habitat for a suite of landscape species. Next, existing conditions are inventoried and parameters are established for measuring changes to these conditions. Then, management actions for maintaining conditions are established and implemented. Finally, monitoring focuses on the indicators to ensure that changes in the conditions don't fall below acceptable limits (McCool 1996).

Planning in a developing nation

This model responds to the need for immediate action to be taken not only for the planning of environmentally sensitive ecotourism, but for any development venture. This landscape ecology approach focuses on spatial patterns to preserve ecological functions, and is beneficial because it can be implemented immediately without environmental and scientific surveys being completed. In a developing nation this is critical since existing resources may not be sufficient to conduct these surveys. One can instead protect spatial patterns that encompass biodiversity. This should not however, replace the detailed scientific study which should be carried out alongside the planning and implementation. A tool such as this model is only as good as the information available. More refined data would inform and strengthen this model by an increased understanding of the ecosystems leading to their more effective protection.

Appendix A

Data modeling steps

Wetlands, riparian forest, bodies of water

1. Converted *sisnat* layer from raster to shapefile, using ArcToolbox
2. Clipped shapefile to Uaxactún concession boundary layer
3. Using "Selected by Attributes", selected: riparian forest, wetlands, bodies of water
4. Created new layer of selected attributes
5. Created a buffer of 300 meters around new layer, named *sensit_buffer*
6. Using "Selected by Location" identified those camps that intersected *sensit_buffer*
7. Classified these camps as unsuitable and all other camps as suitable

Low forest

1. Converted *sisnat* layer from raster to shapefile, using ArcToolbox
2. Clipped shapefile to Uaxactún concession boundary layer
3. Using "Selected by Attributes", selected low forest
4. Created new layer of selected attributes called *lowfrst*
5. Using "Selected by Location" identified those camps that intersected *lowfrst*
6. Ranked these camps: unsuitable
7. Created a buffer of 50 meters around new layer, named *lowfrst_buffer*
8. Clipped the *lowfrst_buffer* with the *lowfrst* layer, leaving only the outside 50 meter buffer named *50m_buffer*
9. Using "Selected by Location" identified those camps that intersected *50m buffer*
10. Ranked these camps: Worth exploring, and
11. Ranked all remaining camps: Suitable

Slopes

1. Used the DEM raster layer to conduct a slope analysis, named the new layer *slope_uax*
2. Reclassified the *slope_uax* into two categories:
   Acceptable slopes = 0 - 14.9%
   Unacceptable slopes = 15% and greater
3. Converted layer from raster to shapefile

Patch enclosed by road

1. Corrected *caminos* layer using the Editor Toolbar, repairing the integrity of the polylines that were the roads: extending them when they did not connect completely or trimming them when they were overextended
2. Applied a 500 meter buffer to the *caminos* layer (250 meters on both sides of the road)
3. Using the "Editor" toolbar in GIS, created additional patches where the buffers overlapped by drawing a line that represented an ecological barrier

4. In the Data Management options in the ArcToolbox, use “Features to Polygons” tool to convert the polyline to a polygon layer
5. The area (in acres) for each patch was calculated and in Properties; Symbology menu, they were grouped manually according to the teams’ designation:
   Small = 0-300 acres
   Medium = 300.01 – 10,000 acres
   Large = greater that 10,000 acres

<u>Roads and cultivated fields</u>

1. Create three buffers around road and cultivated field layers using distances: 50 meters, 300 meters, and 1000 meters
2. Use “Selected by location” to identify the camps located in each zone for both fields and roads
3. In attribute table for camp layer, assign each camp a ranking for road-zone effects described as follows:
   Camp is located within 50 meters of road: Most suitable
   Camp is located between 50 and 300 meters of road: Suitable
   Camp is located between 300 and 1000 meters of road: Least Suitable
   Camp is located beyond 1000 meters of road: Unsuitable
4. Repeat the procedure for camp layer to assign each camp a ranking for cultivated field-zone effects
   Camp is located within 50 meters of cultivated field: Most suitable
   Camp is located between 50 and 300 meters of cultivated field: Suitable
   Camp is located between 300 and 1000 meters of cultivated field: Least Suitable
   Camp is located beyond 1000 meters of cultivated field: Unsuitable

<u>Travel time</u>:

