THESIS

MANAGEMENT ZONING OF DOI SUTHEP- PUI NATIONAL PARK BY USING GEO-INFORMATICS

MD. ZILLUR RAHMAN

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THESIS

MANAGEMENT ZONING OF DOI SUTHEP-PUI NATIONAL PARK BY USING GEO-INFORMATICS

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The objective of this study was to develop a management zoning scheme for Doi Suthep-Pui National Park by using Geo-informatics together with stakeholders' opinion and to make comparison between newly created zoning map and previous zoning map. Purposive sampling was used to select the stakeholders. Stakeholders were interviewed for their opinion about zoning factors and ranking scores. All together nine spatial factors were used to identify seven management zones of the scheme. For the first three zones namely Strict Nature Reserve Zone, Primitive Zone, and Recovery Zone, the zoning models were developed based on Linear Combination Method of five general factors namely land cover, road network, stream network, elevation, and slope. Factors were ranked and weighted based on their suitability for each zone. Other four zones namely Outdoor Recreation Zone, Intensive Use Zone, Special Use Zone, and Other Use Zone were determined using four specific factors like existing tourist attraction sites, intensive use sites, other organizations operating inside park, and existing settlements. GIS package of ArcView and ERDAS Imagine were used to evaluate the locations of the park management zones.

The results indicated that Primitive Zone is the largest zone of the zoning scheme developed, occupying 153.40 km^2 or 54.48 % of the total park area; while Special Use Zone is the smallest, occupying 1.56 km^2 or 0.55 % of the park area. Other zones namely Strict Nature Reserve Zone, Recovery Zone, Outdoor Recreation Zone, Intensive Use Zone, and Other Use Zone occupied 39.71 km^2 or 14.10 %, 51.36 km^2 or 18.24 %, 1.94 km^2 or 0.70 %, 27.71 km^2 or 9.84 % and 5.89 km^2 or 2.09 % respectively.

In comparison of the previous and newly created management zones map it was found that the previous management zones map did not have provision of a Strict Nature Reserve Zone which should be a vital zone for Doi Suthep-Pui National Park. Marked difference was found between the previous Recovery Zone (105.58 km^2 or 37.39 %) and newly created Recovery Zone (51.36 km^2 or 18.24 %) again previous Intensive Use Zone (0.16 km^2 or 0.07 %) and newly created Intensive Use Zone (27.71 km^2 or 9.84 %).

Rahman
Student's signature

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19, May, 2006

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Md. Zillur Rahman
May, 2006

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LIST OF ABBREVIATIONS

CNPPA	=	Commission on National Parks and Protected Areas
DEM	=	Digital Elevation Model
DNP	=	Department of National Park, Wildlife and Plant Conservation
FAO	=	Food and Agricultural Organization
FCC	=	False Color Composite
GIS	=	Geographic Information System
GPS	=	Global Positioning System
Ha	=	Hectare
ICEM	=	International Center for Environmental Management
IUCN	=	The World Conservation Union
IUZ	=	Intensive Use Zone
Km	=	Kilometer
KUFF	=	Kasetsart University Faculty of Forestry
M	=	Meter
MONRE	=	Ministry of Natural Resources and Environment
MSS	=	Multispectral Scanner
NESDP	=	National Economic and Social Development Plan
NGO	=	Non Governmental Organization
NP	=	National Park
NPD	=	National Park Division
NPR	=	National Park Reserve
NRCT	=	National Research Council of Thailand
OEPP	=	Office of Environmental Policy and Planning
ORZ	=	Outdoor Recreation Zone
OUZ	=	Other Use Zone
PA	=	Protected Area
PZM	=	Park Zoning Model
RFD	=	Royal Forest Department
RS	=	Remote Sensing
RZ	=	Recovery Zone
SNRZ	=	Strict Nature Reserve Zone
SUZ	=	Special use Zone
TAT	=	Tourism Authority of Thailand
TM	=	Thematic Mapper
UNDP	=	United Nations Development Program
USOM	=	United States Operations Mission
UTM	=	Universal Transverse Mercator
WARPA	=	Wild Animals Reservation and Protection Act
WCO	=	Wildlife Conservation Office

MANAGEMENT ZONING OF DOI SUTHEP-PUI NATIONAL PARK BY USING GEO-INFORMATICS

INTRODUCTION

Tropical countries are known as the center of biological diversity. Most of the tropical countries are rich in biodiversity both in and outside the forests. Tropical rain forest has high productivity and the most diverse ecosystem on earth. Tropical forests act as Carbon Sinks and hence reduce the greenhouse effect. Countries of tropical region are the suppliers of valuable timbers and many other non timber forest products.

But recently tropical countries suffering from large scale deforestation. After the Second World War, population growth and economic pressure caused depletion to the natural forests of this region. Over logging, agricultural expansion, grazing, resettlement and many other human activities are the primary factors of the forest degradation. The loss of forest caused environmental disaster and natural risks such as draught, flood, landslide, thunderstorms, tornadoes and hurricanes, these also enhancing global worming and Green House Effect. Beside environmental degradation it also caused severe loss of biological diversity.

Thailand is a tropical country located centrally in the Indo-chinese Peninsula between 5° 45` to 20° 30` North latitude and 90° 70` to 105° 45` East longitude. The total area of the country is 513,115 km^2 with a population of about 62 million. The longest North -South span is about 1,920 km, and the widest part is about 750 km. from East to West (Ongsomwang, 2000). Thailand is bordered by Cambodia, Laos, Myanmar and Malaysia. The country is situated between two major bio-geographical regions, the Indo-Chinese in the north and Indo-Malaysian in the South, thus endowing the Kingdom with habitats that contain approximately 7% of the world's flora and fauna (Luangjame *et al.*, 1997). Thailand's rich biodiversity is evidenced by the 3,000 species of fungi, 600 species of ferns, over 1,000 types of orchids, 916 species of birds, 282 mammalian species and approximately 405 species of reptiles and amphibians (Gray *et al.*, 1994). Species such as the Asian elephant, tiger, and hornbill are endangered. Some forests contain valuable trees such as teak, rosewood, bamboo, and rattan.

According to the location, Thailand is dominated by monsoon. Being under the influence of monsoonal climatic condition, the vegetation of Thailand is really a humid tropic one, and vast areas are covered with vegetation. Owing on the composite nature of the topography, the long range of both latitudes and longitudes, the variation in temperature and precipitation, the forests of Thailand are considered varied. Its mild year-round climate and high humidity and rainfall support a biologically diverse flora and fauna that include tropical, deciduous, and mangrove forests. Each forest type provides a unique habitat for plants and animals.

In the past, Thailand was covered with dense forests distributed all over the country, except in some areas of the great central plain where the forest had been

removed to make way for agriculture (Ongsomwang, 2000). In the last few decade forest cover reduced drastically. The forest cover was reduced from over 53% of the kingdom's land area in 1961 to less then 27% in 2000 (RFD, 2000). The factors which contribute to deforestation are fairly extensive and complex, extending from population growth to expanding agricultural production for export. It appears probable that the two main underlying causes of deforestation in Thailand have been the increasing demand for land for agriculture to meet the needs of the growing population and commercial logging. Rapid industrialization, urbanization and building of infrastructure are other major factors of deforestation. Many of the remaining forests have been heavily over-exploited, so that they are now seriously deficient in growing stock and in biodiversity. Many important species of wild life and plant became extinct, endangered or rare as a result of widespread encroachment and poaching. Deforestation also leads a very adverse effect on environment. After a devastating flood wiped out two villages in the southern province in 1988, public opinion pressed the Government to impose a total ban on logging in 1989 in natural forests.

Besides imposing logging ban Government of Thailand also place many of the forest area under protected area system. Thailand's protected area system was established in 1962 when Khao Yai was designated as the country's first national park (Chettamart, 1985). Since then the system has expanded to include protected areas of various descriptions including national parks (both terrestrial and marine) and wild life sanctuaries.

Unfortunately, most parks lack baseline data that could be used for identifying land use suitability and management plan. Therefore, in maximum cases park management tends to be *ad hoc*, lacking clearly stated objectives and long term program. A management plan, especially park management zone, guides and controls the management of natural resources, the uses of the areas, and the development of facilities needed to support that management and use. Management only by intuition is not effective now a day. Information and technical knowledge are keys to protected area management success. Park zoning based on up to date bio-physical and spatial data of a particular area is now considered very appropriate and effective throughout the world. Geo-informatics is using as effective tool in park management zoning in many countries.

Traditionally management of national parks is limited to take place in their legitimated boundaries declared in the national gazette. But in modern approach co-operation between multi-stakeholders both inside and outside the park boundary is needed for effective protection and management of the park area. It is also clearly stated in the New Constitution of Thailand of 1997 about the role and responsibilities of local people and local government in natural resource management.

The research work is intended to develop a new management zoning scheme for Doi Suthep-Pui National Park. Management Plan for Doi Suthep-Pui National Park is existed, which was done couple of years back. Situation is much changed by

this time. The proposed management zoning scheme is developed considering the changed situation through the participation of the multi-stakeholders.

Objectives

1. To gather basic information on bio-physical data of Doi Suthep-Pui National Park and to restore it in GIS format by using Geo-informatics.

2. To develop a management zoning scheme for Doi Suthep-Pui National Park combining the base line data and multi stakeholders' opinion.

3. To compare previous zoning map with the newly created zoning map.

LITERATURE REVIEW

Protected Area

A protected area is defined as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN, 1994).

Protected areas (PAs) are vast reservoirs of natural and cultural resources. In many counties they serve as the watersheds of major river systems and are essential for maintaining ecological integrity and fulfilling human needs. Protected areas are increasingly threatened by the pressure for agricultural land and resource utilization. In many situations, conflicts between the resident communities and park authorities are becoming routine in PA management, sometimes even making PAs hotspots of conflict.

Generally, a country's prime areas of natural and cultural interest have been assigned protected area status at national and sometimes also international level. Therefore, mass tourism and particularly ecotourism, involves visits to protected areas.

IUCN-The World Conservation Union is a pioneer of the modern protected area system. In 1994, IUCN classified protected areas into six categories which are as follows:

Category I Protected areas managed mainly for science or wilderness protection [I(a) Strict Nature Reserves, and I(b) Wilderness Areas].

Category II Protected areas managed mainly for ecosystem protection and recreation (National Park).

Category III Protected areas managed mainly for conservation of specific natural features (Natural Monument).

Category IV Protected areas managed mainly for conservation through management intervention (Habitat/ Species Management Area).

Category V Protected areas managed mainly for landscape/ seascape conservation and recreation (Protected Landscape/ Seascape).

Category VI Protected areas managed mainly for the sustainable use of natural ecosystems (Managed Resource Protected Area).

While each of the protected area categories has a different range of management objectives, all the categories should have one feature in common: a

properly thought through management plan process to ensure that the optimum outcomes are achieved (Thomas and Middleton, 2003).

Protected areas are now increasingly accessible due to modern infrastructure, exposing the neighboring communities to both opportunities and threats. Improved infrastructure has increased accessibility to markets and has brought other economic opportunities such as tourism inside the protected areas. However, it has also encouraged the migration of people from other areas.

Traditionally, the national park has been recognized as the most common and well known type of protected area. But national parks can be complemented by other categories of protected area. And in practice, most countries find it advantageous to have several categories of protected areas, covering a wide range of management objectives and levels of use and manipulation. Such a range of options can increase the level of protection for strictly protected categories by in effect transferring human pressures to those areas which can sustain heavier use.

As described by IUCN (2002) - over 130 nations have established more than 30,000 protected areas of different designations, covering nearly 10 % of the planet's land surface. However, if other areas that do not have legal protection status but that are nevertheless under some form of conservation management procedure are included, the number of protected areas rises more than 50,000 worldwide.

Commission on National Parks and Protected Areas (CNPPA) is specifically responsible for promoting the establishment of a worldwide network of effectively managed territorial and marine protected areas. There are a bewildering number of different names of protected areas in different countries based on few basic objectives for which PAs are established and managed.

Oli (1999) described that over 3000 protected areas in the South and Southeast Asian Region cover more than 1.5 million sq. km and are the largest component of land use allocated for conservation and sustainable use of natural resources therein. The majority of PAs in the region are managed by government, while a few are managed in partnership with resident communities.

Galt *et al.* (2000) said - the protected areas scene in Southeast Asia is a paradox. On the one hand, there has been tremendous expansion in the number and extent of protected areas over the past 20 years or so, reflecting economic growth in the region and the world-wide trend in creating more protected areas. But alongside this growth – roughly threefold over the period - there has not been a corresponding improvement in the quality of protected area management. Indeed, it may sometimes appear that the rapid expansion in protected areas has exceeded the capacity of the relevant management authorities. A few countries have been successful in integrating protected area management into national and provincial planning and decision making.

Thailand's Protected Area System

Forest and wildlife conservation in Thailand has a long history, dating back to the creation of the Royal Forest Department (RFD) in 1896 and the enactment of the Wild Elephant Protection Law of 1900. Protected areas legislation, on the other hand, began in the 1960s with the promulgation of the Wild Animal Preservation and Protection Act (1960) and the National Park Act (1961). The former provided protection for wild animals in general by establishing wildlife sanctuaries and non-hunting areas. The National Park Act laid down provisions for the creation of national parks, which contributed to increased environmental awareness in Thailand. Forest reserves were then established through the National Forest Reserves Act of 1964.

The development of other conservation laws and policies also affected protected area management. The 1985 National Forest Policy first provides the basis for a protected area system and targeted the maintenance of 40% of the total land as forest areas. This would be classified into protected (15%) and productive (25%) forests (Bugna and Rambaldi, 2001). This ratio was then reversed in the 7th National Economic and Social Development Plan (NESDP) for 1992 – 1996, making the objective for conservation forest 25% of land cover, and economic (production) forest 15%. The Policy and Prospective Plan for Enhancement and Conservation of National Environmental Quality (1997 – 2016) targets the increase of forest cover to 50% of the total land area, with 30% to be designated as protected and 20% as productive forest (OEPP, 1997). The 1992 Enhancement and Conservation of National Environmental Quality Act provided policies for the conservation of environmentally critical protected areas.

In 1993, the Thai Forestry Sector Master Plan set down the concept of a protected area system, which was based on the 1985 Thai National Forest Policy. Among the most recent plans compiled by the government is the National Policies, Measures and Plans on the Conservation and Sustainable Utilization of Biodiversity (1998-2002), which was approved as an administrative framework to implement the Convention on Biological Diversity (Bugna and Rambaldi, 2001).

To date there have been 319 units of protected areas in the system, covering 108,064 km^2 or over 21 % of the country's land area. The system comprises 145 national parks, both terrestrial and marine, 53 wildlife sanctuaries, 52 non-hunting areas, and 69 forest parks (DNP, 2003) (Table 1). These do not include the vast areas of watershed protection forests as they often overlap with the already mentioned protected areas and are not possible to be segregated as individual units. The current protected areas also excludes a number of small protected areas of high conservation values as they are smaller than IUCN's minimum size of 10 km^2 (Emphandhu and Chettamart, 2003).

Though the number of protected areas as well as the total size of the system is quite impressive, most areas are smaller than 1,000 km^2 and well over half of the system consists of areas smaller than 400 km^2 (Thaiparks.com, 2003).

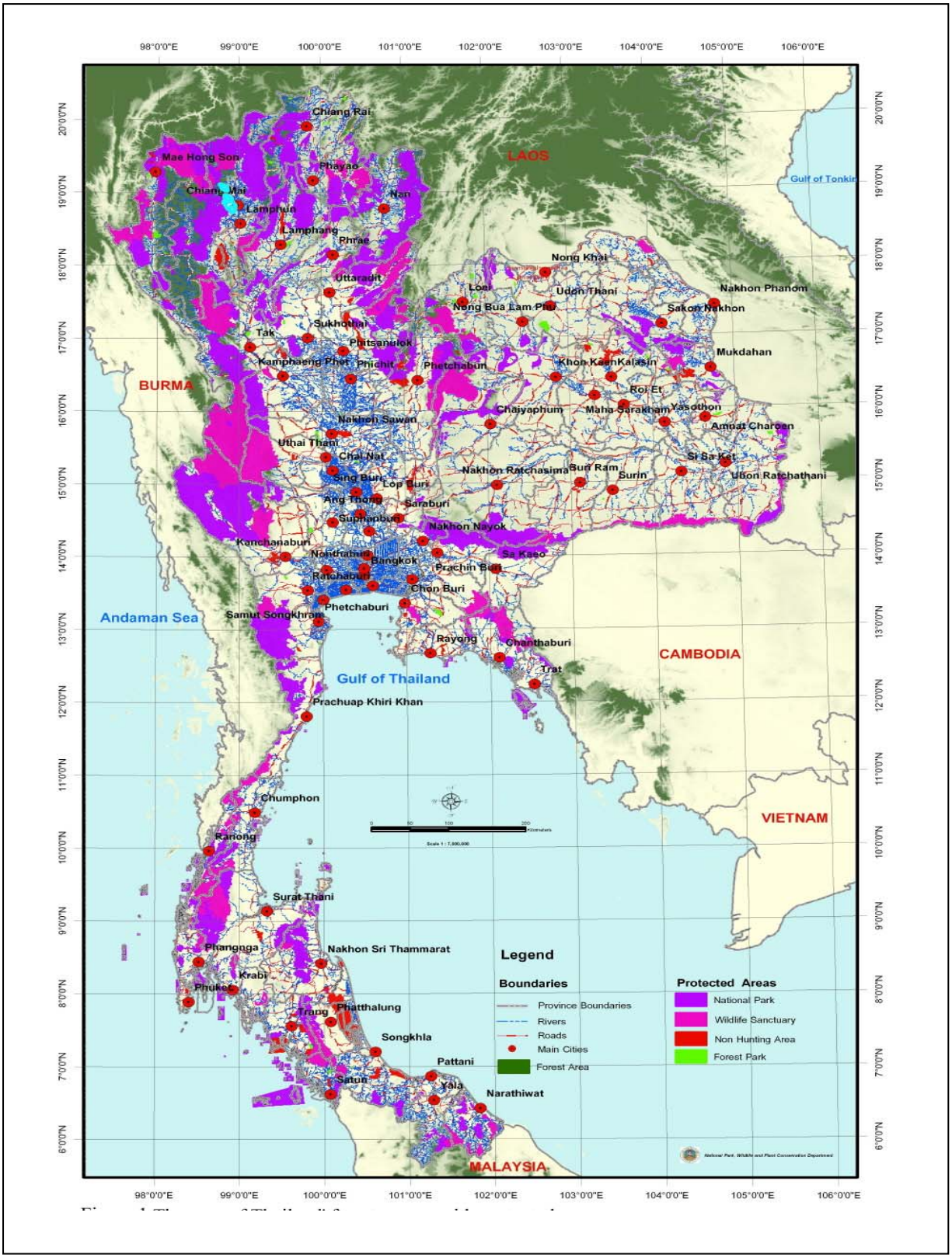


Figure 1 Map showing the forest cover and protected areas of Thailand.
Source: DNP (2006)

Table 1 Thailand's protected area categories, number of units and size

Protected area category	No. of units	Size of coverage (km^2)	% of country's total land area
National Parks (IUCN Category II)	145	68,928	13.46
- Terrestrial	119		12.05
- Marine	26		1.41
Wildlife Sanctuaries (IUCN Category Ia)	53	34,848	6.81
Non-hunting Areas (IUCN Category IV)	52	3,408	0.67
Forest Parks (IUCN Category V)	69	880	0.17
Total	319	108,064	21.11

*Note: The Table does not include Class I Watershed Protection Forest, Mangrove Forest Reserves and other small protected areas. Sites include both already declared and in processing of declaration.

Source: Department of National Park, Wildlife and Plant Conservation (2003)

Technically protected areas in the system are protected from all human use and settlement. In reality, a significant number of people have lived in these areas prior to their gazettal and there has been further encroachment subsequent to designation. Throughout the 1990s, it was estimated that as many 11 million people representing over 20 % of Thailand's 56,000 villages were living in designated National Forest Reserves (Gray *et al.*, 1994).

Components of Thailand's Protected Area System

The legal authorities for Thailand's protected areas are the Wild Animal Reservation and Protection Act of 1960 (revised in 1992), and the National Park Act of 1961 (Arbhabhirama *et al.*, 1988; Dixon and Sherman, 1990; Gray *et al.*, 1994). There are four main types of protected areas in Thailand: national park, wildlife sanctuary, non-hunting area and forest park.

1. National park

The National Park Act of 1961 States that a national park is "land, which mean the surface of the land in general and it includes mountains, streams, swamps, canals, marshes, basins, waterways, lakes, islands and seashores which has been declared a national park under this Act. The features of the land should be of natural interest and must not be owned or legally possessed by any other party other than the public body. This land is preserved in its natural state for the benefit of public education and enjoyment."

The National Park Office has established the following guiding principles for park administration: “National parks are lands preserved for protection of environment, especially forests, wildlife and unique scenery, which impresses the viewer as worthy of preservation in its natural state. National park shall be protected form destruction, alternative uses and incompatible activities so that future generations may enjoy and study these natural treasures in perpetuity.”

In summary, it can be stated that national parks in Thailand are lands which are gazetted in order to preserve and protect the natural environment, especially for the purposes of education, recreation and tourism.

2. Wildlife sanctuary

The Wildlife Conservation Office (WCO) has given the following reasons for establishing wildlife sanctuaries: “To conserve the habitat of various wildlife species, including conservation of essential requirements such as water, food, protective habitat, breeding habitat and rearing habitat, as well as salt licks, wallows, dusting areas and sunning areas so that wildlife may freely exist and propagate.”

Wildlife sanctuaries therefore are lands preserved and protected from human activity which may disturb wildlife. Tourists are generally restricted to areas designated as “Nature Education Center” within sanctuaries. In summary, both national parks and wildlife sanctuaries are established primarily to conserve wildlife and wildlife habitat. The main administrative distinction is that recreation and tourism are encouraged in national parks but discouraged in wildlife sanctuaries.

3. Non-hunting area

It is another protected area designation and has been defined by WCO as: “areas which have been designated by the government for protection of certain specific wildlife species. They are designated by the Ministry of Agriculture and Cooperatives according to Section 26 of WARPA. Non-hunting areas differ from wildlife sanctuaries in that: (i) they generally of smaller sizes; (ii) only the specified wildlife species are protected; and (iii) other uses such as fishing, lumbering, recreation and tourism are permitted.” Thus non-hunting areas are lands designated for the protection of specified wildlife species but which do not prescribe other human activities.

4. Forest park

The following definitions were stated by Thiam Khomkris (1965): Forest areas that contain attractive scenery and developed for public recreation. They are too small for inclusion as national parks, but management aims are similar. DNP normally develops forest parks for public recreation in near population centers.

5. Other protected area designation

There are other categories of forest protected areas in Thailand which have no specific legislation, but fall under the National Reserve Forest Act 1964. These include:

a) Botanical Garden: Locations established to collect indigenous and exotic plant species that are considered rare or have economic values as ornamentals and are planted in taxonomic order for purposes of research and dissemination. These species are propagated for the benefit of the public and the country.

b) Arboretum: Smaller to botanical gardens and are established to collect various plant species, especially economically useful plants and flowering plants, which are indigenous to that area. The plants are not arranged in taxonomic order as in botanical gardens, although all plants are labeled. Arboretums contain roads and walkways for tourism, recreation and research.

c) Biosphere Reserve: The newest and least well known of protected areas, were created by the Man and the Biosphere International Co-ordination Committee. The objectives of the biosphere reserves may be characterized as combining nature conservation with scientific research, environmental monitoring, training, demonstration, environmental education and local participation. They are included as a series of protected areas linked through an environmental network to demonstrate the value of conservation and its relationship with development.

d) Class 1 Watershed: Are the sites designated to have permanent forest cover because of their significance as a head watershed.

e) World Heritage Site: Area with unique natural and cultural values, which are considered to have outstanding universal significance.

f) Conservation Mangrove Forest: Sites which are excluded from utilization to serve as shelter and nursery ground for marine flora and fauna.

Forest Complexes

A newer initiative of managing protected areas of Thailand is the creation of Protected Area Complexes. As stated in “Thailand National Reports on Protected Areas and Development”-nationwide, protected areas have been grouped into 19 “forest complexes” to facilitate their planning and management on an ecosystem basis. Of the 19 complexes, 17 are forest habitats, while 2 are marine habitats.