1. Created three buffers around village of Uaxactún designated:
   5,000 meters: Reachable in half day to full day trip
   10,000 meters: Reachable in full day to overnight trip
   20,000 meters: Reachable in overnight trip or greater
   Beyond 20,000 meters: Reachable in greater than an overnight trip
2. Created buffer around all ancient Maya sites designated:
   1,209.68 meters (0.75 miles): Reachable in short trip
3. Using “Selected by Location” distinguished in which travel time zone each “suitable” or “most suitable”, or “worth exploring” or “most worth exploring” camp was located, and whether or not it intersected any ancient Maya site buffers

Bibliography:

Anderson, D.W. and Keith, S.O. 1980. The human influence on seabird nesting success: conservation implications. *Biological Conservation* **18**: 65-80.

Andrade, G. I. and Rubio-Torgler, H. 1994. Sustainable Use of the Tropical Rain Forest: Evidence from the Avifauna in a Shifting-Cultivation Habitat Mosaic in the Colombian Amazon**.** *Conservation Biology* **8,** No. 2 (June): 545-554.

Bangs, E.E., Spraker, T.H., Berns, B.D. and Baily, T.N. 1982. Effects of increased human populations on wildlife resources of the Kenai Peninsula, Alaska, USA. In: Sabal, V. ed. *Transactions of the North American Wildlife and Natural Resources Conference*. Wildlife management Institute, Washington, D.C., Vol. **47**: 605-616.

Belanger, L. and Bedard, J. 1989. Responses of staging greater snow geese to human disturbance. *Journal of Wildlife Management* **53**: 713-719.

Bell, D.V. and Austin, L.W. 1985. The game fishing season and its effects on overwintering wildfowl. *Biological Conservation* **33**: 65-80.

Bhuju, D.R. and Ohsawa, M. 1998. Effects of nature trails on ground vegetation and understory colonization of a patchy remnant forest in an urban domain. *Biological Conservation* **85**: 123-135.

Birchard, W. and Proudman, R. D. 1981. Trail Design, Construction, and Maintenance: The Appalachian Trail Conference, Harpers Ferry.

Blakesley, J.A. and Reese, K.P. 1988. Avian use of campground and non-campground sites in riparian zones. *Journal of Wildlife Management* **52**: 399-402.

BMP Maryland, USA. 2006. Guide to BMP Selection and Location in the State of Maryland: Chapter 4. Available online.

Bocker, E.L. and Ray, T.D. 1971. Golden eagle population studies in the south west. *Condor* **73**: 463-467.

Brattstrom, S.P. and Bondello, M.C. 1983. Effects of off-road vehicle noise on desert vertebrates. In: Webb, R.H. and Whilshire, H.G. eds. *Environmental Effects of Off-Road Vehicles*. Springer, New York: 167-206.

Buckley, D., Davidson, C., Herweyer, K., Julyk, K., Letourneaux, E., Tuchman, L. 2005. "Sustainable ecotourism design for the Mountain Pine Ridge Forest Reserve in Belize." A Master's Project completed for the School of Natural Resources and Environment, University of Michigan. Advised by Elizabeth Brabec.

Buckley, R.C. 1998. Tourism in wilderness: M and M Toolkit. In: Watson, A.E., Aplet, G.H. and Hendee, J.C. eds. *Personal, Societal, and Ecological Values of Wilderness: Sixth World Wilderness Congress Proceedings on Research, management, and Allocation*. Vol. **1**. RMRS-P-4. USFS, Rocky Mountain Research Station: 115-116.

Buckley, R.C. 2000. Environmental impacts. In: Weaver, D.B., ed. *The Encyclopedia of Ecotourism*. Oxon, UK: CABI Publishing: 379-394.

Buckley, R.C. 2002. Research Note: Tourism Ecocertification in the International Year of Ecotourism. *Journal of Ecotourism* **1**, Nos. 2&3: 197-203.

Buckley, R.C. 2003. Ecological Indicators of Tourist Impacts in Parks. *Journal of Ecotourism* **2**, No. 1: 54-66.

Buehler, D.A., Mersmann, T.J., Fraser, J.D. and Seegar, J.K.D. 1991. Effects of human activity on bald eagle distribution on the Northern Chesapeake Bay. *Journal of Wildlife Management* **55**: 282-290.