Until October 2002, the Protected Area System of Thailand was managed and supervised by the Royal Forest Department. The Kingdom’s protected area system is now administered and managed by the new Ministry of Natural Resources and Environment Management’s Department of National Parks, Wildlife and Plant

Conservation (DNP). The Ministry of Natural Resources and Environmental Management (MONRE) was created in 2002 to act in response of the new Government policy.

Management Planning of National Parks

National parks are traditionally the most important and major component of protected area among protected area system for many countries as well as for Thailand. Management planning is an essential step towards ensuring the proper management of national parks. Management plans bring many benefits to national parks and to the organizations or individuals charged with their management – and, without them, serious problems can ensue. Young and Young (1993) described- "If there is no management plan, preservation, development and activities in a park will occur in a haphazard basis, often in response to political pressures with little consideration as to the implications for the future. The result is likely to be lost opportunities and irreversible damage to park resources and values".

Management plan is the prime document from which other plans flow, and it should normally take precedence if there is doubt or conflict.

Management planning is a continuous process; it is never static; it must adjust to changing conditions and goals. Management planning must fulfill many different purposes. Purposes will vary for different protected areas and will depend on the purpose of the protected area and the policies of the managing organization. The plan may also serve different purposes for different users. It is therefore desirable that the authority make sure to identify what is required of the plan before they start the planning process. IUCN advocates increased partnerships among stakeholders as the most desirable approach in PA management (Oli, 1999).

According to FAO (1988), the plan is usually prepared to cover a long period of time, typically five years, but sometimes longer. Perhaps the most important part of a management plan is the statement of goals and objectives for the park area. From these objectives, all development objectives and management facilities will be derived.

The general objectives of national park management as stated in IUCN's Guidelines for Protected Area Management Categories (1994) are:

- to protect natural and scenic areas of national and international significance for spiritual, scientific, educational, recreational or tourist purposes;
- to perpetuate, in as natural a state as possible, representative examples of physiographic regions, biotic communities, genetic resources, and species , to provide ecological stability and diversity;
- to manage visitor use for inspirational, educational, cultural and recreational purposes at a level which will maintain the area in a natural or near natural state;

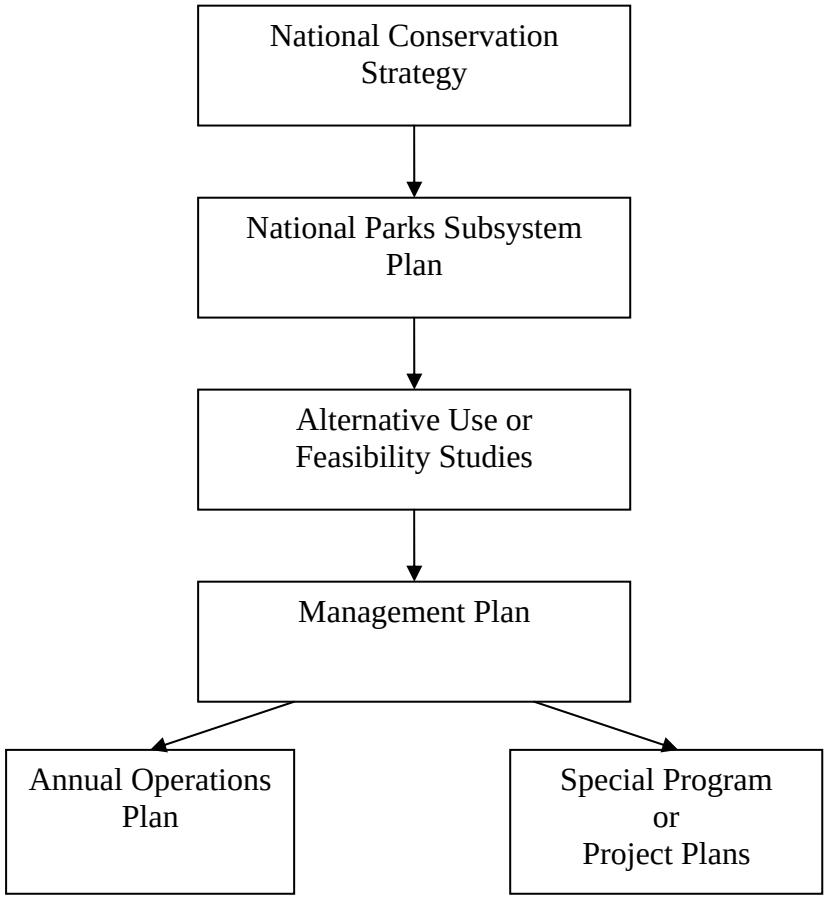


Figure 2 Typical management planning hierarchy
Source: FAO (1988)

- to eliminate and thereafter prevent exploitation or occupation inimical to the purpose of designation;
- to maintain respect for the ecological, geomorphologic, sacred or aesthetic attributes which warranted designation; and
- to take into account the needs of indigenous people, including subsistence resource use, in so far as these will not adversely affect the other objectives.

Management Zoning

Management plans for national parks may identify different management zones which are geographical areas within which similar management emphases are applied and similar levels of use permitted and different uses segregated. Zoning is a widely used and long established method of organizing resource information, and guiding management tasks, in a structured way. Zoning plan is considered as the most practical mean for providing an appropriate level of protection of the natural values of

protected areas and for managing activities which can have adverse impacts on those natural values (Trisurat, 1992; Wet Tropics, 1998).

Young and Young (1993) stated – zoning defines what can and cannot occur in different areas of the park in terms of natural resources management; cultural resources management; human use and benefit; visitor use and experience; access; facilities and park development; maintenance and operations. Through management zoning the limits of acceptable use and development in the park are established. MacKinnon *et al.* (1986) described - zones are also the most common tool for protected area managers for separating areas of conflicting uses and in managing areas for multiple uses and setting the limits of uses.

Zones identify where various strategies for management and use will best accomplish management objectives to achieve the desired future of the protected area. Within each zone, the management prescriptions should be reasonably uniform but may differ in type or intensity from those in the other zones in order to accommodate multiple objectives. According to Thomas and Middleton (2003) typical zoning will be used to:

- provide protection for critical or representative habitats, ecosystems and ecological processes;
- separate conflicting human activities;
- protect the natural and/ or cultural qualities while allowing a spectrum of reasonable human uses; and
- enable damaged areas to be set aside to recover or be restored.

In the zoning plan of protected areas, the social realities have been ignored for a long time. However, the human presence is always a key factor in the definition of the different handling zones for such areas.

The expected output from a zoning plan is a document, accompanied by maps, in which the agreements reached about the use of a determined space inside the protected area are recorded. The expected outcome is the solution of conflicts between the different use interests and the existence of a tool to control those actors that refuse to respect the negotiated decisions made in favor of the protected areas in national, regional and local contexts.

As stated in IUCN website, zoning is an extremely participative task that may take years, depending on the circumstances, the size of the area, and the attitude of the different actors. Each time an agreement is reached with a certain group about the use of an area, it must be filed in the "compendium of laws, rules and agreements." In the process of participative zoning five elements should be worked on:

- the joint definition of the vision of the protected area as a whole, and each of its zones,
- the spatial delimitation of the different zones; in other words, the definition of the areas in which the dispositions will be applied,

- the agreement about detailed rules for the use of natural resources in the different zones, specially endangered plants and animals,
- the definition of the manner in which the monitoring of the agreement will be carried out, and who will carry it out,
- the joint definition of sanction mechanisms to ensure that everyone abides by the agreed rules.

Zoning can be performed taking into consideration the different aspects in the space, with its vertical and horizontal links (sourse: www.iucn.org).

As stated by IUCN (1984) and Wet Tropics (1998), the concept of zoning was developed several decades ago. The number of management zones in each protected area will vary from place to place according to its bio-physical features and management objectives, but at least three-quarters of the total park area should reflect the primary objectives of establishment. Trisurat (1990) quoted about zone classification as the simplest arrangement consists of a core zone where the procedure of the park planning involve natural habitats or fragile resources being least disturbed, surrounded by a buffer zone where more intensive use would be allowed such as accommodations, recreational activities. In large management areas, strict natural or wildlife zones are initiated from the core zone where tourists are prohibited. This zone is surrounded by the protective buffer zone where free access is permitted for observation and study, and where movement is limited to authorized paths for vehicles, bicycles and pedestrians. The third zone is the recreation zone with free access for tourists. However in very large parks a network of cellular nodes connected by linkage consisting of access corridor zones may be best interspersed within the natural environment zones rather than concentric zones (Forster, 1973).

The different types of zones for IUCN Protected Area Categories I – IV describes by Thomas and Middleton (2003) in their “Guidelines for Management Planning of Protected Areas” are:

- Special and/or unique values zone
- Primitive/wilderness zone
- Intensive development/services zone
- Zoning for traditional and indigenous users

Other types of zone described in FAO Conservation Guide (1988) are:

- Restoration/Recovery/Reclamation zone
- Special use/Multiple use/ Socio- economic zone

It is getting importance to creating a zone which consists of human settlements that existed prior to the declaration of the natural protected area, or of areas where, due to a special situation, some types of agricultural, livestock, agrosilvopastoral, or other activities, which imply a transformation of the original ecosystem are performed (IUCN, www.iucn.org).

As referred by Chettamart *et al*. (1997), in Thailand six zones are generally recognized:

1. Strict Nature Reserve Zone: Ecologically fragile areas where use should be strictly controlled. Natural areas with high biodiversity which should be closed to all human activity except scientific studies and/ or ceremonial or religious use by local communities.

2. Primitive Zone: Valuable wild land areas where appropriate nature-based recreational activities may be encouraged through provision of trails and wildlife viewing facilities. The zone shall be retained in its natural state as biotic resources are abundant.

3. Outdoor Recreation Zone: Areas with interesting features (such as waterfalls or scenic overlooks) where visitor use is frequent and may be suitable for various site-hardening techniques in accord with management objectives and carrying capacity determinations. Interpretive facilities should be provided.

4. Recovery Zone: Degraded areas that should be examined for their potential for ecological restoration. Although nature has been ravaged, there is either some forests left or other environmental conditions are such that nature can be restored and where recovery of nature is necessary.

5. Intensive Use Zone: Areas with little ecological value where most of the park infrastructure and tourist facilities are located.

6. Special Use Zone: Areas containing existing installations of national significance but which are not align with the objective of the national park such as telecommunication facilities, major roads, temples and electric power lines. Such installations may be retained subject to mutual agreements among the concerned parties, provided such installations will not violate any prohibitions relating to the protected area.

In this study another zone named “Other Use Zone” is included for Doi Suthep-Pui National Park zoning scheme along with the six zones mentioned above. This zone included because there were some settlements/villages inside the park which are there before the establishment of the park.

7. Other Use Zone: This zone includes human settlements that existed prior to the declaration of the National Park.

The chart presented in Table 2 summarizes the key management concepts relating to management zones and how they are proposed to be used in national park (NP) as stated in Parks Canada’s website.

Table 2 Key management concepts related to management zones

Zone	Key management concepts	How it should applied in NP
Zone 1: Strict Nature Reserve Zone	(1) Used for areas that contain or support unique, threatened or endangered natural or cultural features or which provide the best examples of representative features. (2) Preservation is the key consideration in this zone. (3) No motorized access is permitted. Where warranted, public access may be prohibited.	(1) All Zone 1 areas in NP are closed to access and use for preservation purposes. (2) All zone 1 areas in NP are based on ecological values. (3) Areas of cultural importance are identified with its significance to include in this zone.
Zone 2: Primitive Zone	(1) Cover large areas that are good representations of the ecosystems of the park. (2) Maintaining the ecosystem with minimal human interference is the key consideration in this zone. (3) Motorized access is not permitted. (4) Recreation activities must be dependent upon and within the capacity of the park's ecosystems and require few, if any, rudimentary services and facilities. (5) Visitor opportunities should provide experience of remoteness and solitude.	(1) Used on large and small areas that provide good representative examples of the natural region or that provide a feeling of remoteness or solitude. (2) This zone typifies the type of back-country character proposed for NP.

Table 2 (Cont'd)

Zone	Key management concepts	How it should applied in NP
Zone 3: Recovery Zone	(1) Areas that have been degraded or destroyed by human interference or by natural digester where ecological recovery is necessary to protect the remaining intact areas. (2) The area should have potential for ecological restoration.	(1) Used on all of areas where site has damaged or degraded by destructive cultivation or other destructive activities or by natural calamities. (2) Restoration activities like protection from human and other biotic interference, reforestation where necessary.
Zone 4: Outdoor Recreation Zone	(1) Limited areas capable of accommodating a broad range of opportunities such as frontcountry campgrounds, picnic sites, viewpoints, major trailhead, and other outdoor recreation activities, and their related services and facilities. (2) Defining feature is direct access by motorized vehicles. (3) Motorized access and circulation may be limited.	(1) Used on drive-in campgrounds and other tourists attraction sites suitable for this zone.
Zone 5: Intensive Use Zone	(1) Used for major park operation, staff and tourist accommodations, administrative functions located within a park.	(1) Should be located in areas with little ecological value and have minimum susceptibility to degradation.

Table 2 (Cont'd)

Zone	Key management concepts	How it should applied in NP
Zone 6: Special Use Zone	(1) Used for areas containing existing installations of national significance but which are not align with the objective of the national park.	(1) Such installations may be retained subject to mutual agreements among the concerned parties. (2) It should be ensured that such installations will not violate any prohibitions relating to the protected area.
Zone 7: Other Use Zone	(1) Cover areas where settlement and traditional land-use practices prevailing before the gazettal of the NP. (2) Activities should be regulated.	(1) Settlement and minimal impact extraction and other income-generating or livelihood activities could be allowed for the people who are there before the area gazettal. (2) Should have a written agreement between the park authority and the settler.

Source: Partially modified from Parks Canada's website (www.pc.gc.ca).

Geo-informatics

A working definition of Geo-informatics is - an interdisciplinary field requiring synergistic modeling and analysis for dealing with geospatial data and phenomena. The Geo-informatics approach can be taken to solve problems and address issues related to geospatial data and phenomena. Geo-informatics encompasses geospatial data collection, geospatial information analysis and modeling, geospatial information systems development, implementation, and processing. Geo-informatics is possible through a range of models in such fields as mathematics, computational geometry, graph theory, and statistics (source:http://gis0.exp. sis.pitt.edu).

Geo-informatics technologies include Geographic Information Systems (GIS), Global Positioning System (GPS), and Remote Sensing (RS). Today, numerous applications are benefiting from Geo-informatics techniques and tools and with advances in Geo-informatics and other technologies, such as mobile computing and wireless networks, the emergence of many new applications is expected. Example of

Geo-informatics applications are in-car navigation systems, automatic vehicle location systems, location-based services, transportation planning and engineering, environmental modeling and analysis, telecommunications, agriculture, farming, and public health (source:http://gis0.exp. sis.pitt.edu).

Geo-informatics essentially involves capture, integrating, analysing, managing and depicting geospatial information. There are various ways in which each of these objectives could be achieved. Geo-informatics makes use of various independent subjects like surveying, photogrammetry, remote sensing, GIS etc. The following illustration is a very simple example how these different subjects work in conjunction to achieve the objective of Geo-informatics (source: http://www.geocities.com).

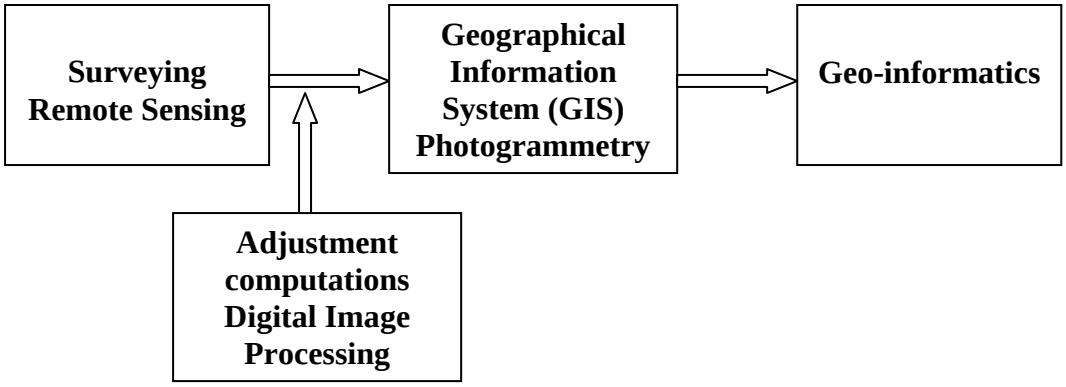


Figure 3 A simple illustration to show how geo- informatics works

The above diagram depicts how the different domains act together to solve a typical geospatial problem.

Geographic Information System (GIS)

A GIS can be seen as a set of tools for analyzing spatial data. These are computer tools, and a GIS can then be thought of as a software package containing the elements necessary for working with special data. One definition of a GIS is the software in the box that gives us the capabilities we need to analyze spatial data (Clarke, 1997).

Burrough (1986) in his pioneer textbook defines GIS as “a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes”. The key word in this definition is “powerful”. Burrough’s definition implies that GIS is a powerful tool for geographic analysis.

Star and Estes (1990) defined a GIS with the following statement; “An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data”. This means that a GIS collects data, sifts and sorts them, and selects and rebuilds them to find the right information to answer a question. The reference to geographic coordinates is an important one, because the coordinates are literally how we able to link with the map.

A GIS uses computer technology, mapping methods and geography to blend spatial data from various sources. It has been rapidly accepted and adopted in many sectors of society in fastest manner in larger community. Geographic Information Systems are being used for planning, decision-making and ecosystem monitoring related to ecosystem management challenges.

A GIS has the capabilities to manage many layers of data for the same points in space in order to perform analyses. Layers represent different sets of geographic information. Layers can provide information on geologies, soil, land use, species distribution, vegetation, etc. GIS applications involve everything from basic to complex functions. These applications include the analysis of spatial referenced data, queries on point or polygons, data classification, map production, area calculations, the creation of buffer, elevation models, etc.

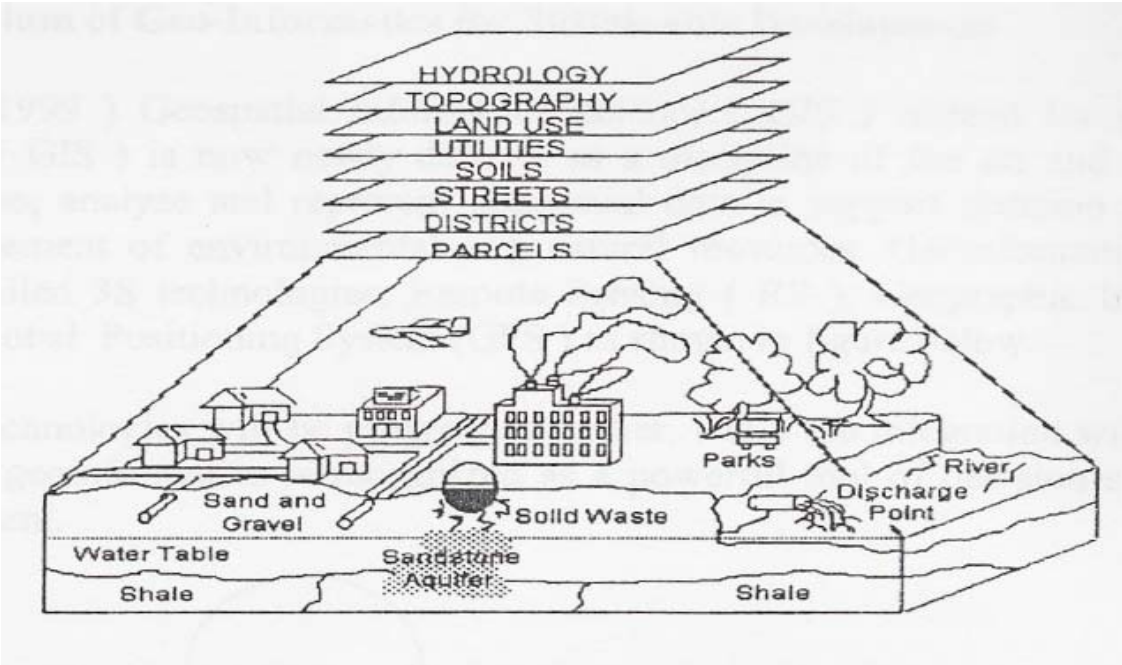


Figure 4 The real world represented as a number of related data layers
Source: Aronoff (1989)

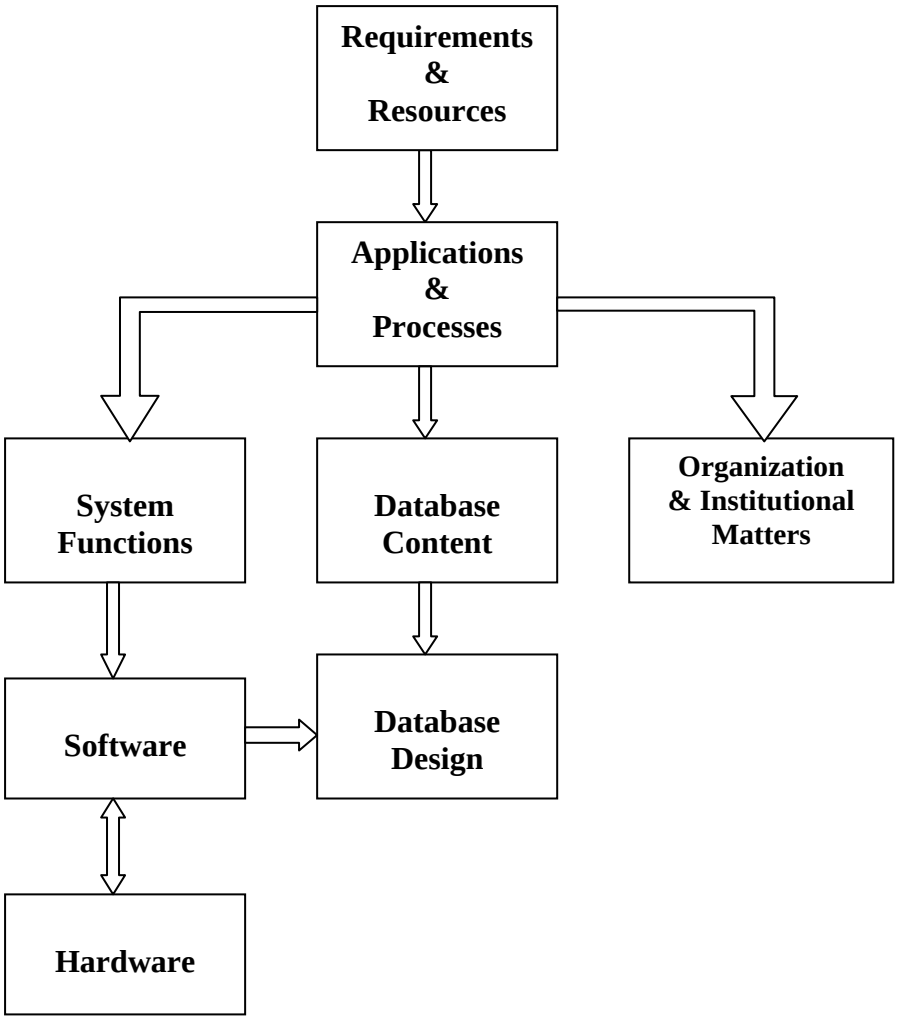


Figure 5 Design philosophy of a GIS functionality
Source: Antenucci et al. (1991)

Remote Sensing (RS)

The primary source of geographic data in the GIS is remote sensing. This includes both digital and non-digital forms (Archibald, 1987). Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 1979). Practically the term remote sensing is used in a restricted sense to refer to the collection of information about the earth's surface and lower atmosphere from a distance above the ground by aircraft or satellites. Remote sensing is achieved using a sensor mechanism fixed to a

platform at some height above ground to detect and record radiation, which has been reflected or emitted from the earth's surface. The characteristics of an object can be determined; using reflected or emitted electro-magnetic radiation from the object because each object has a unique and different reflectance and/or emmitance property. The two most used platforms are aircraft and satellites. The sensor mechanisms used in remote sensing are very variable. Each has a distinct set of characteristics.

Remote sensing and GIS technology are both used to collect, analyze and report information about the earth's resources the infrastructure we have developed to use them. The two technologies provide complementary capabilities. Remote Sensing analyses are improved by the verification data retrieved from a GIS and GIS application can benefit from the information that remote sensing can generate.

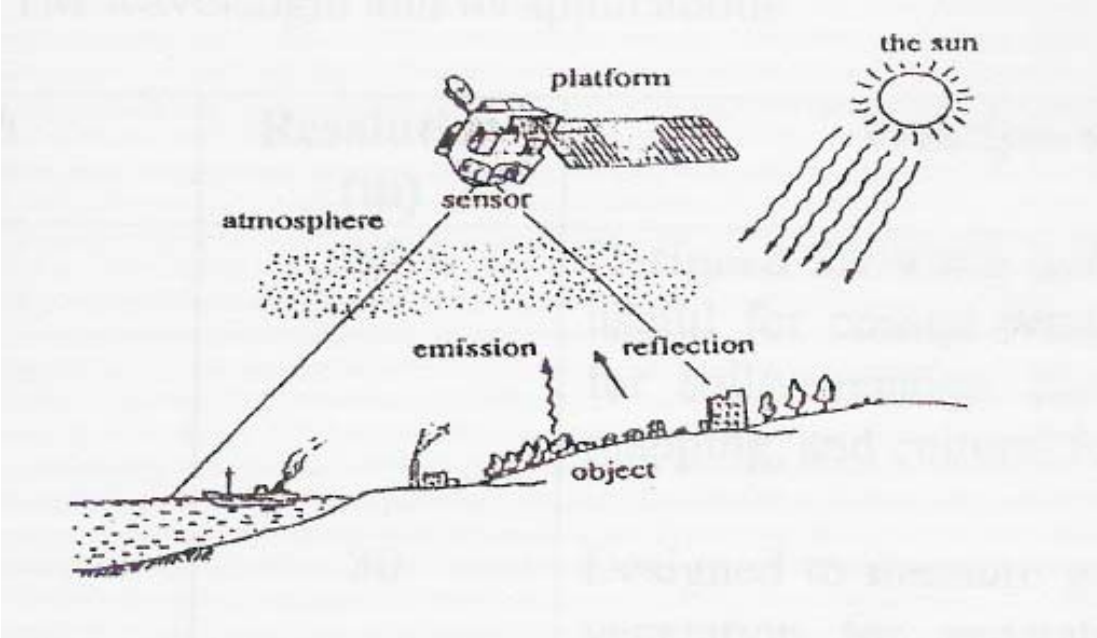


Figure 6 Data collection process by remote sensing
Source: Aronoff (1989)

Often the image data are the most current spatial information available for an area. The use of digital image data offers the additional advantage of a computer compatible format that can be input directly to a GIS. The integrated use of remote sensing and GIS methods and technology can not only improve the quality of geographic information but also enable information previously unavailable to be economically produced (Aronoff, 1989).

Global Positioning System (GPS)

A GPS is a satellite-based navigation system made up of a network of 24 (or more) satellites. These satellites were placed into orbit by the U.S. Department of

Defense as the system was originally intended for military applications. However, in the 1980s, the U.S. government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day.

The 24+ satellites that make up the GPS system are orbiting the earth about 12,000 miles above us. They are constantly moving; making two complete orbits in less than 24 hours (the satellites are traveling at speeds of roughly 7,000 miles an hour). These satellites are equipped with atomic clocks and send out radio signals as to the exact time and their location in space. The radio signals from the satellites are picked up by the GPS receiver. Once the GPS receiver locks on to four or more of these satellites, it can triangulate its location from the known positions of the satellites. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from four or more satellites, the receiver can determine the user's position. GPS technology is able to measure positions within centimeters and an error factor of one part in 1 million (Antenucci *et al.*, 1991).

Applications of Geo-informatics

Remote Sensing, GIS and GPS are widely used technology for natural resource assessment; though the GIS and GPS are comparatively new technology. These are useful tools for evaluating and managing the national park. However, for national park zoning the use of Geo-informatics is rather recent. The followings are some of the studies related to use of Geo-informatics in natural resource management.

Hoogeboom (1983) used the active remote sensing to classify and monitor the growth of agricultural crops. In that study radar remote sensing provided a large amount of valuable information to classify crops.

Juracek (1998) explained the GIS based crop specific model for physical suitability assessment of potato production in a valley of Nebraska. Eight factors, viz, length of growing season, slope, oxygen availability, thermal regime, acidity, salinity, erodibility and rooting condition were selected for that analysis.

Patabendege (1990) utilized the land cover with GIS operation for overlying various thematic information to produce a soil erosion hazard map for Hangurankela, Sri Lanka, and recommended conservation strategies on this basis. The soil erosion hazard map prepared by him was based primarily on estimating rainfall erosivity and soil erodibility at different locations and then overlying these by assigning certain weightings.

Davis *et al.* (1990) proposed an approach to integrate existing data on species distribution and habitat characteristics in bio-diversity assessment using GIS supported by remote sensing inputs.

For wildlife management, Wulf *et al.* (1988) evaluated the Giant Panda habitat in the People's Republic of China by visual interpretation of multitemporal Landsat MSS images combined with ground survey data. The criteria to determine its habitat included topography and forest cover types.

Mead *et al.* (1988) mapped the Gopher Tortoise (*Gopherus polyphemus*) habitat on the Ocala National Forest by using a GIS. This study used the habitat suitability index model based on soil, forest type, condition class and understory type. Similarly Shaw and Atkinson (1988) identified and described potential nesting habitat for the Golden-Checked Warbler by using Landsat MSS data conducted with ERDAS. Five main data had been used for this study: land use, country boundaries, slopes, habitat patches and geographic features such as roads and water ways.

Roseberry *et al.* (1994) evaluated the potential impact of conservation reserves programs land on Bobwhite habitat by using remote sensing and GIS and habitat modeling. Remote sensing, GPS, and GIS were used to locate the habitat of Giant Sequoia Grove on the Squana natural forest.

Pattanapong (2002) applied GIS and remote sensing for habitat suitability analysis of razor clams (*Solen strictus* Gould) in the muddy coast between the Mae Klong and Tha Chin rivers, Gulf of Thailand. Landsat TM images taken in 1993 and 2000 were classified to detect change in land use patterns and emerged area during low tide of the study area. The GIS database were overlaid and calculated for suitability classes by Linear Combination Model (Razor Clam Model).

Stummawong (2005) use GIS for habitat modeling to predict the distribution of diving ducks, Baer's pochard *(Aythya baeri)* and Ferruginous pochard *(A. nyroca)* in Nong Bong Kai Ramsar Site. Geographic Information System was used for data handling, storage, analyzing and running the model. Spatial variables derived from GIS and used for constructing the models included distance to lake edge, distance to fishing net site, distance to other waterfowl, and interpolated vegetation cover, benthos density, water depth and water quality. Model variables and coefficients were determined using logistic regression.

Musekawat (2004) applied remote sensing and GIS as tools for spatial data analysis toward the zoning and management of land use in tambon Bang Khunsai, Phetchaburi province, Thailand. Aerial photographs taken in 1994 and 2002 were interpolated to detect changing in land use and land cover pattern of the study area.

Srirattanatum (1989) used biophysical factors of topography, soil, vegetation, wildlife, water resources, accessibility and aesthetics to identify management zones at Tarutao National Park, Thailand by using manual overlay techniques.

Trisurat (1990) applied Linear Combination Method of multiple criteria of eight bio-physical factors to create management zones in Phu Rua National Park in northeastern part of Thailand. Each factor was ranked and weighted based on its suitability for each zone.

In this study knowledge of protected area system of Thailand and protected area management helped to realize the background of establishing Doi Suthep-Pui National Park and it's objectives for establishment. Knowledge of Park zoning is applied to develop conceptualized management zones and determine objectives and fixing potential spatial criteria for each zone. GIS data layers have created from existing GIS database and from visual interpretation of topographic map and air photos. Preliminary management zones have created by using raster based GIS Arc View Modeling considering multi stakeholders opinion together with data layers. GPS has used for ground checking and together with expert consultation to have final management zones.

General Overview of the Study Area

Location

Doi Suthep-Pui National Park is situated in northern Thailand to the west of the city of Chiangmai in the districts of Muang, Hang Dong, Mae Rim and Mae Tang, Chiang Mai Province. It is one of the Thailand's premier national parks. Doi Sthep is the 24th national park of Thailand declared on April 14, 1981. Originally, it was a national reserved forest. It is situated between 18°49'-18°56 N latitude, and 98°43'-98°-51' E longitude (Doi Suthep-Pui National Park Office, 2005). Doi Suthep-Pui national park contains the watersheds of many rivers and streams. The twin-peaked park dominates the northern city of Chiang Mai, its slopes harboring a dramatically scenic Buddhist Temple and a Royal Palace (TAT, 2000).

Doi Suthep is regarded as the symbol of Chiang Mai, as it has the Buddha's relics at Wat Phra Borommathat Doi Suthep Worawihan at the top. It is, therefore, a sacred place for Thai people in general and for the people of Chiang Mai in particular. The park has a good communication system linking it with national capital Bangkok. From Bangkok, Highway 1 leads up to Lampang (600 km). Then the road to Doi Suthep turnes left to follow Highway 11 up to Chiang Mai (100 km). Park headquarters is located 12 kilometers west of Chiang Mai. The way follows Chiang Mai-Huai Kaew Road passing Chiang Mai University and the zoo until arrive temple car park. A little further down the road, at the junction, there is a sign that points to the Doi Suthep-Pui National Park Office.

Doi Suthep-Pui National Park has two sections; the southern section is bigger and more mountainous than the northern section. The northern section is situated 6.25 km. away from the southern section and can be entered by Mae Malai-Pai road (Highway no. 1095).

Topography

The topography of Doi Suthep is mountainous composed of many ridge systems. The national park is part of the Thanon Thongchai Mountain Range. It is characterized with complex features and high cliffs, with a geological profile of granite, quartzite and sandstone. Doi Suthep (1,601 m) and Doi Pui (1,685 m) are part

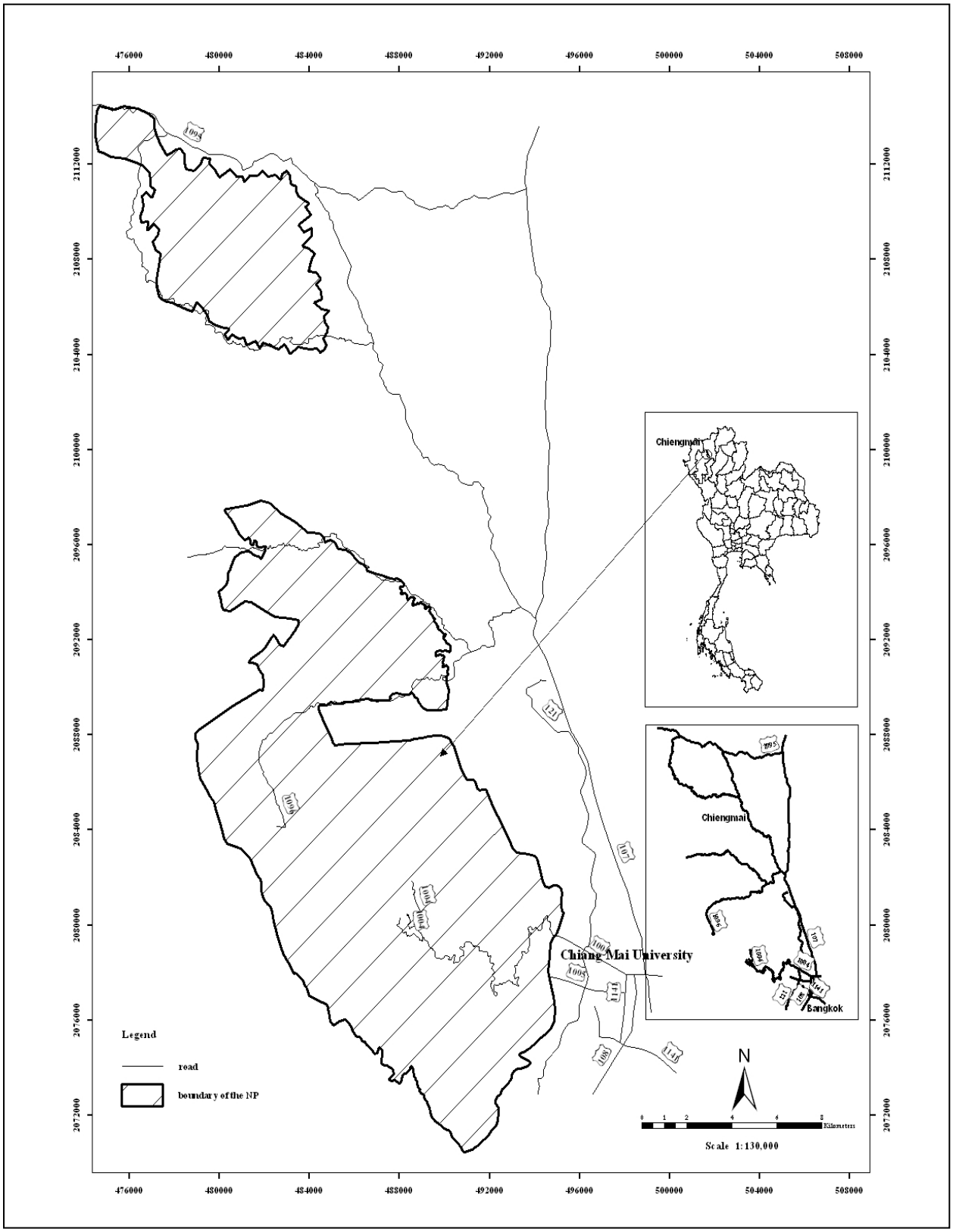


Figure 7 Map of Doi Suthep-Pui National Park and its location in Thailand

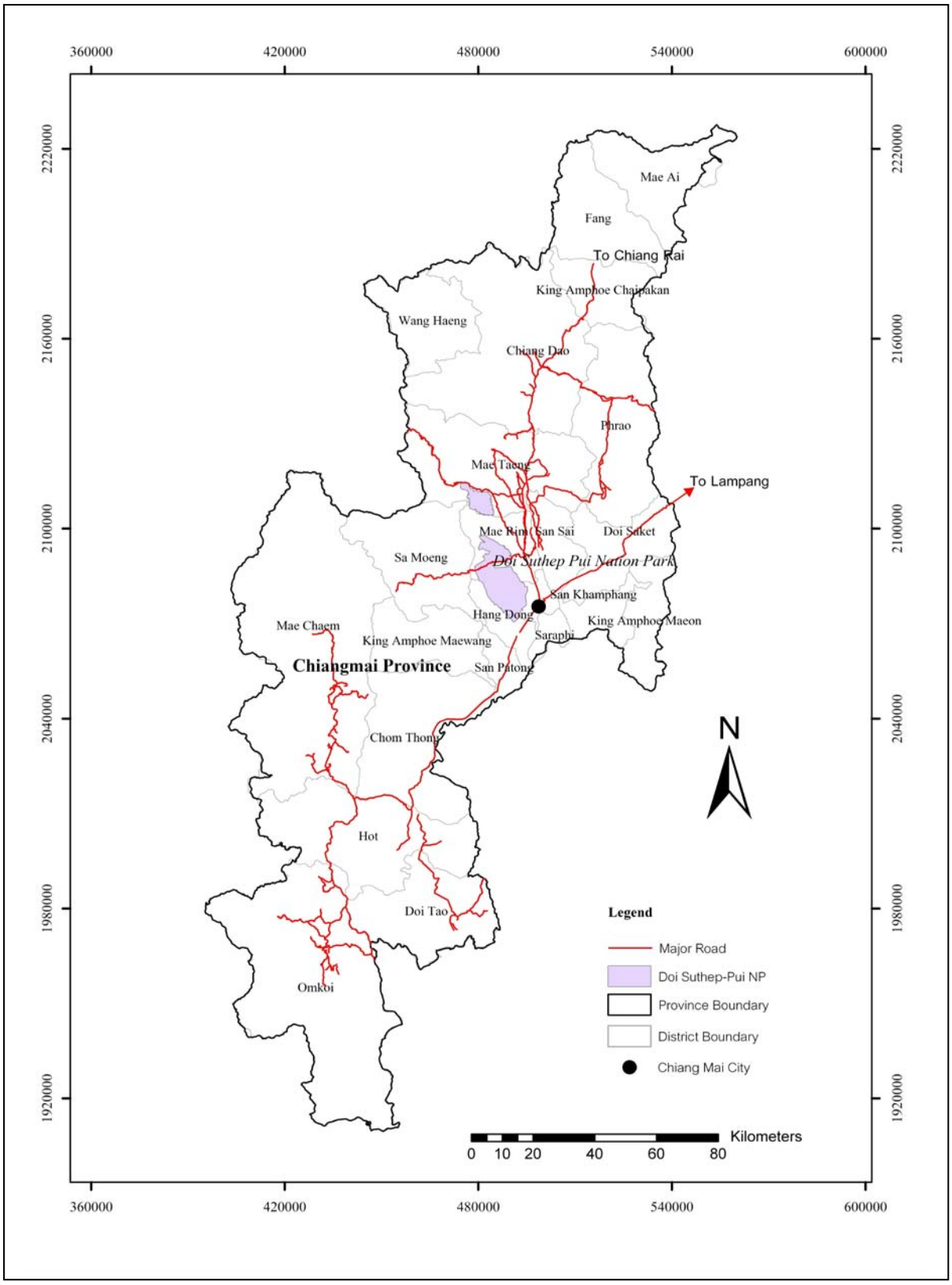


Figure 8 Map of Chiang Mai Province showing the location of Doi Suthep-Pui National Park
Source: DNP (2006)

of a geologically ancient ridge forming the western boundary of the Pink River Valley. Other prominent peaks are: Doi Mae La Noi (1,549 m), Doi Khom Rong (1,459 m) and Doi Buak Ha (1,400 m). Owing to its mountainous and forest features, the national park is the source of several rivers, streams and basins, e.g. Mae Hang, Mae Rim, Mae Ram and Mae Sa. These waterways flow to the east of the national park into the Ping River, Mae Rim district.

Doi Suthep-Pui Nationl Park's highest peak, Doi Pui, rises 1,685 meters above mean sea level. Altitudes of the national park vary from 330 meters to 1,685 meters from above sea level. The terrain in the Mork Fa Waterfall area is mostly at 400-980 meters above sea level. More than one third of the land has slopes of greater than 35%.

The Suthep basin provides water for use and consumption for Chiang Mai (specially before the irrigation canals were put in place). It is made up of several other small basins and streams flowing towards the south and southeast of the National Park. The water of the Tha Chang basin on the east side of the National Park is vital for the livelihood of the people and agriculture of Hang Dong district before it flows into the Ping River. In other words, the water basins of the National Park nourish Chiang Mai and its neighboring areas.

Climate

Climatological data gathered over 15 years indicate that the climate is characterized by distinct wet (April-November) and dry (December- March) seasons, with most of the rain falling from May to October (Table 3). The average annual rainfall ranges from 1300 mm. near the plain to over 2000 mm. near the summit of Doi Pui. December to March experiences a monthly mean rainfall of less than 33mm. November to February are relatively cool months, with average temperatures at 18 °C or lower, with occasional night of minimum temperature at 5-6 °C. But frost is extremely rare. By the end of February the temperature begins to rise, to peak with the average of 24 °C in April (Figure 9). March and April are very hot and dry months, with an average of relative humidity around 60%, high winds (11-13 km./hour), coupled with a high temperature (absolute maximum temperature at 35 °C) and high probability of forest fires. Tropical storms are common at the break of the wet season by the end of April. The mean annual temperature is 20°C, with a mean maximum and minimum of 24°C and 17°C, respectively. In February, the air is crisp and clear and the landscape is sharply visible from the parks viewpoints (Rerkasem and Rerkasem, 1995).

Table 3 Last 15 years' climatic data of Doi Suthep-Pui area (1990-2004)

Month	Temperature (^{o}C)			Rainfall (mm)
	Mean	Max	Min	
January	16.8	21.0	10.3	9.0
February	19.3	22.0	12.7	3.4
March	22.7	25.0	16.6	21.0
April	24.2	29.8	19.5	63.3
May	23.5	29.7	19.3	247.2
June	23.0	27.5	18.1	209.3
July	22.6	27.0	17.4	334.3
August	22.5	26.0	17.6	388.9
September	22.7	26.5	18.0	318.5
October	22.2	25.5	17.8	171.4
November	19.6	25.5	14.3	68.2
December	17.4	21.0	11.0	19.5

Source: Agricultural Research Station and Training Center, Mae Hia (2005).

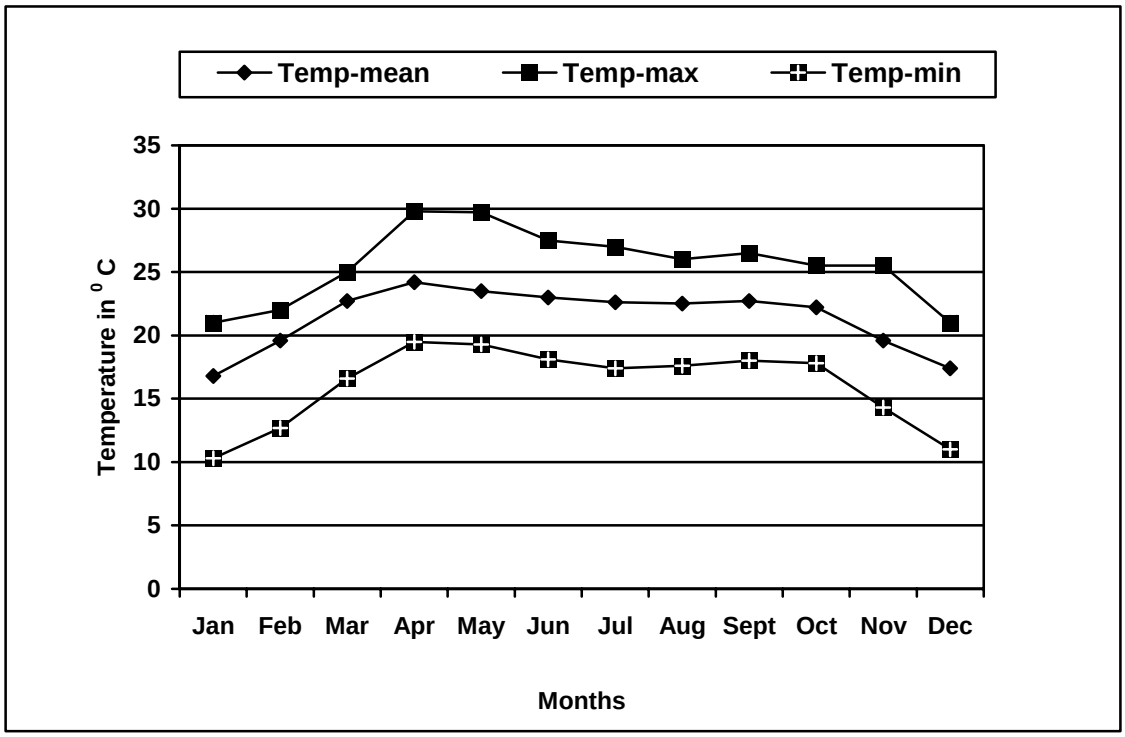


Figure 9 Graphical presentation of last 15 years' monthly average temperature data

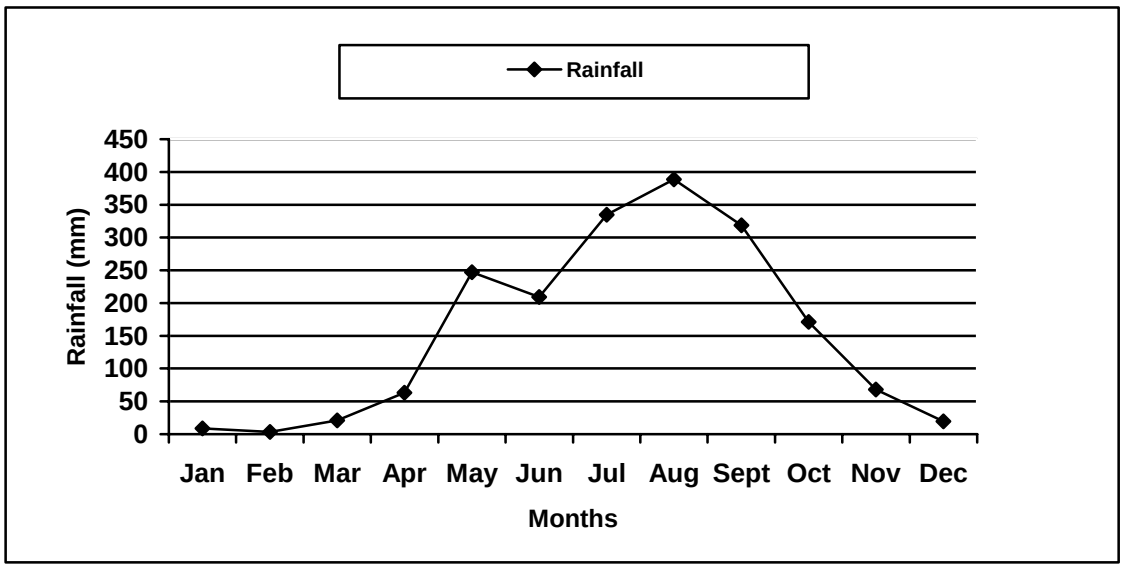


Figure 10 Graphical presentation of last 15 years' monthly average rainfall data

Land Cover Classes

Land cover classification (as in 2000) was derived from existing GIS database of Doi Suthep-Pui National Park. The total area of the Park is 281.57 km^2; nine land cover categories were recognized as presented in table 4. The area covered by different forest types is 230.81 km^2 or 81.97 % of the total park area, the detailed analysis of the forest cover indicated that five categories of the forest/vegetation were identified namely - Dry Dipterocarp Forest, Hill Evergreen Forest, Mixed Deciduous Forest, Secondary Growth and Disturbed Forest, Plantation Area, which occupies 18.73 %, 19.23 %, 43.39 %, 0.39 %, and 0.23 % of the total park area respectively.