Burden, R.F., and Randerson, P.F. 1972. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. *Journal Applied Ecology* **9**: 439-457.

Cater, E. and Lowman, G. 1994. *Ecotourism: A Sustainable Option?* London, Wiley.

Chin, C.L.M., Moore, S.A., Wallington, T.J. and Dowling, R.K. 2000. Ecotourism in Bako National Park, Borneo: Visitor's Perspectives on Environmental Impacts and their Management. *Journal of Sustainable Tourism* **8**(1): 20-35.

Cole, D.N. 1978. Estimating the susceptibility of wildland vegetation to trailside alteration. *Journal of Applied Ecology* **15**: 281-286.

CI, Conservation International. 2004. Ecosystem Profile: Northern Region of the Mesoamerica Biodiversity Hotspot: Belize, Guatemala, Mexico. Critical Environmental Partnership Fund: www.cepf.net/xp/cepf/resources/publications. Accessed 6-20-06.

Crawshaw, P.G.J., and Schaller, G.B. 1980. Nesting of Paraguayan caimen *Caimen yacare* in Brazil. Papers *Auulsos Zoologica*, Sao Paulo, **33**: 283-292.

D'Eon, R.G., Glenn, S.M., Parfitt, I., and Fortin, M.-J. 2002. Report: Landscape Connectivity as a Function of Scale and Organism Vagility in a Real Forested Landscape. *Conservation Ecology* **6**(2): 10.

Elliot, W.J. and Hall, D.E. 1997. Water Erosion Prediction Project (WEPP) Forest Applications. United States Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report Draft, March.

Forman, R. T. T. 1995. Land Mosaics: The ecology of landscapes and regions, Cambridge

University Press.

Forman, R. T. T. and Alexander, L. E. 1998. Roads and Their Major Ecological Effects. *Annual Review of Ecology and Systematics* **29**: 207-31.

Forman, R. T. T. and Godron, M. 1981. Patches and Structural Components for a Landscape Ecology. *Bioscience* **31**(10): 733-740.

Forman, R. T. T., Sperling D., *et al*. 2003. Road Ecology: Science and Solutions. Washington, D. C. , Island Press.

Garcia, R. and Radachowski, J. (Eds). 2004. Ecological evaluation of the Mirador- Rio Azul National Park Petén, Guatemala. Wildlife Conservation Society.

G.H.F. Global Heritage Fund and Foundation for Anthropological Research and Environmental Studies (F.A.R.E.S.). 2004. Maya Biosphere Conservation Trust: An Innovative Private-Sector Trust for Establishing Sustainable Wilderness, Wildlife and Archaeological Parks to Save the Heart of the Maya Biosphere. March, 2004.

Gonzalez, L.M., Bustamante, J. and Hiraldo, F. 1992. Nesting habitat selection by the Spanish imperial eagle *Aquila adalberti*. *Biological Conservation* **59**: 45-50.

Goodrich, J.M. and Berger, J. 1994. Winter recreation and hibernating black bears *Ursus americanus*. *Biological Conservation* **67**: 105-110.

Goodwin, H. 1996. In Pursuit of Ecotourism. *Biodiversity and Conservation* **5**(3). March.

Goosem, M. 2000. Effects of tropical rainforest roads on small mammals: edge changes in community composition. *Wildlife Research* **27**: 151-163.

Grossberg, R., Treves, A. and Naughton-Treves, L. 2003. The incidental ecotourist: measuring visitor impacts on endangered howler monkeys at a Belizean archaeological site. *Environmental Conservation* **30** (1): 40-51.

Grunberg, W., Guertin, D.P. and Shaw, W.W. Unpublished report. Modeling Deforestation Risks for the Maya Biosphere Reserve, Guatemala. School of Renewable Natural Resources, The University of Arizona, Tucson, Arizona, USA.

Hammitt, W. E. and Cole, D. N. 1987. Wildland Recreation: Ecology and Management. New York, Wiley.

Hartshorn, G. S. 1983. “Manilkara zapota.” In Costa Rican Natural History, ed. Daniel H. Janzen, Chicago: Univ. of Chicago Press: 276-277.

Hidinger, L. 1999. Measuring the Impacts of Ecotourism on Animal Populations: A

Case Study of Tikal National Park, Guatemala. *Yale F and ES Bulletin*: 49-59.