From Table 4, it was also observed that an area of 50.76 km^2 or 18.03 % is under non-forest types, of which 45.73 km^2 or 16.24 % lies in agricultural area, 0.96 km^2 or 0.34 % lies in urban/ built up area, 3.88 km^2 or 1.38 % Old Clearings area, and 0.19 km^2 or 0.07 % is water bodies like ponds and lakes or reservoir.

Detailed description of major forest types in Doi Suthep-Pui National Park is given below under flora sub heading. Other land cover types are described as follows:

Secondary growth and disturbed forest

Secondary growth and disturbed forest cover 1.09 km^2 or 0.39 % of the total area of the park, this is the results of long term disturbance by human, the rare and valuable species and big stands are rarely found because of illegal logging and encroachment. Crown closure is approximately 35 - 45 %. This vegetation type scattered all over the park area. The dominant species includes *Imperata cylindrica, Chrysopogon aciculatus*, *Saccharum spontaneum*, and several types of bamboo.

Table 4 Area distribution under different land cover classes in Doi Suthep NP

Land Cover Types	Area (km^2)	Percentage (%)
Dry Dipterocarp Forest	52.73	18.73
Hill Evergreen Forest	54.15	19.23
Mixed Deciduous Forest	122.19	43.39
Secondary Growth Forest	1.09	0.39
Plantation	0.65	0.23
Total forest types	230.81	81.97
Agriculture Area	45.73	16.24
Old Clearings	3.88	1.38
Urban Area	0.96	0.34
Water body	0.19	0.07
Total non forest types	50.76	18.03
Total	281.57	100.00

Source: From existing GIS database of Doi Suthep-Pui National Park

Forest plantation

Land with planted forest accounts for 0.23 % of the total area, this forest type includes mainly Teak and Acacia species; they are grown on deep moist soil and low slope gradient.

Agricultural area

There are about 45.73 km^2 of cultivated areas were found in the national park. They are located mainly along the periphery of the national park where soil is deep and moist as well as in low gradient areas. In previous time farmers/ villagers used to produce crops includes upland rice, maize, opium and cash crops of tare, cabbages, and cassava under shifting cultivation. But recently permanent cultivation of cash crops, often with irrigation, largely replaced shifting agriculture. Opium cultivation area has virtually stopped. New annual cash crops are cabbages, carrots, ginger, flowers, potatoes, sweet potatoes, strawberry, tare, and beans. Lychee and mangoes are now productive and beneficial.

Urban area

These are the built up areas other than villages inside the park. They cover 0.96 km^2 or 0.34 % of the park's area.

Old clearings

These are barren areas without or very scattered vegetation cover. They are created due to human activities in past times. There are about 3.88 km^2 of barren land

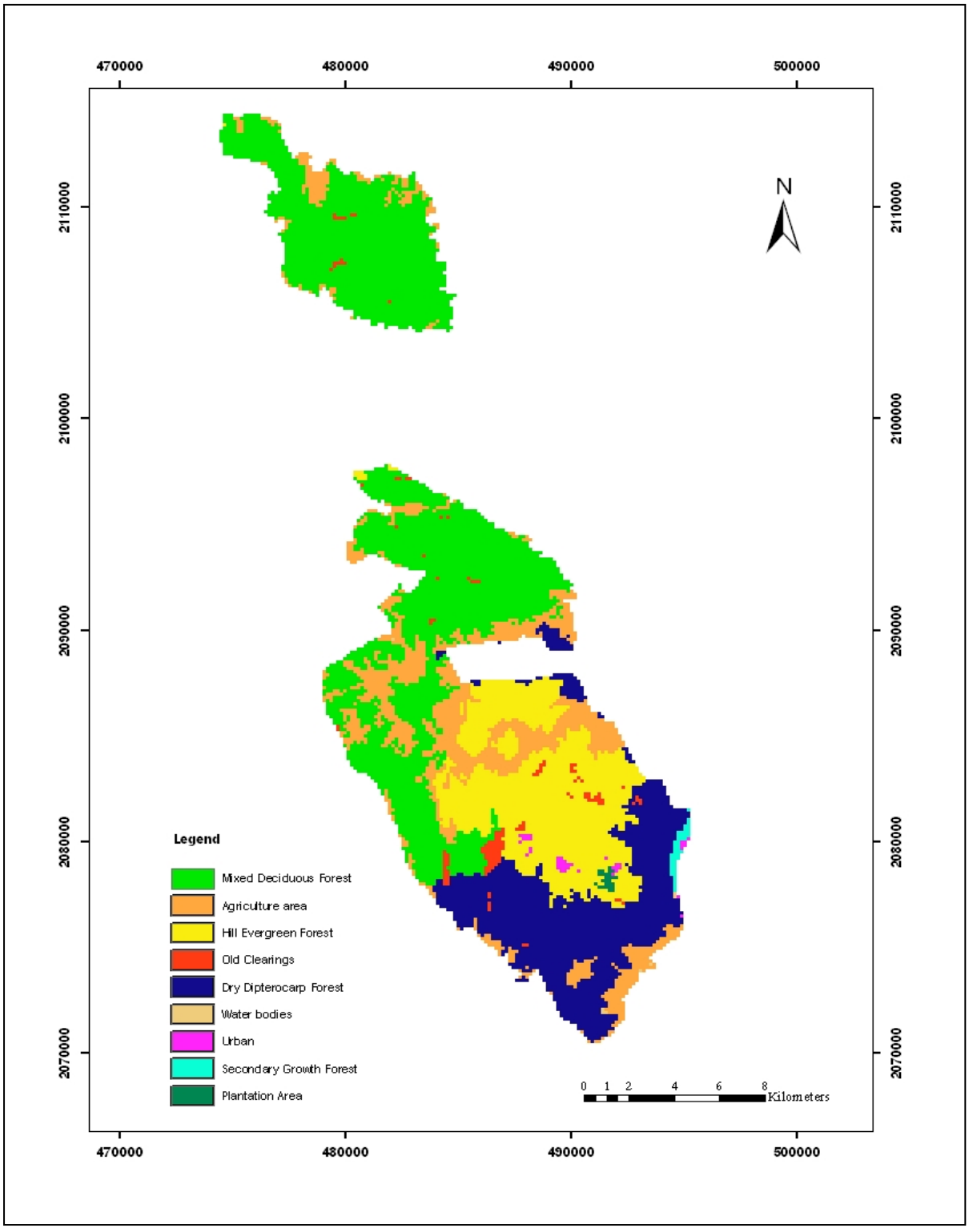


Figure 11 Land cover map (2000) of Doi Suthep-Pui National Park
Source: From existing GIS database

or 1.38 % of the total area of the park and they are located scatteredly throughout the park. In general, they are areas of thin soil, vegetation is very wide spaced or without vegetative cover because of man's activities.

Water bodies

Water bodies cover about 0.19 km^2 or 0.07 % of the park area. They are the ponds, lakes and Reservoirs inside the parks.

Flora and Fauna

Flora: Due to different altitude from 330 m to 1,685 m above sea level, the national park boasts a great variety of floras. Surveys conducted since 1904 have revealed that there are at least 2,092 species of 193 families (17% of the total flora in Thailand) and new species are still being discovered (Maxwell, 1988). Some rare plants are found here. These rare species therefore have scientific names with *suthepensis.* Recent studies indicated that the park's deciduous forests may contain more tree species than any other tropical deciduous forest so far studied (Gray *et al*, 1994). The plant community consists of different types of forests. The park's deciduous and evergreen forests shelter what may be the most profuse plant life in Thailand despite the loss of some species due to human interference.

Mixed deciduous forests are found on the plains at the foot of the hill at a lower altitude than dry dipterocarp forests. Common plant varieties include teak (*Tectona grandis*), redwood (*Xylia xylocarpa*), Pradu Pa (*Pterocarpus macrocarpus*), Rok Fa (*Terminalia alata*), Samo Thai (*Terminalia chebula*), Ceylon oak (*Schlechera oleosa*), Tin Nok (*Vitex limoniifolia*), Tio Kliang (*Cratoxylum cochinchinnense*), Makok Kluean (*Canarium subultum*), Yo Pa (*Morinda tomentosa*), and other plants of Fagaceae family. On the tree tops there are varieties of orchids, e.g. those of the Denbrobium genus, Rhynchostylis genus, Aerides genus and Smitinandia genus.

Dry dipterocarp forests are found at an altitude lower than 800 meters. The plant varieties found are Hiang (*Dipterocarpus obtusifolius*), Phluang (*D. tuberculata*), Thiya (*Shorea obtuse*), Rang (*S. siamensis*), Phayom and Khaeng (*Wendlandia tinctoria*). There are also several types of the Fagaceae (*Shorea roxburghii*) plants, e.g. Ko Phae (*Quercus kerrii*), Ko Daeng (*Lithocarpus lindheyanus*) and Ko Hua Mu (*Lithocarpus sootepensis*).

Evergreen rain forests are found at the higher altitudes, over 600 meters above sea level, usually near creeks and streams with high moisture. Trees are taller than 35 meters. Plant varieties found are usually of the Fagaceae family, e.g. Ko Paen (*Castanopsis diversifolia*), Ko Mon (*Lithocarpus elegans*), Ko Dueai (*Castanopsis acuminatissima*) and Ko Daeng (*Lithocarpus lindleyanus*). Some big plants found are Yang Pai (*Dipterocarpus costatus*), Champi Pa (*Michelia baillonii*), Montha Doi (*Mangliertia garrettii*), Saraphi Pa (*Anneslea fragrans*), Thalo (*Schima wallichii*) and Ma Huat (*Lepisanthes rubiginosa*). Some plants are fond of streams and creeks, e.g. Tong Lat (*Actinodaphne henryi*) and wild banana plants. Some of the rare varieties

are also found here, e.g. aloewood (*Aquilaria malaccensis),* Kam Yan (*Styrax bensoides*), cinnamon (*Cinnamomum spp*.). The ground is covered with Kha Luang Lang Lai (*Cynatheaceae chinensis*) and a variety of ferns.

Hill evergreen forests cover most of the areas of the Doi Suthep-Pui national park. Structurally, they are similar to the dry evergreen forests but are found over 1,000 meters above sea level. Trees are mostly scrubby undergrowths. Mosses and ferns cover the forest ground. Plants are of the Fagaceae Variety, e.g. Ko Paen (*Catanopsis diversifoliia*), Ko Dueai (*Castanopsis acuminatissima*), Ko Daeng (*Quercus kingiana*), Ko Dam (*Lithocarpus truncatus*), Ko Mu (*Castanopsis calathiformi*), Ko Dang (*Lithocarpus lindleyanus*), Thalo (*Schima wallichii*), Kam Yan (*Styrax benzoides*), cinnamon (*Cinnamomum spp.*), Kamlang Suea Khrong (*Betula alnoides*), Khaeng Kwang (*Wendlandia tinctoria*), Mueat (*Symplocos macrophylla*), Phikun Pa (*Adinandra integerrima*) and Makhampom (*Phyllanthus emblica*). On the ground grow wild roses, white and red *Vanda, Paphiopedilum and phalaenopsis*. The ground is usually covered with mosses and ferns.

Hill evergreen forests associated with pine are scattered on high grounds, especially along the ridges of the mountains, e.g. Doi Pui, Doi Buak Ha, Pha Dam and Laem Son. Although both two-needled pine and Three-needled pine trees are found, the later are more common. There are also plants of Fagaceae family (Bänziger, 1988).

Fauna: At present there is no report of big animals in this national park, intensive human use of the area has eliminated large mammals, but bird life is still rich. There are reportedly 58 species of mammals, 28 amphibian, 44 reptiles, 306 species of birds, 500 butterfly and 300 moth species (Elliott, 1991).

Medium sized mammals which are still visible are barking deers, sambar deers, wild boars and flying squirrels. Rare species of birds that are found here are Silver Pheasant (*Lophura nycthemera*), Hume's Pheasant (*Syrmaticus humiae*) and Wedge-tailed Green Pigeon (*Treron spenura*). Birds that are commonly found are, White- rumped Shamas, Maroon Orioles, Scarlet Minivets, Ashy Drongos, Blue-throated Barbets, Great Tits, Velvet-fronted Nuthatches, Chestnut-bellied Nuthatches, Blue-winged Leafbirds, Hill Blue Flycatchers, Black-naped Monarchs, White-throated Fantails and Gould's Sunbirds. River chats, birds indigenous to a few Asian countries that migrate from the cold winter, are found here (Elliott, 1991).

Reptiles found are, for instance, Siamese Big-headed turtles (*Platysternon megacephalum*), Impression turtles (*Manouria impressa*), Thai water skinks (*Tropidophorus berdmori*), Red-bellied water skinks, Spiked lizards and Doi Suthep green frog (*Ichthyophorus youngorum*).

Unusual reptiles include the reddish colubrid snake, (*Elaphe porphyracea* Cantor) and the Chinese big-headed turtle (*Platysternon megacephalum* Gray), a carnivore capable of tree climbing. Remarkable rarities among amphibians are the placid crocodile salamander (*Tylototriton verrucosus* Anderson), Thailand's only salamander, and a legless creature, the worm-like caecilian (*Ichthyophis youngorum*

Taylor). While the former has been reported at just four localities in Thailand, the latter has been found exclusively on Doi Suthep. *I. kohtaoensis* Taylor is a more common caecilian of the foot of the mountain (Bänziger, 1988).

Insects found are in great number, especially butterflies. It is reported that there are over 500 species of day butterflies, e.g. Paris Peacocks, Great Mormons, White Dratontails, Red-base Jezebels, Junglekings, Crusers, Orange Oakleafs, Common Archdukes, Indian Purple Emperors, Common Nawabs and Purple Sapphires.

Mae Sa - Kog Ma Biosphere Reserve

The area declared by the Man and the Biosphere Programme (MAB) committee as the Mae Sa-Kog Ma Biosphere Reserve is largely overlaid by the area of Doi Suthep-Pui National Park. This Biosphere Reserve covers a total area of about 360 km^2. It encompasses a former project area of the Mae Sa Integrated Watershed and Forest Land Development Project of the Thai Royal Forestry Department, and the Kog Ma Watershed Research Station of the Faculty of Forestry, Kasetsart University. So far there is still no legislation to support the establishment of Mae Sa-Kog Ma Biosphere Reserve.

Kog Ma Watershed Management Research Project

It is a small (64.46 ha.) field research station run by the Faculty of Forestry, Kasetsart University. It begun in 1963, with an initial funding from the United States Operations Mission (USOM) and later supported through the regular research budget of Kasetsart University. The project's first phase (1963-1985) was run with collaboration of KUFF and University of Colorado. And the second phase (1997-till now) is running with the collaboration of KUFF and University of Tokyo. The research plot is on 1348 m above MSL. The data collected included climate, stream flows, surface runoff and sedimentation.

Chiang Mai Night Safari

This night safary is just recently established inside Doi Suthep-Pui National park area. This open zoo is established on 131 ha of park land situated in Muang district's tambon Suthep and Hang Dong district's tambon Nong Khwai. The night safary has three zones- Jaguar Trail (1.2 km.), Savannah Safary and Predator Prowl. The zoo now has 729 animals of 103 species, mostly from the National Park, Wildlife and Plant Conservation Department's domestic purchases and exchanges (Personal communication, 2006).

Human Settlement

About 10% of the park area is inhabited by the hilltribe community and farmers who grow lychees, coffee, cabbages and rice (TAT, 2000). Doi Suthep-Pui contains many local villages inside the park, on the park boundary, and within 5 km.

of the park boundary. A survey completed by the park agency in 1995 found that there were 9 villages located inside the park boundaries (464 households; population of 2,708), 15 villages located on the edge of the park boundary (810 households; population of 4,225), and 25 villages located within 5 km. of the park boundary where most villagers have used park lands for agriculture (681 households; population of 3,032). According to another survey conducted by Department of Land Development only 46 % of the population are ethnic Thais, the balance is made up of people who belong to ethnic minority groups, with the Hmong, at 50 % the dominant group, and small numbers of Karen, Shari, Yao, Lahu and Lisu. A recent list provided by the park office shows that there have 15 villages inside the park (Table 5) which are resided by different ethnic group including the Thais and tribal minorities.

Conflict over agricultural land uses and park management is an important issue for Doi Suthep-Pui. Because of a dramatic increase in tourism, many resorts have been developed near the park. Many of the local people sold their lands to resort owners and have then encroached on park land for agriculture. Illegal logging by local people is another problem in the management of Doi Suthep-Pui national park (Tanakanjana, 1996).

The west side of the park has been heavily degraded and disturbed by several human activities like tourism accommodations, agricultural research stations, television relay tower and settlement of at least 500 tribal families. Several efforts over the years have been made to relocate the tribal people who have contributed to forest eradication through their slash- and burn farming methods, but all of these efforts failed due to political pressures. Animal poaching and collection of rare wild plants continues while some lower slopes were denuded in 1991 to install a water reservoir to service a recreation complex which includes a shooting range.

A seminar in 1991 described Doi Suthep as “a mountain of greed”, regarded by many as merely a profitable commodity. As part of an effort to preserve the traditional character of Chiang Mai, local groups and individuals are fighting against plans to string a cable car up the mountain, widen the road to Doi Suthep’s famous temple and further promote mass tourism (Gray *et al*, 1994).

Park Administration and Management

Doi Suthep-Pui National Park is centrally administered by the National Park Office, Department of National Park, Wildlife and Plant Conservation of the Ministry of Natural Resources and Environmental Management located in Bangkok. The chief of national park is designated as Park Superintendent. Between park office in Doi Suthep and Head Office in Bangkok there has Regional Office which is situated in Chiangmai. However the superintendent has to liaison with other local and district administrative offices too. Park management rest mainly on three objectives-preservation of biological diversity; enhance recreation and tourism and providing opportunities for conservation education, and scientific research.

Table 5 Villages in Doi Suthep-Pui National Park

No	Name of village	Location		Number of HHs	Number of peoples	Ethnic group
		District	Tambon			
1.	Doi Pui	Muang	Shuthep	153	1,193	Hmong
2.	Doi Suthep	Muang	Suthep	97	1,600	Local
3.	Phu Phing	Muang	Suthep	97	307	Local
4.	Khun Chang Khian	Muang	Chang Phuak	94	879	Local
5.	Huai Kaew	Muang	Suthep	112	400	Local
6.	Chang Khim	Muang	Suthep	295	1,195	Local
7.	Mae Lord Tai	Mae Tang	Sob Pueng	34	120	Karen
8.	Lisaw Tha Pha	Mae Tang	Pha Pae	11	55	Lisaw
9.	Pha Nok Kok	Mae Rim	Pong Yang	57	295	Hmong
10.	Mae Sa Mai	Mae Rim	Pong Yang	94	1,045	Hmong
11.	Mae Sa Noi	Mae Rim	Pong Yang	86	605	Hmong
12.	Pong Hai	Mae Rim	Mae Ram	32	157	Local
13.	Huay Rai	Mae Rim	Kee Leg	46	244	Local
14.	Machia Noi	Mae Rim	Mae Sa	22	122	Local
15.	Pha Tack	Mae Rim	San Pong	13	63	Local

Source: Doi Suthep-Pui National Park Office (2005).

The entire Doi Suthep-Pui National Park is divided into two major management and administrative components - Park Headquarters and Ranger Station Units. The headquarters is the center of administration, protection, maintenance, and interpretation and headed by superintendent. Rangers Station Units are mainly responsible for protection which are also provide services for tourists and manage camp sites. There are seven Ranger Station Units in Doi Suthep-Pui namely- Ranger Station Unit 1 (Pha Dam), Ranger Station Unit 2 (Sri Sang Wan Waterfall), Ranger Station Unit 3 (Maesa Waterfall), Ranger Station Unit 4 (Mae Hia), Ranger Station Unit 5 (Mork Fa Waterfall), Ranger Station Unit 6 (Tard Mok Waterfall), and Ranger Station Unit 7 (Chang Khian). There are four check points in Park area namely- Doi Pui Check Point, Huay Khaew Check Point, San Pa Yang Check Point, and Huay Terng Thow Check Point. Each station consists of 1-2 rangers and 8-10 temporary workers (Doi Suthep-Pui National park office, 2005).

Conservation management

The park has botanical and ornithological interest, and its principal values include watershed protection for nearby lowlands and as a recreational area for domestic and foreign visitors. The site is also a key area for organized bird watching tours, as it is easily accessible. Conservation management is focused primarily on prevention of uncontrolled fires, establishment of stable agricultural practice amongst local people and control of poaching and illegal timbering.

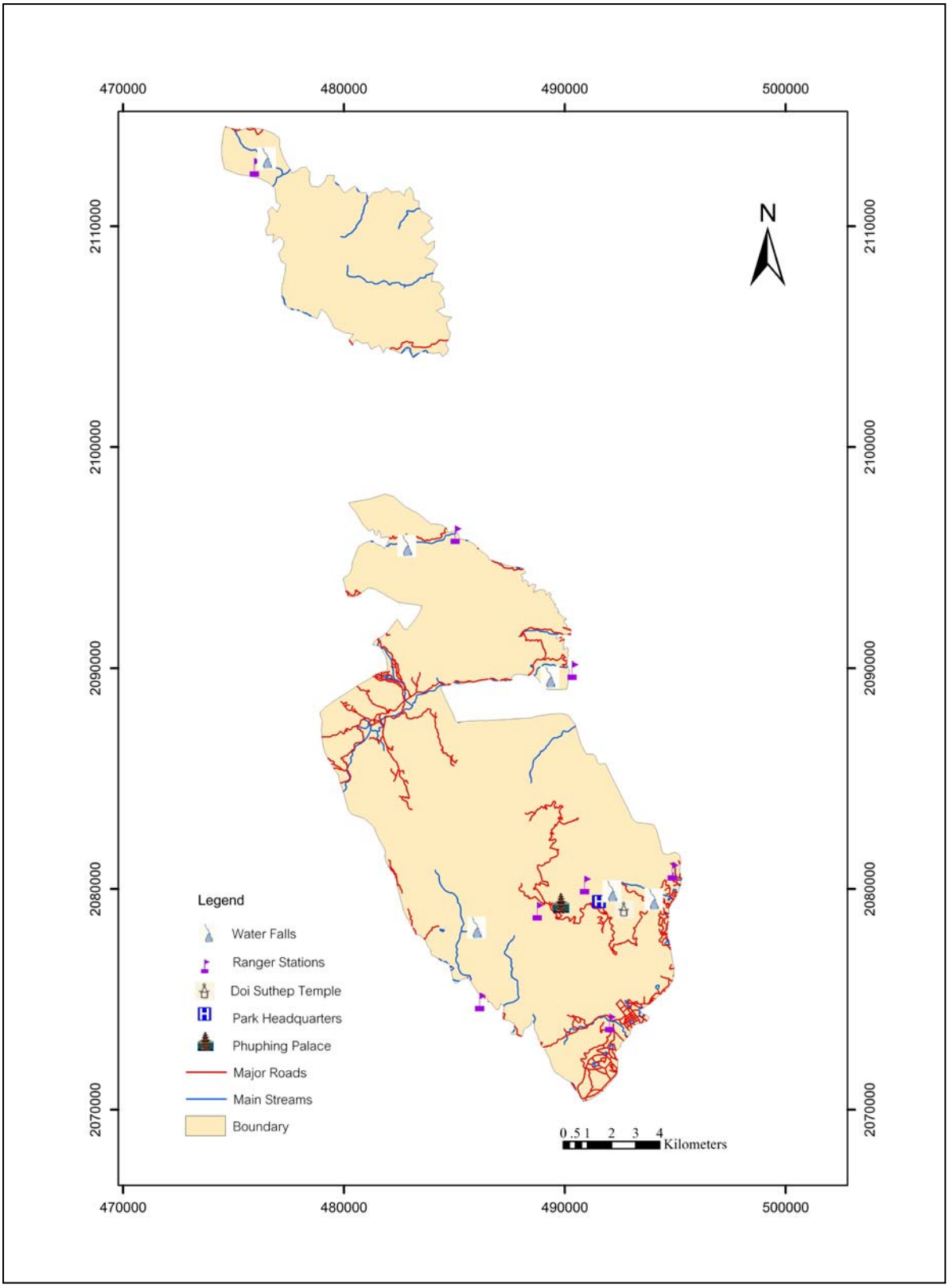


Figure 12 Map of Doi Suthep-Pui National Park showing important physical features

Management constraints

The principal management problems stem from the agricultural activities of the hill tribes and pressure from tourism. Repeated burning of undergrowth, selective cutting of larger trees and complete denudation of areas of mixed deciduous forest, which formerly occupied areas around the foothills, have contributed to a substantial loss of forest cover and a gradual degradation of remaining habitat (Round, 1984).

Problems from tourists tend to be extensive, with a proliferation of local traders around the Wat and the Phuping Palace, uncontrolled fires, litter and disturbance to wildlife. Proposals to build a cable car on Doi Suthep, which would lead to severe management problems, have not yet received government approval (Bänziger, 1988).

Tourism and Recreational Facilities

The proximity to Chiang Mai, the Wat Prahat, Phuphing Palace, hilltribe villages and a mild climate make the park popular with both domestic and overseas visitors. There is ready access to the park from Chiang Mai by road. The road continues to the Palace and a dry weather road leads to Doi Pui Summit. There are also a number of nature trails running to waterfalls and hilltribe villages. Bungalow and dormitory accommodation is available. Doi Suthep-Pui National Park has seventeen bungalows and dormitories near park headquarters that can accommodate up to 168 people; Monthathan Waterfall has two guest houses that can accommodate 12 people and Mork Fa waterfall has accommodation for 60 people (Doi Suthep-Pui National Park Office, 2005). There has a canteen and stationary shop near park headquarters, small restaurants are found at the temple parking area and near the Phuphing Palace. Chiang Mai is one of the country's major tourist destinations, offering a great range of accommodations, restaurants and shopping bargains as well as the rich culture of northern Thailand.

The attractive sites for tourists are Wat Phra Borommathat, Phuphing Ratchaniwet Palace, Chruba Siwichai Monument, the areas behind Phuphing Palace, Mae Sa Waterfall, Scenic View Point at Kilometer 5 of Wichai roadside, Huai Kaew Waterfall, Wang Bua Ban Basin, Monthathan Waterfall, Doi Suthep Summit-San Ku, Doi Pui Summit and Laem Son, Tat Mok Waterfall, Mork Fa Waterfall, Si Sang Wan Waterfall. Beside this bird and butterfly watching, visiting tribal villages and hiking or mountain biking in the trails are other tourists attractions in this park. The main factors that lead the tourists to the park are good communication, cool and charming weather, rich flora and fauna and excellent scenery and cultural life in and around the area. The visiting seasons begins from October until February with the peak in December and January. The average number of visitor is 3.4 million/year within 1998-2003 (Doi Suthep-Pui National Park Office, 2005).

Table 6 Number of visitor arrived in Doi Suthep-Pui National Park within 1998 to 2003

Month	Year						Average
	1998	1999	2000	2001	2002	2003	
January	218,361	352,493	332,570	324,596	290,829	292,503	301,892
February	156,333	168,875	327,523	348,210	325,801	282,544	268,214
March	166,429	238,362	346,614	106,383	434,724	254,744	257,876
April	193,299	322,986	421,748	523,578	534,086	559,025	425,787
May	230,395	211,080	360,248	458,499	298,408	450,740	334,895
June	155,029	257,635	314,922	422,848	438,559	429,072	336,344
July	103,352	200,106	249,562	331,283	213,485	148,748	207,756
August	157,714	281,826	240,693	295,843	199,179	279,916	242,529
September	269,264	187,122	252,909	175,281	266,265	384,373	255,869
October	137,265	132,958	225,325	388,238	312,223	255,793	241,967
November	142,951	151,249	298,219	271,834	326,681	275,017	244,325
December	175,592	167,004	369,657	311,249	500,331	317,949	306,964
Total	2,105,984	2,671,696	3,739,990	3,957,842	4,140,571	3,930,424	3,424,418

Source: Doi Suthep-Pui National Park Office (2005).

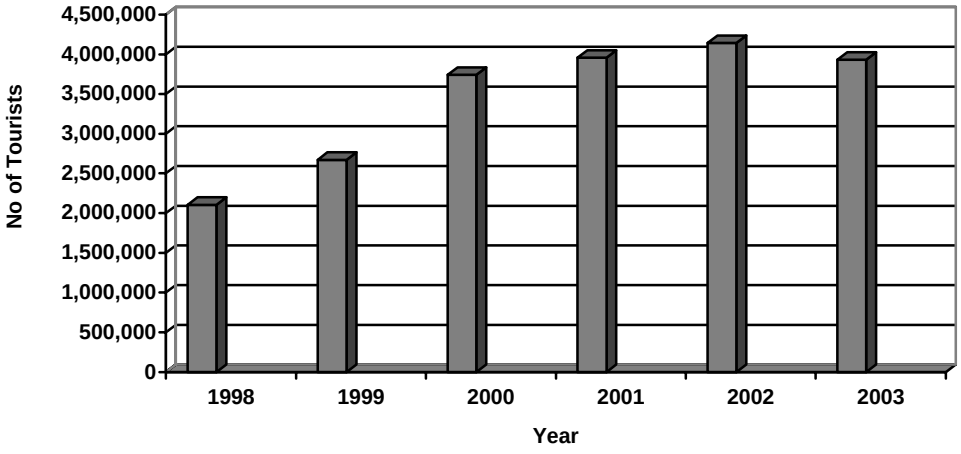


Figure 13 Yearly average visitor number in Doi Suthep-Pui (from 1998-2003)
Source: Doi Suthep-Pui National Park Office (2005)

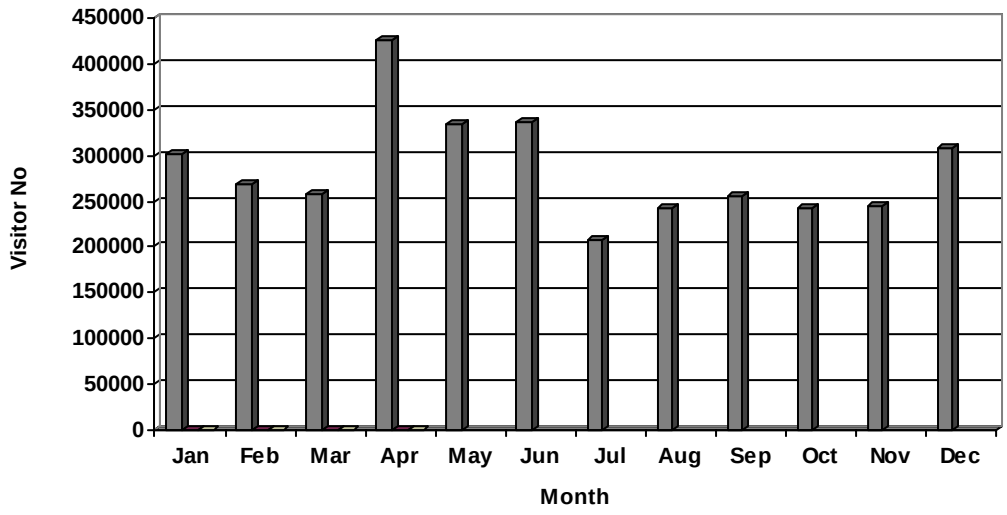


Figure 14 Monthly average visitor number in Doi Suthep-Pui (from 1998- 2003)
Source: Doi Suthep-Pui National Park Office (2005)

MATERIALS AND METHODS

The major portion of the study involved with the collection and organize geospatial data from existing GIS database, from existing maps and aerial photos and also directly from field, taking multi stakeholders' opinion for fixing spatial criteria and getting ranking and weighting score for the zoning model used, field check and taking expert suggestions to have final management zone map of Doi Suthep-Pui National Park.

Materials

Materials and equipments used are shown in the following list:

1. GIS data from existing database of Doi Suthep
   - Landcover/land use
   - Road network
   - Stream network
   - Contour

These data were obtained from Department of Conservation, KUFF.

2. Aerial photograph (1:15,000), year 2002 obtained from DNP.

3. Topographic map (1:50,000), sheet no 4746 I, 4746 II, 4747 II published by Royal Thai Survey Department, year 1999.

4. Mirror Stereoscope

5. GPS (Global Positioning System)

6. Digitizing table for map digitizing

7. Interview schedule

8. Micro computer with suitable hardware and software

   - Software package- Arc View 3.2 for spatial analysis and for producing map.
   - ERDAS Imagine 8.4 for derive slope and elevation from existing contour.
   - ARC Map 8.3 for delineating area and producing map.

9. Scanner and printer

10. Camera

11. Vehicle etc.

Methods

The work for this study conducted in five main steps including: - 1) collection and gathering information from existing GIS database, remote sensing data and from other sources and directly from field; 2) defining management zones and developing spatial criteria and ranking and weighting scores for zoning model used with the help of multi-stakeholders opinion; 3) spatial analysis with Arc View GIS software to develop preliminary management zones' map; 4) ground truthing and consultation with experts and park officials to have final management zones' map; and the last step is 5) to compare this management zones' map with the previous one.

In this study GIS was used to store, manipulate, and analyze spatial data as well as to assist the modeling process. Data sets are developed in different layers that require for several stage of processing to be successfully integrated for the purpose of spatial modeling and further analysis. The process of bringing disparate data into compatible formats for spatial modeling is one of the subjects of this study.

Data Collection and Types of Data Used

The data was collected in two ways: one collected through survey and another from non- survey, these are as follows:

1. Survey sources:

   - Interview schedule - for taking multi stakeholders' opinion.
   - GPS survey - about location of sites.

2. Non- survey sources:

   - Data from existing GIS database
   - Aerial photographs
   - Existing maps
   - Other secondary sources.

The primary and secondary data were collected to meet the objectives of the study. The data collection procedure is presented in Figure 15.

The primary data of multi stakeholders' opinion about zoning criteria and ranking and weighting scores were collected using interview schedule. The researcher conducted the interview with the help of interpreter. Earlier it was decided to get the opinion from stakeholders by brainstorming in an arranged workshop. But due to language barrier it was conducted by personal interview survey.

Locations of existing tourists' attraction sites, park headquarters, staff and tourists' facilities, research stations and TV relay stations were obtained directly from field by using GPS and then later on their area were delineated from aerial photographs. Locations and area of settlements were interpreted and digitized from aerial photo and existing topographic maps.

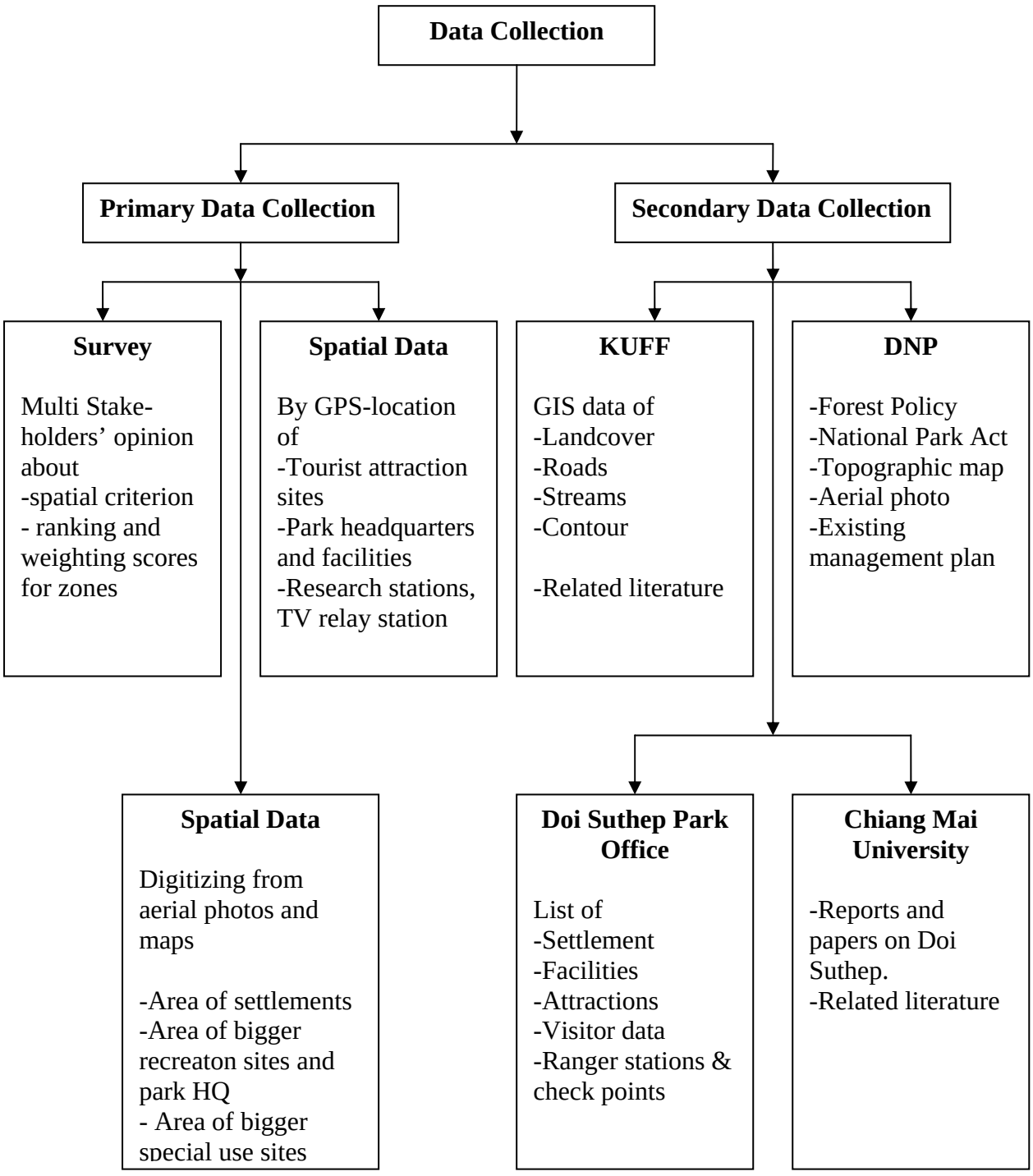


Figure 15 Flow diagram showing data collection procedure and data source

Vegetation / land cover type was obtained from existing GIS database and later transformed from vector to raster format for facilitating spatial analysis. Similarly data about roads and trails, permanent and seasonal streams, contour was obtained from existing GIS database and later transformed to raster format. The slope

and elevation data were derived from contour grid by using ERDAS Imagine 8.4 application. Information about present management zoning scheme was obtained from existing management plan and from park authority.

Data Processing

Data collected by personal interview survey (Appendix-A) from nine categories of stakeholders (Table 7). Purposive sampling was used to obtain the respondents categories and no of respondents in each category. Selected stakeholders were requested to rank for each factor against each zone and total 17 factors were presented for rating. There were options for five scale rating. The scales are - 5 (strongly desirable), 4 (desirable), 3 (neither desirable nor undesirable), 2 (undesirable) and 1 (strongly undesirable). Total respondent number was 65. The following is the list of stakeholders' category and number of respondent in each category.

Table 7 Respondents' category and no of respondent under each category

Serial no	Respondents' category	No of respondent
1	Researchers	3
2	Park officials/staffs	15
3	NGO	3
4	Local tambon authority	3
5	Highland people	6
6	Lowland people	4
7	Doi Suthep Foundation/temple authority	6
8	Small businessman/tour operator	10
9	Tourists	15
Total	All category	65

After receiving the interview schedules from respondents the entire data were processed together by using excel worksheet. Standard deviation and mean of each value were calculated to find the variation of opinion among the selected stakeholders. The values of standard deviations were found too high in relation to the means. Standard deviations and means of values for all selected respondent types are given in tabular form in Appendix-B. From the table we can see that for the factor Dry Dipterocarp Forest for SNRZ the mean of the values is 3.14 and standard deviation is 1.21; again for the factor Mixed Deciduous Forest for IUZ the mean of the values is 2.08 and standard deviation is 1.33. Similarly standard deviations for other values are also high in relation to means as we can see from the table. This means that the stakeholders varied too much in their opinions. This is due to different education, knowledge level and professional background of the respondents. Then again the same procedure was applied for different category of stakeholders separately instead of doing it combinedly. This time the standard deviations for values were found within considerable range for three categories of stakeholders namely

researchers, park official/staffs and NGO. Standard deviation and mean of values for these three categories of respondents are given in tabular form in Appendix-B. In this case from the table we can see that for the factor Dry Dipterocarp Forest for SNRZ the mean of the values is 4.42 and standard deviation is 0.50; again for the factor Mixed Deciduous Forest for IUZ the mean of the values is 4.43 and standard deviation is 0.59. Similarly standard deviations of other values for these three respondents' types are also quite low in relation to means if we compare with that of all respondent types mentioned earlier. This means that the stakeholders in this case are more or less similar in their opinions. For other categories i.e. tambon authority, highland people, lowland people, Doi Suthep Foundation/temple authority, small businessman/tour operator and tourists, values of standard deviations in relation to means were not found within considerable range. So the opinions of first three categories of stakeholders were taken into consideration. The spatial criteria for zoning and ranking and weighting scores were determined based on stakeholders' opinion.

Spatial Analysis

The spatial analysis of GIS Arc View 3.2 was employed to perform spatial analysis functions. Before spatial analysis vector based GIS datasets were converted to raster format because it is more powerful and more user friendly than vector-based modeling. Grid size was designated at 30 m x 30 m which is appropriate for zoning at national park level. The whole procedure is shown in Figure 16.

Conversion of Data Layers for Analysis

1. Land cover map layer

Land cover/land use is very important for determining zones' locations of a zoning model. It may indicate suitability for habitats of many wild flora and fauna. Land cover map was derived from existing GIS database and later converted into grid. The land cover for Doi Suthep-Pui National Park is classified into nine classes namely Agricultural Area, Dry Dipterocarp Forest, Hill Evergreen Forest, Mixed Deciduous Forest, Old Clearings, Secondary Growth Forest, Plantation Area, Urban / Built up Area and Water Body. Detailed description and area coverage of each land cover type was given in pages 30-33.

2. Slope map layer

Slope can be important factor in determining and selecting suitable location for each zone of the national park zoning model, because it may indicate flat soil or erosion and deposition of soil. At first the Digital Elevation Model (DEM) was interpolated from 30 m contour map which is from existing GIS database, by using ERDAS Imagine software. Then this 30 m DEM was later transformed into slope grid. According to the DEM the slope of Doi Suthep-Pui National Park was classified into five classes: gentle sloping (0 - 10 %), sloping (10-25 %), moderately steep (25 - 35 %), steep (35-55 %) and very steep (> 55 %) which is shown in Table 8.

Table 8 Area distribution under different slope classes in Doi Suthep-Pui National Park

No	Slope class (%)	Area (km2)	Percentage (%)
1	0-10	29.38	10.43
2	10-25	72.84	25.87
3	25-35	69.30	24.62
4	35-55	87.65	31.13
5	>55	22.40	7.95
Total	-	281.57	100.00

3. Elevation map layer

Elevation of Doi Suthep-Pui National Park was derived from existing contour by using DEM and converted to grid. The elevation of Doi Suthep-Pui National Park varies from 330 m to 1685 m; the lowest point lies in the southern part of the park and the highest point lies in Doi Pui peak in the central part. Elevation classes of the national park are 0 - 600 m, 600 - 800 m, 800 - 1000 m, 1000 - 1200 m and > 1200 m based on the distribution of vegetation cover types. These cover 85.82 km^2, 65.19 km^2, 57.71 km^2, 40.02 km^2, and 32.83 km^2 respectively (Table 9).

Table 9 Area distribution under different elevation classes in Doi Suthep-Pui National Park

No	Elevation range (m)	Area (km2)	Percentage (%)
1	0-600	85.82	30.48
2	600-800	65.19	23.16
3	800-1000	57.71	20.49
4	1000-1200	40.02	14.21
5	>1200	32.83	11.66
Total	-	281.57	100.00

4. Road networks map layer

Road networks map include trails and roads was also produced from existing GIS data and later transform into grid. The proximity to the roads and trails were classified into 5 classes:

i) 0-500 m from the roads and 0-300 m from the trails
ii) 500-1000 m from the roads and 300-600 m from the trails
iii) 1000-2000 m from the roads and 600-900 m from the trails
iv) 2000-3000 m from the roads and 900-1200 m from the trails
v) 3000 m from the roads and >1200 m from the trails

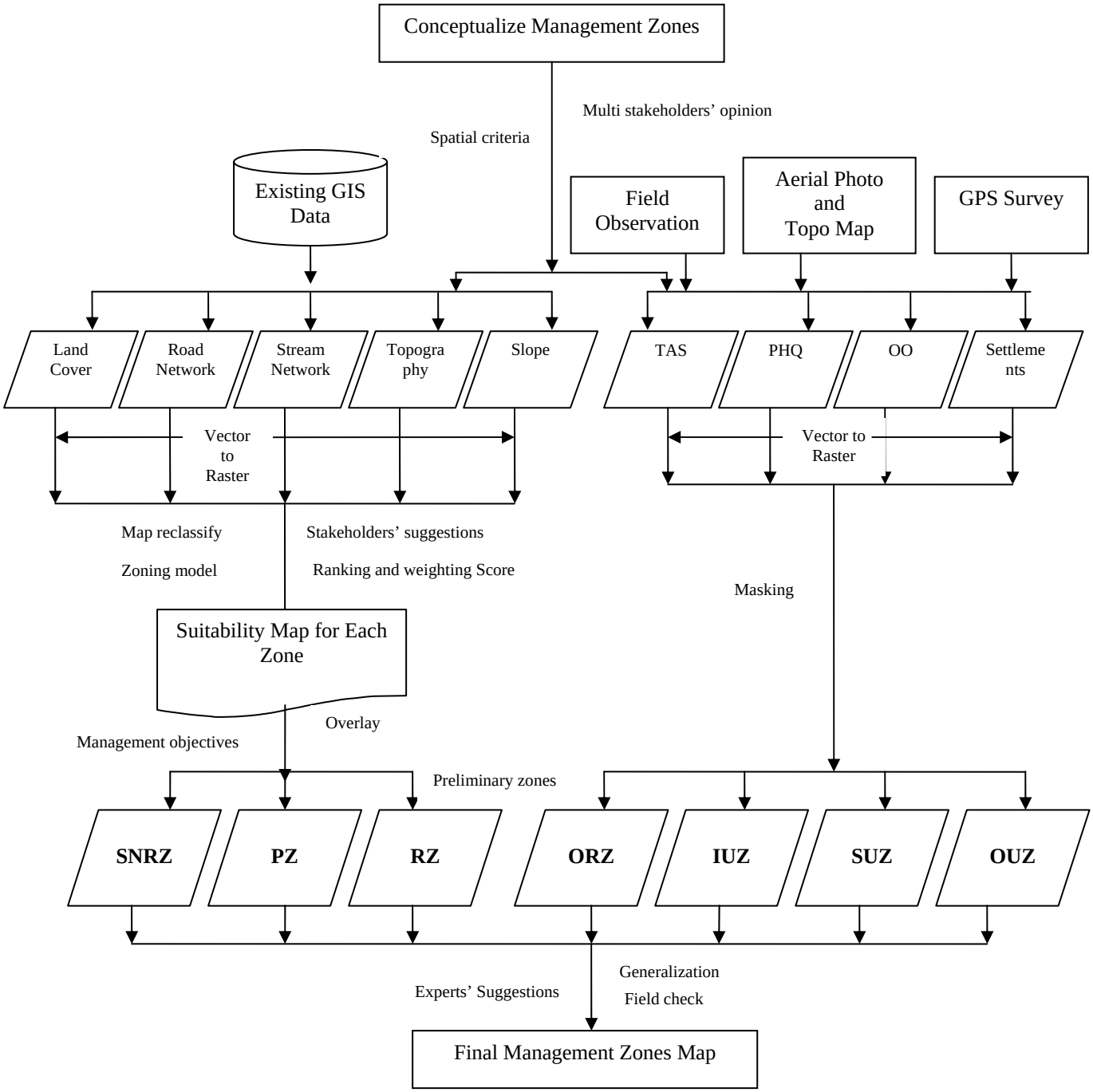


Figure 16 Flow diagram of the whole procedure

*Note: TAS= Tourists' Attraction Sites; PHQ= Park Head Quarters; OO= Other Organizations

5. Stream networks map layer

Stream networks map was made from existing GIS data and later transform into grid. The proximity to the main stream and seasonal stream were classified into 5 classes:

i) 0-500 m from the main stream and 0-300m from the seasonal stream
ii) 500-900 m from the main stream and 300-600m from the seasonal stream
iii) 900-13000 m from the main stream and 600-900m from the seasonal stream
iv) 1300-1700 m from the main stream and 900-1200m from the seasonal stream
v) >1700m from the main stream and >1200m from the seasonal stream

Creation of Park Zoning Model

There is no unique model for zoning of the national parks. The type of modeling depends on the experts or organizations who prepare management zones. Generally they use overlay technique but the number of bio-physical factors and criteria may different. Therefore this technique cannot be duplicated to other national parks that do not have same biophysical conditions.