Hill, J. K. and Hamer, K.C. 2004. Determining impacts on habitat modification on diversity of tropical forest fauna: the importance of spatial scale. *Journal of Applied Ecology*, Vol. **41**, No. 4 (August): 744-754.

IUCN, Conservation International, and NatureServe. 2006. Global Amphibian Assessment. <www.globalamphibians.org>. Accessed on 04 May 2006.

Jacobsen, T. and Kushlan, J.A. 1986. Alligators in natural areas: choosing conservation policies consistent with local objectives. *Biological Conservation* **36**: 667-679.

Jeppesen, J.L. 1987. Impact of human disturbance on home-range movements and activity of red deer *Cervus elaphusis* in a Danish environment. *Danish Review of Game Biology* **13**: 1-38.

Juska, C. and Koenig, C. 2006. "Planning for Community-Based Ecotourism in Uaxactún, Guatemala". A Master's Practicum completed for the School of Natural Resources and Environment, University of Michigan. Advised by Professor Ivette Perfecto and Associate Professor Arun Agrawal.

Kazmierski, J., Kram, M., Mills, E., Phemister, D., Reo, N., Riggs, C., Tefertiller, R. 2002. "Upper Manistee River Watershed Conservation Plan". A Master's Project completed for the School of Natural Resources and Environment, University of Michigan. Advised by Professor Donna Erickson.

Keller, V. 1989. Variations in the response of great crested grebes *Podiceps cristatus* to human disturbance – a sign of adaptation? *Biological Conservation* **49**: 31-45.

Knight, R.L. 1998. Ecosystem management and conservation biology. *Landscape and Urban Planning* **40**: 41-45.

Kricher, J.C. 1997. A Neotropical Companion: an introduction to the animals, plants, and ecosystems of the New World tropics. Princeton: Princeton University Press, 451pp.

Kuss, F. R. 1986. A review of major factors influencing plant responses to recreation impacts. *Environmental Management* **10**: 637-650.

Laidlaw, R.K. 2000. Effects of Habitat Disturbance and Protected Areas on Mammals of Peninsular Malaysia. *Conservation Biology* **14** (6): 1639-1648.

Leung, Y. and Farrell, T. 2002. Visitor Impact Knowledge is Basic. *A Statement for the World Ecotourism Summit, May 19-22, 2002; Quebec City, Canada*. Thematic Session: D- Monitoring Costs and Benefits of Ecotourism.

Lynn, N.A. and Brown, R.D. 2003. Effects of recreational use impacts on hiking experiences in natural areas. *Landscape and Urban Planning* **64**: 77-87.

MacArthur, R.A., Geist, V. and Johnston, R.H. 1982. Cardiac and behavioural responses of mountain sheep to human disturbance. *Journal of Wildlife Management* **46**: 351-358.

McNab, R.B. 1998. Comparative impacts of chicle and xate harvests on wildlife of the Maya biosphere reserve, Guatemala. M.A. Thesis. University of Florida 175 pp.

Mull, D.S., Liebermann, T.D., Smoot, J.L., and Woosley, L.H., Jr. 1988. Application of Dye Tracing Techniques for Determining Solute-Transport Characteristics of Ground Water in Karst Terrains. U.S. Environmental Protection Agency, Ground Water Protection Branch. U.S. Geological Survey, Water Resources Division.

OMYC. 1999. Management Plan. Wildlife Conservation Society. Uaxactún, Guatemala.

Radachowsky, J. 2002. Endemism in the Maya Forest. A report prepared by Wildlife Conservation Society for FIPA and USAID. March, 2002. (Revised June 2002).

Reed, R. A., Johnson-Barnard, J., *et al*. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. *Conservation Biology* **10**(4): 1098-1106.

Rejmankova, E., Pope, K. O., *et al*. 1996. Herbaceous Wetlands of the Yucatan Peninsula: Communities at Extreme Ends of Environmental Gradients. *Int. Revue ges. Hydrobiol*. **81**(2): 223-252.

Roberts, B.C. and White, R.G. 1992. Effects of angler wading on survival of trout eggs and pre-emergent fry. *North American Journal of Fish Management* **12**: 450-459.