In this study, it is decided to create seven management zones based on the bio-physical condition of the park area and park management objectives. The name of the zones are: *Strict Nature Reserve Zone (SNRZ), Primitive Zone (PZ), Restoration or Recovery Zone (RZ), Outdoor Recreation Zone (ORZ), Intensive Use Zone (IUZ), Special Use Zone(SUZ), and Other Use Zone (OUZ).* Definitions and key management concepts of these zones are given in pages 15 - 18. Based on multi stakeholders' opinion two types of spatial criteria were determined:

1. General criteria

- Land cover
- Slope
- Elevation
- Proximity to roads and trails
- Proximity to streams

2. Specific criteria

- Location of existing tourists' attraction sites
- Location of existing park headquarters, staffs' and tourists' facilities
- Location of existing research stations and TV relay station.
- Location of existing settlements

The general spatial criteria/factors namely- land cover, elevation, slope, proximity to roads and trails and proximity to water were used for spatial analysis of the first three zones i.e. *Strict Nature Reserve Zone, Primitive Zone,* and *Restoration or Recovery Zone.* General factors were used for these three zones because they supposed not to be located in a particular area of the park. They could be located in several areas in the park if the general spatial criteria fixed for them support them for these areas.

The specific spatial criteria/factors were used to identify other four zones namely *Outdoor Recreation Zone, Intensive-use Zone, Special use Zone and Other use Zone.* Specific criteria used to identify these zones because they are confined in specific areas. Doi Suthep-Pui National Park is already a built up park and there has limited possibility to expand these built up areas in near future. There was no spatial analysis for these four zones; rather they were masked directly later at the final stage of the process. The model used was a Linear Combination Method of ranking and weighting scores. Ranking and weighting scores were obtained based on stakeholders' opinion.

Ranking scores for the general factors/criteria

The ranking score presents how suitable of each type (e.g. land cover type) of each factor (e.g. land cover) for each zone. The rating assumes consideration of all characteristics of the types and all the costs and impacts of the land if located on this type (Hopkins, 1979). Rating was assigned for the general criteria in five scales depending on the degree of suitability (Table 10). For example- for land cover type of SNRZ, rating score 5 was given against Hill Evergreen Forest because it is most important forest type in Doi Suthep in terms of species diversity. It is also regarded as fragile habitat and situated in higher elevation and slope forming important head watersheds. Rating score 4 is for Mixed Deciduous and Dry Dipterocarp Forest types because this forest types also important but situated in lower elevation and not so diverse in species composition compare to Hill Evergreen Forest. Secondary growth and plantation area have less biodiversity and species composition and less important in conservation point of view, so they ranked as 2 for SNRZ.

If we consider the PZ it gets its position after SNRZ in terms of strictness in preservation. Rating score is similar to SNRZ in case of land cover type because it is also very important zone for preservation and it should comprise the maximum area of a park, areas with higher slope and vulnerable biodiversity will be in SNRZ. In case of RZ the old clearings area get most importance and ranked highest. Agricultural areas were not given highest rating because though agricultural areas are much suitable for recovery but in practice it is not possible to get the land for recovery activities from the existing users.

In case of proximity to roads/trails rating was done similarly for SNRZ and PZ because both area is susceptible to damage, the more the area will be accessible the more the possibility of damage. Rating increases with the distance from roads and

trails. But for RZ the rating will be reversed because we need accessibility for doing recovery activities and replanting if necessary and also we have to be invest for recovery activities, if the site is near the road investment cost will be less if it is far investment will be higher.

Again for proximity to water the more the area is near to the water the higher will be the score because water is most important for the plants as well as animal. This is equally important for SNRZ, PZ as well as RZ because we need water for forest restoration/recovery or for new enrichment plantation.

Elevation is an important factor for determining zones. The higher the elevation the higher will be ranking score for SNRZ and PZ and reverse for the RZ.

For SNRZ we consider slope as an important factor. The higher the slope the more the area will be susceptible to erosion and damage. So as the slope (%) is increased the rating also increased. For primitive zone we don't rank the highest elevation (>55%) as 5 because these areas will be under SNRZ because they are more susceptible to soil erosion and damage. Slope > 55% is ranked as 4 for PZ. The raw rating scores are listed in Table 10.

The raw rating scores are later standardized from 0.01-1.00 by using the following formula (Perkins, 2005).

$$C_i = \frac{fi - f\ \min}{f\ \max - f\ \min}$$

Where C_i = standardized rating score, f_i = raw rating score, f_{min} = minimum rating score of the factor's classes, f_{max} = maximum rating score for the factor's classes. For example in case of factor class 600-800 m of proximity to road for SNRZ the raw rating score is 2 the standardized value for it will be:

$$C_1 = \frac{2-1}{5-1}$$

$$\text{or } C_1 = 0.25$$

Similarly other values are calculated and listed in Table 11.

1. Raw rating score: The following table shows the raw rating scores of all the factors for three zones.

Table 10 Raw rating score for the general criteria/factors of park zoning model

Factors/criteria		Raw rating score for each zone (f_i)		
		SNRZ	PZ	RZ
PROXIMITY TO ROAD				
Road	Trail			
0-500 m	0-300 m	1	1	3
500-1000 m	300-600m	2	2	3
1000-2000 m	600-900 m	3	3	2
2000-3000 m	900-1200 m	4	4	1
>3000 m	>1200 m	5	5	1
PROXIMITY TO STREAM				
Main stream	Seasonal stream			
0-500	0-300	5	5	5
500-900	300-600	4	4	5
900-1300	600-900	3	3	3
1300-1700	900-1200	2	2	2
>1700	>1200	1	1	1
ELEVATION				
0-600m		1	2	5
600-800m		2	3	4
800-1000m		3	4	3
1000-1200m		4	5	2
>1200m		5	3	1
SLOPE (%)				
0-10		1	1	1
10-25		2	2	2
25-35		3	3	2
35-55		4	4	3
>55		5	4	3
LAND COVER TYPE				
Agriculture Area		1	1	2
Dry Dipterocarp Forest		4	4	1
Hill Evergreen Forest		5	5	1
Mixed Deciduous Forest		4	4	1
Old Clearings		1	1	5
Secondary Growth Forest		2	3	3
Plantation		2	2	2
Urban Area		1	1	1
Water body		1	1	1

2. Standardized rating score: The following table shows the standardized rating scores of all the factors for three zones.

Table 11 Standardized rating score for the general criteria/factors of park zoning model

Factors/criteria		Standardized rating score for each zone (C_i)		
		SNRZ	PZ	RZ
PROXIMITY TO ROAD				
Road	Trail			
0-500 m	0-300 m	0.01	0.01	1.00
500-1000 m	300-600m	0.25	0.25	1.00
1000-2000 m	600-900 m	0.50	0.50	0.50
2000-3000 m	900-1200 m	0.75	0.75	0.01
>3000 m	>1200 m	1.00	1.00	0.01
PROXIMITY TO STREAM				
Main stream	Seasonal stream			
0-500	0-300	1.00	1.00	1.00
500-900	300-600	0.75	0.75	1.00
900-1300	600-900	0.50	0.50	0.50
1300-1700	900-1200	0.25	0.25	0.25
>1700	>1200	0.01	0.01	0.01
ELEVATION				
0-600m		0.01	0.01	1.00
600-800m		0.25	0.33	0.75
800-1000m		0.50	0.66	0.50
1000-1200m		0.75	1.00	0.25
>1200m		1.00	0.33	0.01
SLOPE (%)				
0-10		0.01	0.01	0.01
10-25		0.25	0.33	0.50
25-35		0.50	0.66	0.50
35-55		0.75	1.00	1.00
>55		1.00	1.00	1.00
LAND COVER TYPE				
Agriculture Area		0.01	0.01	0.25
Dry Dipterocarp Forest		0.75	0.75	0.01
Hill Evergreen Forest		1.00	1.00	0.01
Mixed Deciduous Forest		0.75	0.75	0.01
Old Clearings		0.01	0.01	1.00
Secondary Growth Forest		0.25	0.50	0.50
Plantation		0.25	0.25	0.25
Urban Area		0.01	0.01	0.01
Water body		0.01	0.01	0.01

Weighting scores for the general factors/criteria

A number of suitability zones are decided and grouped accordingly to the specific zone requirement and was also determined by consensus. Each factor in the

zone requirement may contribute to significance differently, hence different weight should be given to each factor from 1 to 100%, the greater the weight, the larger the value, the important the decision factor.

In order to decide overlay weighting for each factor (or each map), the weights may be developed from an average of different decision makers' ranking, hence we can base on interviewing the people who has experience and knowledge in this field. At the same time it was also determined based on ranking the five factors from most important to least important, this is using pair-wise comparisons between each of the factor, determine which is the most important, the next most important and so forth, until the least important is reached (e.g. in this National Park zoning model, if we consider ranking of the factors for a strict nature reserve zone from most to least important it will be- vegetation, slope, elevation, proximity to road, proximity to water etc.).

For this study it was decided earlier to obtain weighting score for each factor of each zone directly by brainstorming from the stake holders' in general meeting. But due to communication problem it could not done. The weighting scores were derived from the multi stakeholders' opinion- how they given importance of each factor against each zone. In this case the total weighting score of the factors for each zone is equal to one hundred.

1. Raw weighting score: The following table shows the raw weighting scores of all the factors for three zones.

Table 12 Raw weighting score for the general criteria/factors of park zoning model

Factors/criteria	Raw weighting score for each zone (m_i)		
	SNRZ	PZ	RZ
Proximity to road	5	10	25
Proximity to stream	15	15	20
Elevation	20	25	10
Slope (%)	25	20	15
Land cover type	35	30	30

The raw weighting scores are later standardized by using the following formula (Perkins, 2005).

$$W_i = \frac{1}{m} \div \frac{1}{ki}$$

Where W_i = standardized weighting score, m = raw weighting score, k_i = is a constant which is equal to $(\frac{1}{m}+\frac{1}{n}+\frac{1}{o}+\frac{1}{p})$ where m, n, o and p are the value of the raw weighting scores for each of the factor of a particular zone. For example in case

of factor of proximity to road for SNRZ the raw rating score is 5 the standardized value for it will be:

$$W_1 = 1 / (\frac{1}{5}) \div 1 / (\frac{1}{5} + \frac{1}{15} + \frac{1}{20} + \frac{1}{25} + \frac{1}{35})$$

$$\text{or } W_1 = 1.92$$

Similarly other values are calculated and listed in the Table 13.

2. Standardized weighting score: The following table shows the standardized weighting scores of all the factors for three zones.

Table 13 Standardized weighting score for the general criteria/factors of park zoning model

Factors/criteria	Standardized weighting score for each zone (W_i)		
	SNRZ	PZ	RZ
Proximity to road	1.92	2.90	7.25
Proximity to stream	5.77	4.35	5.80
Elevation	7.70	7.25	4.35
Slope (%)	9.63	5.80	2.90
Land cover type	13.48	8.70	8.70

According to ranks and weights, the score for the factors are summed to get a total score (final score) for a site. The method of calculation for each park zoning model can be expressed in the following formulas:

$$SNRZ = 1.92\ C_1 + 5.77\ C_2 + 7.70\ C_3 + 9.632\ C_4 + 13.48\ C_5$$

$$PZ = 2.90\ C_1 + 4.35\ C_2 + 7.25\ C_3 + 5.80\ C_4 + 8.70\ C_5$$

$$RZ = 7.25\ C_1 + 5.80\ C_2 + 4.35\ C_3 + 2.90\ C_4 + 8.70\ C_5$$

Where C_1, C_2, C_3, C_4, and C_5 are the standardized ranking score of the value of each characteristic as presented in Table 11.

There were no ranking and weighting for the specific criteria which are related to other four zones namely- *Outdoor Recreation Zone, Intensive-use Zone, Special Use Zone and Other use Zone.* These zones are confined in specific areas and their parameters were used later to delineate these four zones after completion of the previous three zones.

Identification of Suitability Classes for Each Zone

To identify suitability classes the ranking and weighting scores for each zone was summed based on the formula of the park zoning model. Total score for a site was calculated from five general spatial factors (land cover, elevation, slope, accessibility to roads and accessibility to streams). Map query, map calculation and reclassification were done to get the total score. The total score have been grouped into 3 distinct classes (low suitability, moderate suitability and high suitability) for each zone based on standard deviation (STD). This created three suitability maps for three zones.

- Low suitability = < (Mean -1 STD)
- Moderate suitability = Mean ± 1 STD
- High suitability = > (Mean + 1 STD)

Final Management Zones' Map

The three suitability maps were superimposed in order to get the composite map for the three zones. Part of three suitability maps may overlap because the same area may serve more than one objective. In this case zone priority was used to revise the three zones' boundaries. To select the appropriate zone for consideration we have to prioritize from different objectives of national park establishment. For example, for a national park (IUCN category II) establishment the sequence of objectives as per importance is- 1). Preservation of species and genetic diversity, 2). Wilderness protection, 3). Maintenance of environmental service, 4). Tourism and recreation and so on. If we prioritized from the park management objectives it is ranked from Strict Nature Reserve Zone, Primitive Zone, and Recovery Zone. However the composite map still has some small areas such as: a small primitive zone site or recovery site located in the centre of strict nature reserve zone that can not be implemented in practical field. These areas were generalized by using 5×5 neighborhood matrix of ERDAS Imagine 8.4 software.

Existing recreation sites and facilities, other organizations operating inside park area, existing settlements were derived from field observation, aerial photos and topographic maps. GPS was used to find the locations of these sites. These locations (UTM) were used to subjectively find the places in the aerial photo. Then the areas of these sites were delineated from the aerial photo by using Arc Map program. Area was determined for larger sites like park headquarters, Doi Suthep Temple, Phuphing Palace, TV relay stations, Chiangmai Night Safari, Chiangmai University Mae Hia Campus, and 15 settlements inside the park; areas for smaller sites like water falls, research stations were not determined. Instead a buffer of 100 m was taken to locate them in map. Buffer distance 100 m also taken for main roads inside the parks. Main roads were included in the intensive use zone together with the park headquarters and existing tourists' facilities.

These information were excluded initially from the park zoning model, however they were masked directly later on the composite map of first three zones to

determine an Outdoor Recreation Zone, an Intensive Use Zone, a Special Use Zone and an Other Use Zone. It is assumed that no more recreation, intensive use, special use of the park area within next five years of the proposed management zoning scheme. At the last step this preliminary zoning map was simplified based on expert and park planner suggestions as well as field check.

RESULTS AND DISCUSSION

In this study a series of maps were produced by using park zoning model together with multi-stakeholders' opinion and software package Arc View 3.2, ERDAS Imagine 8.4. and Arc Map 8.3. The zoning model developed by Linear Combination method is found as an important and useful technique for management zoning in a national park. In this chapter the results of the GIS modeling for evaluating, separating, and identifying the location of desirable site for a Strict Nature Reserve Zone, a Primitive Zone, a Recovery Zone, an Outdoor Recreation Zone, an Intensive Use Zone, a Special Use Zone and an Other Use Zone is highlighted.

Results of Park Zoning Model

Suitability Classes Maps

1. Strict Nature Reserve Zone

In order to select the suitable locations for a Strict Nature Reserve Zone, total score for five factors were determined from map query, map calculation and reclassify; the result of calculation is to multiply and summed all ratios together to obtain a number indicating which area is the preferred site for a Strict Nature Reserve Zone. A preferred number merely indicates the decision that is consistent with the preference (the score and weight) expressed in the model. According to the park zoning model, the Strict Nature Reserve Zone were classified into 3 classes including high suitability (32.45-45.14), moderate suitability (19.75-32.44) and low suitability (0-19.74). The suitability classes were determined based on standard deviation. The score distribution and area of each suitability class for Strict Nature Reserve Zone are shown in Table 14 and the location of each suitability class was shown in Figure 17.

Table 14 The score and area distribution under different suitability classes of Strict Nature Reserve Zone

No	Score	Suitability class	Area in km2	Percentage (%)
1	0-19.74	Low suitability	45.63	16.21
2	19.75-32.44	Moderate suitability	192.10	68.22
3	32.45-45.14	High suitability	43.84	15.57
Total	-	-	281.57	100.00

The high suitability area of a Strict Nature Reserve Zone situated mainly in Hill Evergreen Forests along the ridges which are consist of habitat of wild rare and valuable species of flora and fauna, this cover about 15.57 % of the total area of the park. The moderate suitability class is located in the remaining forest, excluding high suitability area and low suitability area this includes transition area between other major forests and cultivated area, and it covers 68.22 % of the park area. The low

suitability area contains mainly agricultural area, old clearings and secondary growth forest, covering approximately 16.21 % of the total park area.

2. Primitive Zone

In order to identification of the suitability site for a Primitive Zone based on the total score; the final score for PZ was classified into 3 distinct classes for mapping: low suitability (0-15.81), moderate suitability (15.82-25.43) and high suitability (25.44-35.05). The distribution of area of each suitability class for this zone is presented in Table 15.

Table 15 The score and area distribution under different suitability classes of Primitive Zone

No	Score	Suitability class	Area in km^2	Percentage (%)
1	0-15.81	Low suitability	45.40	16.12
2	15.82-25.43	Moderate suitability	192.20	68.26
3	25.44-35.05	High suitability	43.97	15.62
Total	-	-	281.57	100.00

The high suitability area for a PZ is located mainly in the Hill Evergreen Forests and Mixed Deciduous Forests below the ridges. This is about 25.62 % of the park area. The moderately suitable area is 68.26 % of the park and is located through out the remaining forest excluding the agricultural area, secondary growth and old clearings. The low suitability area covers 16.12 % which is mainly in secondary growth and agricultural area (Table 15 and Figure 18).

3. Recovery Zone

The suitability classes for a Recovery Zone are determined by considering score distribution based on park zoning model: High suitability (27.69-40.96), medium suitability (17.13-27.68) and low suitability (0-17.12), the location of suitability areas is shown in Figure 19.

Table 16 The score and area distribution under different suitability classes of Recovery Zone

No	Score	Suitability class	Area in km2	Percentage (%)
1	0-17.12	Low suitability	46.41	16.48
2	17.13-27.68	Medium suitability	191.58	68.04
3	27.69-40.96	High suitability	43.58	15.48
Total	-	-	281.57	100.00

The high suitability area of the Recovery Zone is mainly located in old clearings, agricultural area and some of secondary growth areas, this covers about 15.48 % of the park area, the moderate suitability class of a recovery zone contains approximately 68.04 % area situated through out the park, while 16.48 % is in low suitability area which is mainly danced forests (Table 16).

The suitability class was not done for the other four zones which were not included in the zoning model initially. They were masked later directly after determining the first three zones.

Composite Map for Three Zones

The three suitability maps mentioned above were superimposed to derive a composite map of the first three zones. This map contains overlapping areas. The overlapping areas were redistributed based on zone priority among three zones. To select the appropriate zone for consideration management objectives were prioritized. The composite map still has some smaller areas or noises; which are impractical for implementation as a part of the original zone. These areas were generalized by using 5×5 neighborhood matrix of ERDAS Imagine 8.4 software. This composite map consisting of first three zones is shown in Figure 20 and the distribution of areas for each zone presented in Table 17.

Table 17 Area distribution of the three zones in composite map

No	Zones	Area (km^2)	Percentage (%)
1	Strict Nature Reserve Zone	43.84	15.57
2	Primitive Zone	167.82	59.60
3	Recovery Zone	69.91	24.83
Total	-	281.57	100.00

An assessment of the distribution of area under each zone between composite map and individual map shows that areas increased in case of Primitive Zone and Recovery Zone; this difference caused because of the redistribution of over lapped areas and map generalization. This composite map has an area of 43.84 km^2 or 15.47 % under Strict Nature Reserve Zone, 167.82 km^2 or 59.60 % under Primitive Zone and 69.91 km^2 or 24.83 % under Recovery Zone (Table 17).

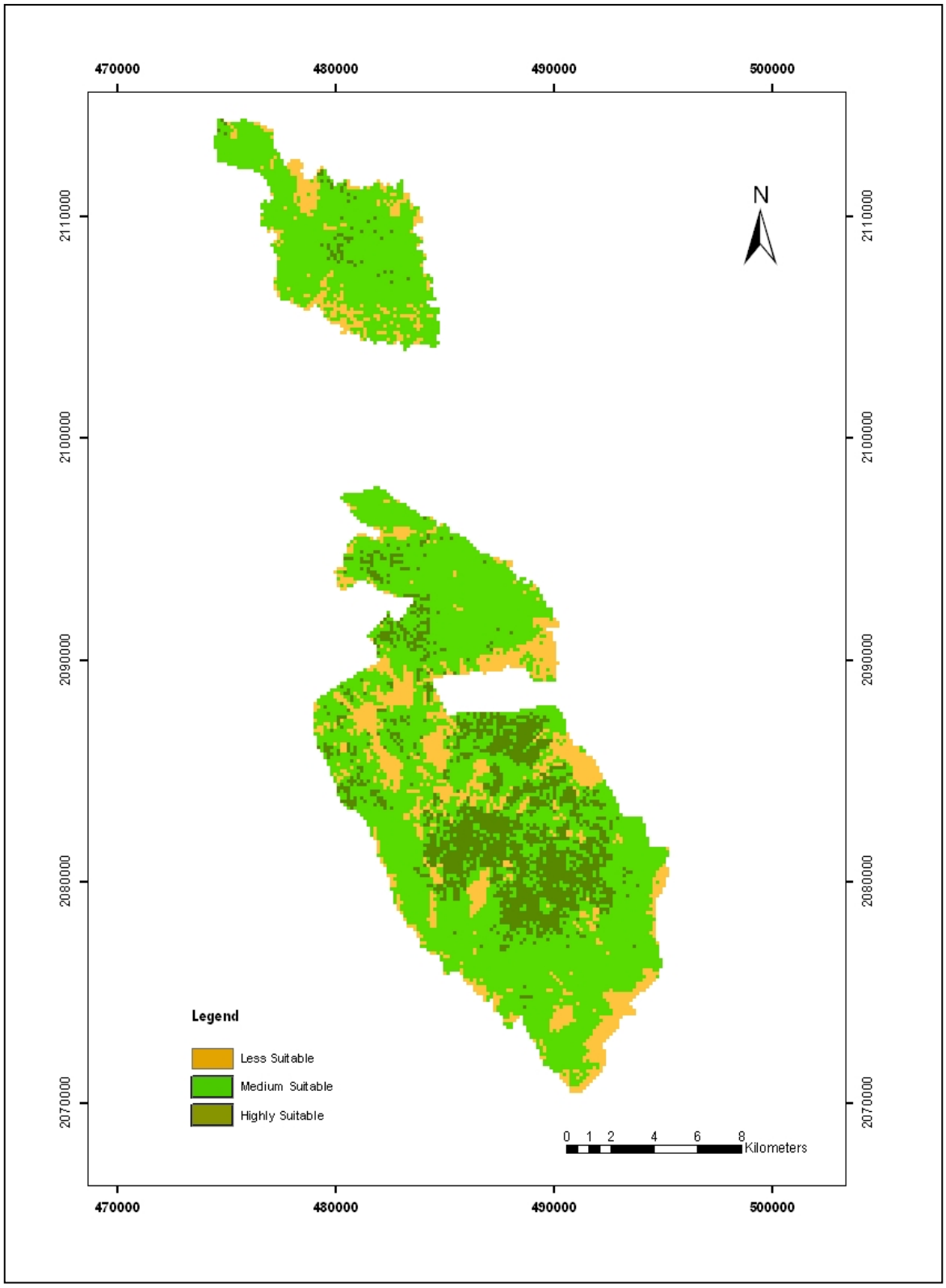


Figure 17 Suitability map of the Strict Nature Reserve Zone

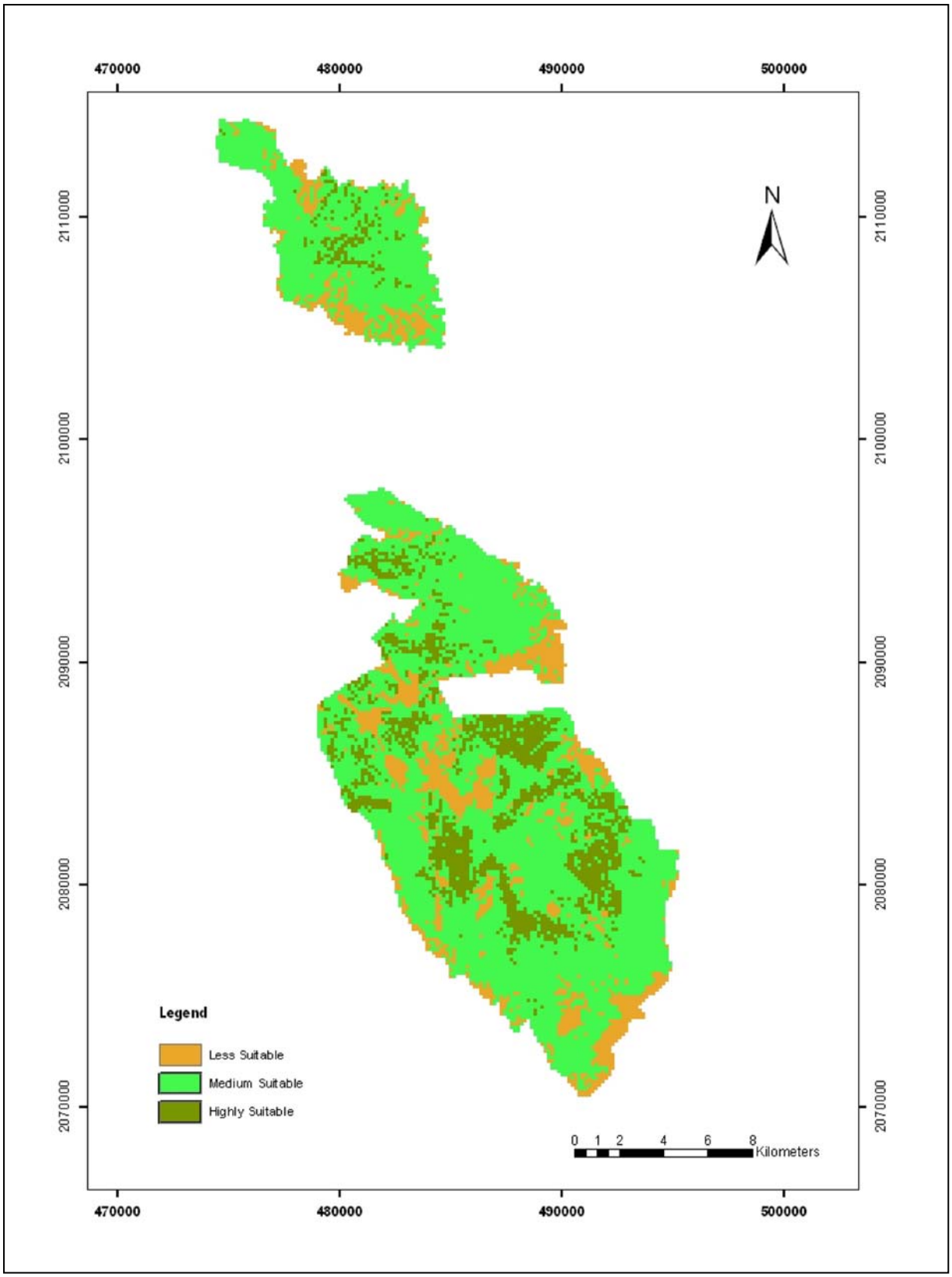


Figure 18 Suitability map of the Primitive Zone

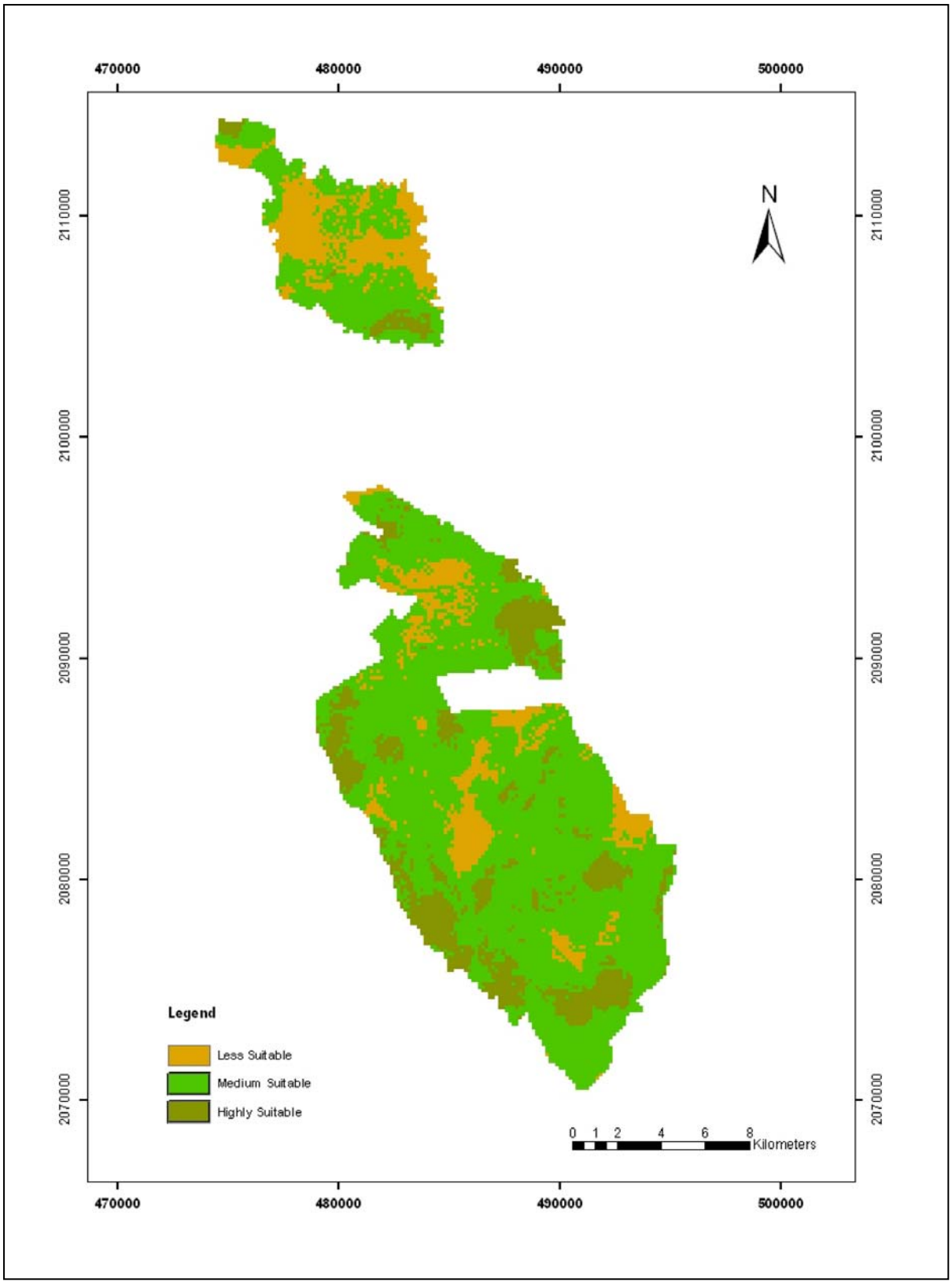


Figure 19 Suitability map of the Recovery Zone

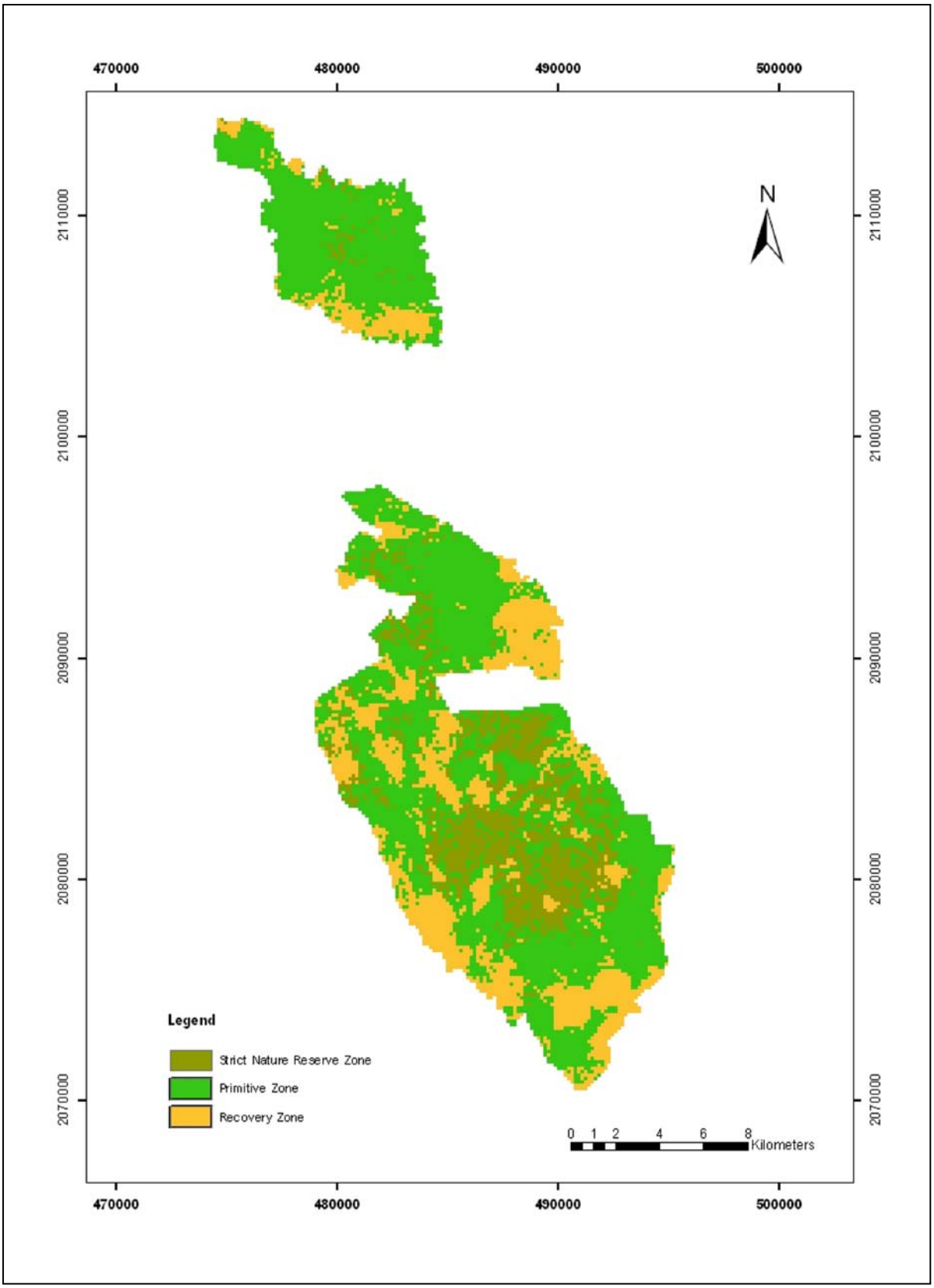


Figure20 The composite map for three zones

The Final Management Zones' Map

The areas of existing tourists' attraction sites, intensive use sites, special use sites and settlements were masked directly on the composite map of first three zones to determine the boundaries of an Outdoor Recreation Zone, an Intensive Use Zone, a Special Use Zone and an Other Use Zone. Now this preliminary map has all seven zones included. This preliminary national park zones map was simplified according to suggestions of the park officers and experts, in addition to field check. The area of each management zone is presented in Table 18 while the final park management zoning map is shown in Figure 22.

Table 18 Area distribution of the final management zones in Doi Suthep-Pui National Park

No	Zones	Area (km^2)	Percentage (%)
1	Strict Nature Reserve Zone	39.71	14.10
2	Primitive Zone	153.40	54.48
3	Recovery Zone	51.36	18.24
4	Outdoor Recreation Zone	1.94	0.70
5	Intensive Use Zone	27.71	9.84
6	Special Use Zone	1.56	0.55
7	Other Use Zone	5.89	2.09
Total	-	281.57	100.00

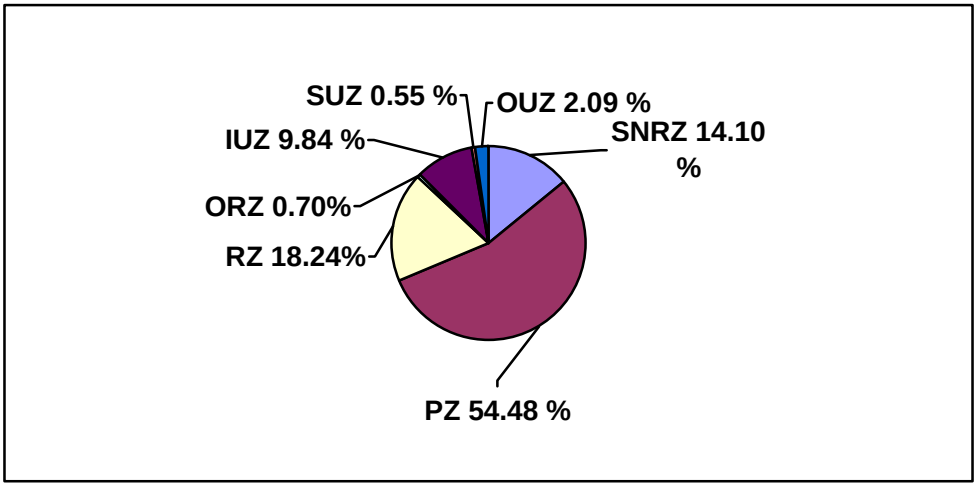


Figure 21 Pie chart showing area distribution (in %) of the final management zones of Doi Suthep-Pui National Park

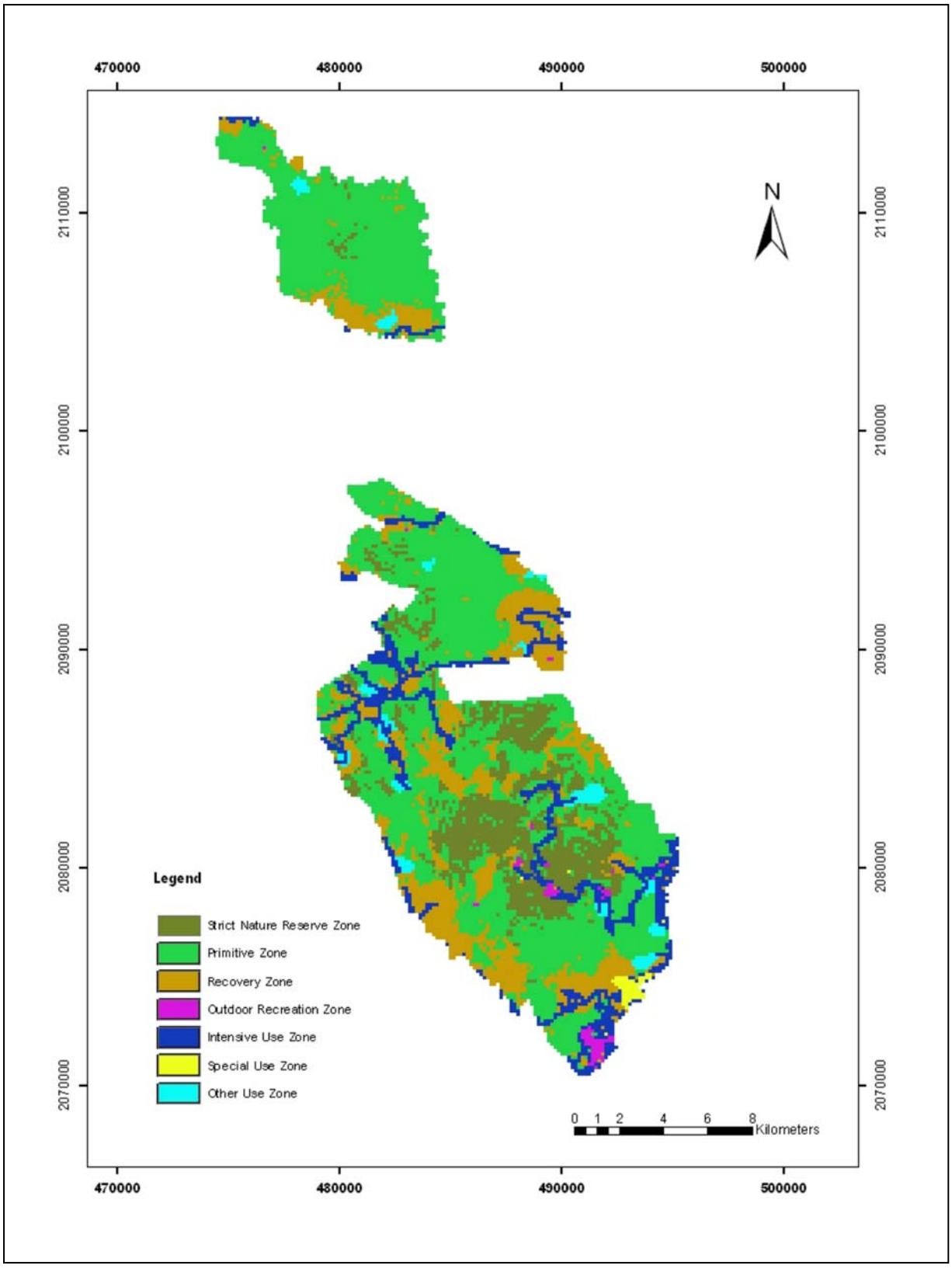


Figure 22 The final management zones' map of Doi Suthep-Pui National Park

The Strict Nature Reserve Zone mainly covers mountainous area which deserves special preservation because they contain rare, valuable and fragile natural features. This zone occupied 39.71 km^2 or 14.10 % of the park area. Principally, it is located in the center of the park, and upper watershed basin which is susceptible to damage, this zone should be prohibited for visitors, only trails for official use are provided, scientific study is allowed when appropriate.

The Primitive Zone covers an area of 153.40 km^2 or 54.48 %, which is the largest zone in the scheme. This zone covers all major forest types and situated all over the parks except the areas of other zones. The major objectives of this zone are to preserve natural environments and wilderness areas and serve as water recharge area. This zone may contain nature trails which could be use for environmental study and nature education but should not be use as massive tourism.

Most of the Recovery Zone is basically scattered along the peripheries of the national park where native forest or original ecosystems have been modified to old clearings, degraded forest or secondary growth. The total area of this zone is 51.36 km^2 or 18.24 % of the park area. The management objective of RZ is to rehabilitate degraded areas to forest cover through various means such as plantation establishment or natural succession as appropriate.

From Table 18, it is observed that an area of 1.94 km^2 is under Outdoor Recreation Zone. Totally, this zone occupied 0.70 % which is second smallest zone of this zoning scheme. The outdoor recreation zone contains viewpoints, pretty waterfalls, spectacular mountain scenery, temple, palace, night safari for the refreshment of the visitors. Nature trails for hiking and camping grounds are available in this zone.

The Intensive Use Zone is situated scatteredly in the park. These areas are mainly major roads, headquarters and tourists' facilities areas inside the park. This zone situated on low slope gradient and easy to access as well as not virgin areas. These will cause minimum physical impact to remaining forests. The Intensive Use Zone covers 27.71 km^2 or 9.84 % of the total area of the park.

The Special Use Zone includes areas containing existing installations of national significance but which are not align with the objective of the national park such as research stations, TV relay stations, and educational institution. Such installations retained subject to mutual agreements among the concerned parties. This zone occupies 1.56 km^2 or 0.55 % of the total park area; the smallest area of this zoning scheme for Doui Suthep-Pui National Park.

The Other Use Zone includes the existing settlement areas in side the park. This zone is considered because it is now widely recognized that settlers who are there before the park establishment should be considered as a part of the park. There should be adequate measures in the management plan for uplifting the lives of this indigenous people so that they can reduce their dependency on parks natural resource base. This zone occupies an area of 5.89 km^2 or 2.09 % of the park. Strict law

enforcement and regular monitoring here is very essential to ensure that villagers do not expand the present agriculture or settlement area.

Management intense in different zones

Strict Nature Reserve Zone serves as a reserve of genetic resources of plants and animals (a gene pool) and as an entirely natural area. As such this zone functions an important reference to full natural circumstances and fully natural growth. Management of land in this zone is aiming at protecting its natural state and avoid disturbance because recovery to the original state is very difficult. No activities other than scientific research are allowed to be practiced within this zone.

Primitive Zone should contain extensive areas that are good representations of a natural region and are conserved in a wilderness state. The perpetuation of ecosystems with minimal human interference is the key consideration. This zone offer opportunities for visitors to experience, first hand, the park's ecosystems and require few, if any, rudimentary services and facilities. In much of this zone visitors have the opportunity to experience remoteness and solitude. Motorized access is not permitted. Areas in this zone cannot support high levels of visitor use. Facilities are restricted to trails, backcountry campgrounds, and trail shelters.

Recovery Zone is basically scattered along the areas where native forest or original ecosystems have been modified to degraded forest or secondary growth. The management objective of this zone is to rehabilitate degraded areas to forest cover through various means such as plantation establishment or natural succession as appropriate.

In Outdoor Recreation Zone visitors experience the park's natural and cultural heritage through outdoor recreational activities that require minimal services and facilities of a rustic nature. While motorized access may be allowed, it will be controlled. Rigorous protection is required because of the areas' ecological and aesthetic importance.

Intensive Use Zone accommodates a broad range of opportunities for understanding, appreciation and enjoyment of the park's heritage. Direct access by motorized vehicles is permitted. Any major construction in the area should be avoided because that may change sedimentation and erosional patterns of that area. Care must be taken that future development and use do not have a negative impact on the area's special resources.

Other Use Zone or the settlement areas should be well demarcated. The boundary and some general guidelines for the community should be prepared. The management plan will guide land use in the community.

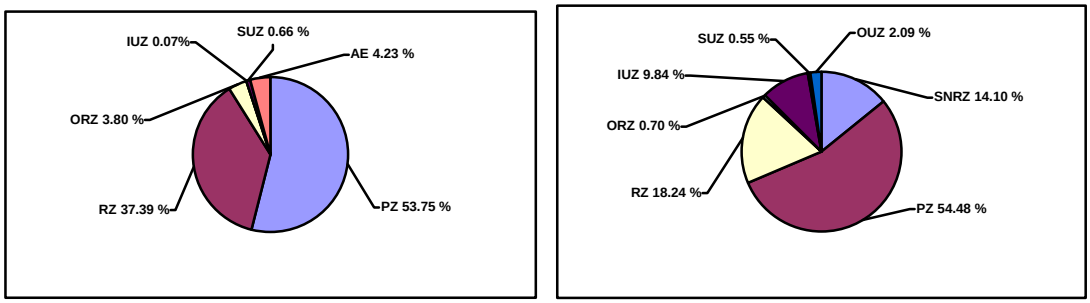
Comparison Between Previous Zoning Map and Newly Created Zoning Map of Doi Suthep-Pui National Park

The previous zoning map of Doi Suthep-Pui National Park which was created in 1998 has five management zones whereas the newly created zoning map has seven zones. The five management zones of the previous zoning map are - 1) Primitive Zone, 2) Recovery Zone, 3) Special zone, 4) Intensive Use Zone and 5) Outdoor Recreation Zone. Area distribution under these zones is shown in Table 19.