Roos, G. Th. de 1981. *The Impact of Tourism upon some Breeding Wader Species on the Isle of Vlieland in The Netherlands Wadden Sea*. Mededelingen Landbouwhogeschool, Wageningen: 81-114.

Sader, S. A., Coan, M. and Hayes, D. 1998. Time-series tropical forest change detection for the Maya Biosphere Reserve: Updated Estimates for 1995 to 1997. Maine Image Analysis Laboratory, Department of Forest Management, University of Maine. Unpublished report. CI-ProPeten. Petén, Guatemala.

Saris, F.J.A. 1976. *Breeding Populations of Birds and Recreation in the Duivelesbert*. Free University Institute of Environmental Studies Working Paper **66**. Vrieje Universitat, Brussels.

Schlesinger, V. 2001. Animals and Plants of the Ancient Maya: A Guide. Austin: University of Texas Press, 351 pp.

Semlitsch, J.R. and Bodie, R. D. 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology* **17**(5): 1219-1228.

Sennstam, B. and Stalfelt, F. 1976. Rapport angaende 1975 ars femdanger-sorienterings inverkan pa klouviltet. *Rapport* **12**: 35.

Shoka, D. 2006. An Analysis of Tourist Preferences for the Development of Ecotourism in Uaxactun, Guatemala, Using Choice Experiments. A Master's Thesis completed for the School of Natural Resources and Environment, University of Michigan. Advised by Associate Professor Michael Moore.

SMARN/CONAP, 2000, Secretaría del Medio Ambiente y Recursos Naturales (SMARN) and Consejo Nacional de Areas Protegidas (CONAP) (2000), Propuesta de políticas para orientar los beneficios del ecoturismo hacia las comunidades de Guatemala, SMARN/CONAP, 2000, Guatemala.

Talbot, L.M., Turton, S.M., and Graham, A.W. 2003. Trampling resistance of tropical rainforest soils and vegetation in the wet tropics of north east Australia. *Journal of Environmental Management* **69**: 63-69.

Ticktin, T. 2004. The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology* Vol. **41**, Issue 1 (February): 11.

Tiner, R. W. 2003. Geographically Isolated Wetlands of the United States. *Wetlands* **23**(3): 494-516.

Turton, S.M., Kluck, T., and Day, T.J. 2000. Ecological impacts of recreation along walking tracks. In: Bentrupperbaumer, J. and Reser, J.J. eds. *Cairns Impacts of Visitation and Use in the Wet Tropics of Queensland World Heritage Area*, Stage 2, Australia: 135-142.

UNEP. 2002. *UNEP Manual for the International Year of Ecotourism (IYE 2002)*. UNEP.

United Nations Educational, Scientific and Cultural Organization (UNESCO) (Ed). 1984. *Action plan for biosphere reserves*, Nature and Resources, **20** (4): 1-12.

USDA Conservation Service. 1975. Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts. United States Department of Agriculture, April.

Warnken, W. 1996. *Threshold detection of ecotourism impact: microbiological and chemical indicators of recreational effect on water quality in a subtropical rainforest conservation reserve*. PhD thesis, Griffith University, Gold Coast, Australia.

Watson, A. 1976. Human impact on animal populations in the Cairngorms. *Landscape Research News* **1**: 14-15.

Weaver, T., Dale, D. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. *Journal Applied Ecology* **15**: 451-457.

Wells, M. and Brandon, K. 1992. *People and Parks: Linking Protected Area Management with Local Communities.* The World Bank, World Wildlife Fund, and USAID, Washington, DC.

White, W.B. 1988. Geomorphology and hydrology of karst terrains. New York: Oxford University Press, 464 pp.

Wilkie, D., Shaw, E., *et al*. 2000. Roads, Development, and Conservation in the Congo Basin. *Conservation Biology* **14**(6): 1614-1622.

Yalden, P.E. and Yalden, D.W. 1990. Recreational disturbance of breeding golden plovers *Pluvialis apricarius*. *Biological Conservation* **51**: 243-262.

Zhou, W. and Beck, B. F. 2005. Roadway construction in karst areas: management of stormwater runoff and sinkhole risk assessment. *Environ Geol* **47**: 1138-1149.

Ziemer, R.R. 1981. Roots and the stability of forested slopes. *Int. Assoc. Hydrol. Sci.* Pub. No. **132**: 343-361.