Table 19 Area distribution under different zones in the previous zoning plan of Doi Suthep-Pui National Park

No	Zones	Area (km^2)	Percentage (%)
1	Primitive Zone	151.36	53.75
2	Recovery Zone	105.58	37.39
3	Outdoor Recreation Zone	10.67	3.80
4	Intensive Use Zone	0.16	0.07
5	Special Use Zone	1.88	0.66
6	Area Excluded	11.92	4.23
Total	-	281.57	100.00

The pie charts in Figure 23 show the comparative area distribution (in %) under different zones of the previous zoning map and newly created zoning map.



A. Previous management zones B. Newly created management zones

Figure 23 Comparative area distribution (in %) under different zones of A) the previous zoning map and B) newly created zoning map

From Table 19 and Figure 23 we can realize that the previous zoning map did not include any Strict Nature Reserve Zone and Other Use Zone. But Doi Suthep-Pui national park has many rare and valuable species of plant and animal life which needs to be preserved. A major portion of this park is part of a MAB area. For preserving its valuable and rare species and to protect fragile areas Doi Suthep-Pui National Park should have a Strict Nature Reserve Zone and this zone included in the new scheme

which have an area of 39.71 km^2 or 14.10 % of the total park. Doi Suthep-Pui National Park has many settlements inside the park. The villagers or settlers use park area for cultivation. There have no specific areas for confining their activity. So to confine them in a particular zone the newly created zoning scheme has identify an Other Use Zone which occupy 5.89 km^2 or 2.09 % of the park area.

In the previous zoning map Primitive Zone occupied 151.36 km^2 or 53.75 %; whereas the newly created Primitive Zone occupies 153.40 km^2 or 54.48 % of the park area which indicate a slight increase of the PZ area in the new zoning map. The previous Recovery Zone occupied 105.58 km^2 or 37.39 %; whereas the newly created Recovery Zone occupies 51.36 km^2 or 18.24 % of the park area. The new zoning map has fewer areas for recovery than the previous zoning map. This difference is due to the reason that the previous zoning map included mainly the existing agricultural areas used by the settlers as RZ but the newly created map was generated from linear combination method of multiple criteria and by doing this very few agricultural areas were included in the new zoning map. It is realized that the areas used by the settlers are not easy to get for recovery activities.

The previous Outdoor Recreation Zone occupied 10.67 km^2 or 3.80 %; whereas the newly created Outdoor Recreation Zone occupies 1.94 km^2 or 0.70 % of the park area. This difference caused due to taking more buffer areas surrounding the existing recreation sites in the previous zoning map. The previous Intensive Use Zone occupied 0.16 km^2 or 0.07 %; whereas the newly created Intensive Use Zone occupies 27.71 km^2 or 9.84 % of the park area. Area increased in the IUZ of the newly created zoning map because it includes all the major roads inside the park with 100 m buffer around them. The previous SUZ occupied 1.88 km^2 or 0.66 %; whereas the newly created SUZ occupies 1.56 km^2 or 0.55 % of the park area. There has no marked difference about area inclusion in the SUZ of the two zoning map.

Table 20 Matrix to show the overlapping areas (in %) of previous zoning map and new zoning map of Doi Suthep-Pui National Park

Previous zones	New zones (%)						
	SNRZ	PZ	RZ	ORZ	IUZ	SUZ	OUZ
PZ	61.58	54.14	45.44	12.34	30.77	2.30	53.98
RZ	25.48	38.89	39.81	60.84	31.10	32.12	32.97
ORZ	6.04	1.91	4.74	11.56	9.18	2.13	0.58
IUZ	0.09	0.01	0.16	0.88	0.01	0.00	0.00
SUZ	0.90	0.37	0.74	4.34	1.28	0.00	1.14
AE	1.08	1.28	3.50	8.97	12.73	58.78	10.63
Total	95.17	96.6	94.39	98.93	85.07	95.33	99.3
Map distortion	4.83	3.40	5.61	1.07	14.93	4.67	0.70

The matrix in Table 20 shows overlapping areas of the previous management zoning map and the newly created zoning map. These are expressed in % of the total area of each zone of the newly created zoning map. From this matrix it could be seen that the exact location of the new zones and previous zones are not same. There has

marked difference on the locations of the zones. This is due to the difference of the zoning method and also zoning criteria used to identify the zones. The sum of the overlapping areas of a particular zone should be 100 %. But we find some differences due to distortion between the previous zoning map and the newly created zoning map.

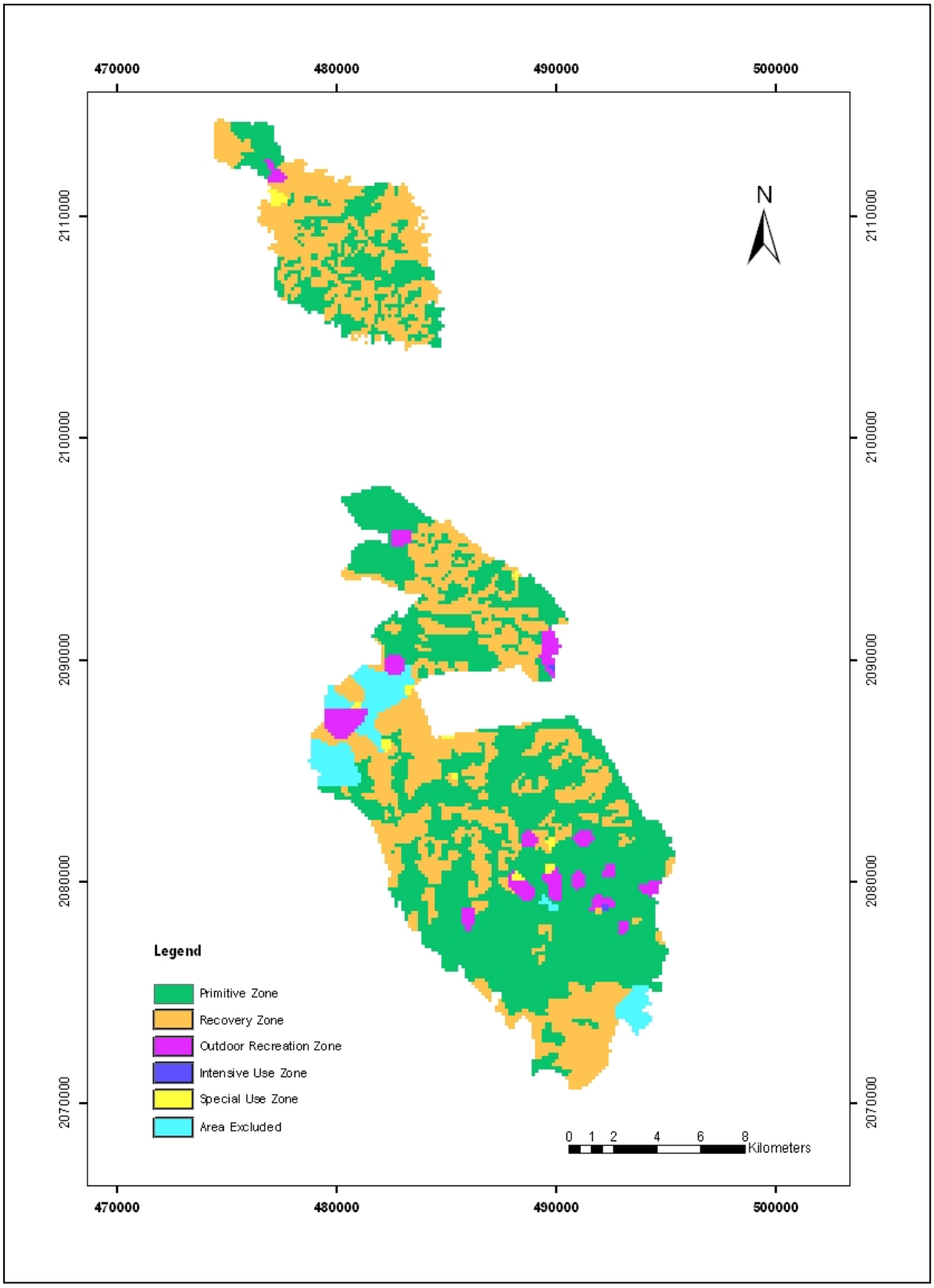


Figure 24 The previous zoning map of Doi Suthep-Pui National Park

CONCLUSION

The park zoning model offers considerable promise for creating management zones in the park; it has been applied successfully for choosing the best site for a national park zone system and could be used as well to guide the identification of the most approximate boundaries for each zone. Some of its real advantages are that the factors that will be used in the site selection decision must be explicitly stated along with the important place on each weight. The results of the park zoning model will ultimately help planner to determine the best sites for location of different zones in the park. At the same time, it will help the park managers to determine an adequate degree of protection for each zone and specify approximate levels of use to ensure the maintenance of the park's ecological integrity.

In this study Geo-informatics in addition to the field survey information and ground truthing together with stakeholders' suggestions are found very useful tools for developing park management zoning scheme. But at the same time it was realized that involvement of all stakeholders for all steps of the zoning scheme is not practical and realistic. Specially for deciding about technical matters such as fixing criteria for zoning and ranking and weighting score. Only experts could be engaged initially for these technical matters. After completion of the zoning scheme it could be presented in stakeholders meeting for suggestion to further improvement.

The zoning model defined seven management zones for Doi Suthep-Pui National Park using nine spatial criteria (five general criteria e.g., land cover, proximity to roads, proximity to streams, slope and elevation; and four specific criteria; e.g., existing tourists attraction sites, park headquarters and main roads, other organizations, settlements). Grid-based GIS modeling was employed to analyze the zoning scheme through the participation of multi-stakeholders. Seven management zones- Strict Nature Reserve Zone, Primitive Zone, Recovery Zone, Outdoor Recreation Zone, Intensive Use Zone, Special Use Zone, and Other Use Zone have been developed for effective management purposes and the area coverage under different zones are 14.10 %, 54.48 %, 18.24 %, 0.70 %, 9.84 %, 0.55 % and 2.09 % of the total park respectively.

Comparison between previous and newly developed management zoning scheme indicated that in the previous zoning scheme there was no provision for Strict Nature Reserve Zone. But Doi suthep-Pui National Park has great species diversity and the home for many rare plant (e.g. *Dendrobium parvum* Seid) and animal species (e.g. Crocodile Salamander), which deserve preservation. Moreover part of the park's area is under a MAB reserve. So the Strict Nature Reserve Zone is included in the new zoning scheme.

Lastly we can conclude that management zoning is the most practical means for providing an appropriate level of protection of the natural values of national parks and for managing activities which can have adverse impacts on those natural values. Large compact tracts of protected wilderness are becoming a scarce and valuable

resource. Most of the habitats are becoming fragmented. Through management zoning we can ensure protection of wilderness areas and can take initiative to link fragmented habitat for better management of these habitats. There should be continuous effort to emphasize the importance of maintaining the integrity and critical ecological role of the wilderness areas through management zoning.

RECOMMENDATIONS

Considering the findings of this research some recommendations for the park management zoning and further research are presented hereunder, these might be helpful for future park planning and management.

The previous management zoning plan of Doi Suthep-Pui National Park was formulated in 1998; there is a need for updating and revision of the previous zoning plan to suit the present need and conditions of the park. The previous zoning plan has given a little consideration for protection of the valuable and rare flora and fauna of Doi Suthep-Pui National Park and also to the people in the surrounding communities. The recommendations, formulated are as follows:

1. Though it is not included in this zoning scheme due to lack of GIS data but it is found that the habitats of rare and valuable species of plant and animal should be included as an important factor for identifying a strict nature reserve zone of the zoning scheme.

2. Multi stakeholders' opinion was considered for this zoning scheme. But it is found that all stakeholders are not capable of suggesting all steps of a zoning process due to gap of knowledge. Some technical matters like fixing zoning criteria, obtaining ranking and weighting scores for zoning model, should be decided by academia and technicians who use to work in this field. After developing the zoning scheme this could be placed in stakeholders' meeting for further improvement.

3. Preference should be given for obtaining ranking and weighting score from academia and technicians using brain storming techniques if possible; instead of personal interview survey because experts could have opportunities to discuss for better results.

4. Demarcation of management zones should be emphasized in SNRZ and ORZ or OUZ; similarly for PZ and ORZ or OUZ; because intensive human activities in these zones usually affect the ecological integrity of the reserves.

5. SNRZ and also PZ in many cases serve as pristine habitats. There should be adequate measures to link the fragmented patches of SNRZ and PZ for the better management of these habitats.

6. There should be strict law enforcement and regular monitoring in Other Use Zone to ensure that villagers do not expand the present agriculture or settlement area to surrounding pristine habitat.

7. Management zones should be monitored or justified at least every five years for big changing in land use / land cover.

It has been concluded that the management zoning is a tool to strengthen management of the national park at the macro level. For ground implementation, it is

strongly recommended that park officials use these management zones in conjunction with other tools or additional information. For instance, management of human settlements in Doi Pui, where Hmong hill tribes are dominant, and Mae Lord Tai, where Karen is the main residence, should be different even though both communities are located in zone seven i.e. other use zone. Because the way of living and resource use of the two tribes are not the same.

It is important to keep in mind that management zoning is neither a blue-print nor a static process. It should be updated or modified whenever more accurate and reliable data are discovered or it is found that the existing management zone is not practical for implementation. The appropriate duration for revision is between 5 and 10 years. In addition, although the boundary between each zone is clearly classified on the map, it is often very difficult to notice the real boundary on the ground because ecological capability changes continuously. Therefore, park official should bring a topographic map, hand compass, and GPS for ground verification to assist management implementation.

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APPENDIX

Appendix – A

Interview Schedule

Respondent no……..

INTERVIEW SCHEDULE

SURVEY ON THE STAKEHOLDERS PERCEPTIONS ABOUT PARK MANAGEMENT ZONING CRITERIA OF DOI SUTHEP PUI NATIONAL PARK.

For the purpose of conducting Master degree thesis
"Management Zoning of Doi Suthep-Pui National Park by Using Geo-informatics"

Conducted by:
Md. Zillur Rahman
Student, M.S. in Tropical Forestry
Faculty of Forestry
Kasetsart University
Thailand.

Information

By responding carefully to the questionnaire, you will be providing useful information for having an up-to-date and better management zoning of the park and hence will help to have better management tools. Your assistance is appreciated.

Please answer all questions.

Interviewer……
Date……

1. Name of respondent (optional): ……

2. Occupation and Designation: ……..

……
…….

3. Address in brief: ……

……

……

4. Job responsibilities: ……....
……
……
……
……
……..

5. Age: ……

6. Sex:

Male	Female

7. Religion: [ ] Buddhism [ ] other, specify ……

8. Marital status:

Married	Unmarried	Divorced/widower

9. Educational qualification: [ ] Grade school [ ] High school

[ ] Vocational/ Technical school

[ ] Two-year college degree [ ] Bachelor's degree

[ ] Master's degree or higher

10. Can you please tell how you think you are related to Doi Suthep-Pui National Park?
……
……
……
……
……

11. How long you are in your present position?.....
……
……..

12. For how many years you are conscious about the management activities of Doi Suthep-Pui National Park?
……

13. Do you think Doi Suthep-Pui National Park has any contribution to biodiversity conservation or environmental protection? …….
……..

14. Do you have any perception of Park Management Zoning? Why do you think zoning is
required?.....
……
……
……
……..

15. Please read the following descriptions and try to conceptualize different park management zones.

Potential management zones and their definitions

Zone	Definition
Zone 1 **Strict Nature Reserve Zone**	Ecologically fragile natural areas with high biodiversity which should be closed to all human activity except scientific studies and/ or ceremonial or religious use by local communities.
Zone 2 **Primitive Zone**	Valuable wildland areas that comprises with the maximum of park areas where appropriate nature-based recreational active-ties may be encouraged. The zone shall be maintained in its natural state as biotic resources are abundant.
Zone 3 **Restoration Zone**	Degraded areas that should be examined for their potential for ecological restoration. Environmental conditions are such that nature can be restored and where recovery of nature is necessary.
Zone 4 **Outdoor Recreation Zone**	Areas with interesting features (such as waterfalls or scenic overlooks) where visitor use is frequent and which is suitable for sustainable ecotourism, recreation and conservation education.

Zone	Definition
Zone 5 Intensive Use Zone	Areas with little ecological value where most of the park infrastructure and tourist facilities are located.
Zone 6 Special Use Zone	Areas containing existing installations of national significance, such as research stations, telecommunication facilities, palace, major roads, temples and electric power lines.
Zone 7 Other Use Zone	Areas where settlement and traditional and sustainable land-use, including agriculture, agro forestry, extraction activities and other income-generating or livelihood activities, may be allowed

Now rank and give score for each of the zones against the factors stated in the following table:

Score 5, 4, 3, 2, 1.

5= Strongly desirable; 4= Desirable; 3= Neither desirable nor undesirable

2= Undesirable; 1= Strongly undesirable

Factors	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
1.Land Cover a. Dry Dipterocarp Forest							
b. Hill Evergreen Forest							
c. Mixed deciduous Forest							
d. Agricultural Area							
e. Old Clearings							
f. Secondary Growth Forest							
g. Plantation							
h. Built Up Area							
i. Water Body							

Factors	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
2.Proximity to roads a. Close to road (0-1000 m)							
b. Away from road (1000-3000 m)							
c. Far from road (>3000 m)							
3. Proximity to trails a. Close to trail (0-600 m)							
b. Away from trail (600-1200 m)							
c. Far from trail (>1200 m)							
4. Proximity to permanent stream a. Close to per. stream (0-900 m)							
b. Away from permanent stream (900-1700 m)							
c. Far from permanent stream (>1700 m)							
5. Proximity to seasonal stream a. Close to seasl stream (0-600 m)							
b. Away from seasonal stream (600-1200 m)							
c. Far from seasonal stream (>1200 m)							
6. Park office/staff quarters							
7. Tourist Information Centre							
8. Tribal village/ settlements							
9. Shifting cultivation/ cultivation area							
10. Slope a. Steep slope (>55%) area/ fragile area							
b. Moderate Slope (25-35 %)							
c. Gentle slope (<25%) area							
11. Reforestation/ Restoration							
12. a. High elevation area (>1200 m)							
b. Medium Elevation (600-1200 m)							

Factors	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
c. Low elevation area (< 600m)							
13. Souvenir shop, food shop and parking area							
14. Tourist attraction sites							
15. Dormitories and other tourists facilities							
16. Temple							
17. Research stations 18. Do you think other factors should be included? Please specify: I. II. III. IV.							

16. What's your suggestion for better management of Doi Suthep-Pui National Park?
……
……
……
……
……..

Thank you for your kind cooperation

Appendix - B

Standard Deviation and Mean of Values

All Respondent Types

Factors		SNRZ	PZ	RZ	ORZ	IUZ	SUZ	OUZ
1.Land Cover	Stdev	1.212489	1.331804	1.249286	1.314134	1.148545	1.357519	1.254473
a. Dry Dipterocarp Forest	Mean	3.142857	3.160714	3.303571	2.017857	2.089286	2.107143	2.660714
b. Hill Evergreen Forest	Stdev	1.285281	1.256671	1.340672	1.34152	1.11876	1.308811	1.190874
	Mean	3.642857	2.857143	3.142857	1.982143	1.803571	2.178571	2
c. Mixed deciduous Forest	Stdev	1.296849	1.285281	1.256671	1.247205	1.338612	1.286165	1.216766
	Mean	2.75	3.642857	2.857143	3.160714	2.089286	3.267857	2.714286
d. Agricultural Area	Stdev	1.294845	1.23254	1.205507	1.228318	1.430194	1.407655	1.11876
	Mean	3.321429	2.839286	2.464286	2.732143	2.25	2.267857	1.803571
e. Old Clearings	Stdev	1.108263	1.028017	1.378758	1.388146	1.530533	0.873677	1.153059
	Mean	2.160714	2.125	2.660714	3.482143	2.196429	1.517857	1.625
f. Secondary Growth Forest	Stdev	0.958726	1.063564	1.006473	1.336306	1.348279	1.222622	1.34152
	Mean	1.660714	1.821429	2.071429	3.321429	3.517857	3.178571	3.017857
g. Plantation	Stdev	1.252011	1.103566	1.022951	1.164268	1.369306	1.347918	1.221028
	Mean	2.321429	2.017857	1.839286	1.910714	2.625	3.535714	4
h. Built Up Area	Stdev	1.20389	1.29935	1.270929	1.283132	0.82945	1.070107	1.028806
	Mean	3.571429	3.357143	2.946429	3.089286	1.553571	1.982143	1.678571
i. Water Body	Stdev	1.235697	1.451265	1.346472	1.1974	1.340551	1.357519	1.157696
	Mean	2.767857	3.553571	2.928571	2.857143	1.946429	3.107143	2.071429
2.Proximity to roads	Stdev	1.091734	0.892792	1.069045	1.062801	1.111919	1.049273	1.10958
a. Close to road (0-1000 m)	Mean	1.589286	1.553571	1.857143	2.875	4	3.910714	3.071429
b. Away from road (1000-3000 m)	Stdev	1.17537	1.045553	1.185957	1.274628	1.278062	1.213426	1.256541
	Mean	1.767857	1.875	1.892857	2.607143	3.696429	3.017857	3.196429
c. Far from road (>3000 m)	Stdev	1.326919	1.234646	1.141883	1.221028	1.166497	1.190738	1.145148
	Mean	1.946429	3.303571	2.928571	3.5	2.946429	2.517857	2.875
3. Proximity to trails	Stdev	1.423367	1.190329	1.507449	1.11294	1.008406	1.229375	1.41318
a. Close to trail (0-600 m)	Mean	2.285714	1.964286	3.267857	2.125	2.035714	2.625	3.446429
b. Away from trail (600-1200 m)	Stdev	1.461186	0.87312	1.490664	1.231091	1.074951	1.049273	1.33095
	Mean	2.214286	1.535714	2.321429	2.107143	1.839286	2.089286	3.214286
c. Far from trail (>1200 m)	Stdev	1.301223	1.216232	1.34152	1.166497	1.069045	1.256671	1.135038
	Mean	3.625	3.107143	2.982143	2.196429	1.857143	2.142857	1.857143
4. Proximity to permanent stream	Stdev	1.32005	1.285281	1.210211	1.244077	1.26645	1.292837	1.297225
a. Close to per. stream (0-900 m)	Mean	2.696429	3.642857	4.089286	3.625	3.321429	2.964286	3.089286
b. Away from permanent stream (900-1700 m)	Stdev	1.251363	1.248376	1.210211	1.188691	1.261699	1.187462	1.135038
	Mean	1.875	2.071429	1.910714	2.928571	3.839286	2.839286	2.857143
c. Far from permanent stream (>1700 m)	Stdev	1.404885	1.349844	1.166497	1.340672	1.137182	1.150804	1.297225
	Mean	2.089286	3.178571	2.053571	3.857143	3.625	2.803571	2.910714
5. Proximity to seasonal stream	Stdev	1.0519	1.205507	1.414099	1.308811	1.134895	1.27195	1.176474
a. Close to seasl stream (0-600 m)	Mean	1.642857	2.035714	2.232143	3.178571	4.053571	2.982143	2.875
b. Away from seasonal stream (600-1200 m)	Stdev	1.036822	1.073893	1.129878	1.139606	1.127576	1.345387	1.359908
	Mean	1.625	1.785714	1.821429	2.285714	2.535714	3.589286	3.071429
c. Far from seasonal stream (>1200 m)	Stdev	1.408578	1.237404	1.034471	1.080524	1.225142	1.402688	1.197264
	Mean	2.375	2.178571	2.142857	2.178571	2.660714	3.678571	3.053571
6. Park office/staff quarters	Stdev	0.958726	1.063564	1.006473	1.336306	1.348279	1.222622	1.34152
	Mean	1.660714	1.821429	2.071429	3.321429	3.517857	3.178571	3.017857
7. Tourist Information Centre	Stdev	1.252011	1.103566	1.022951	1.164268	1.369306	1.347918	1.221028
	Mean	2.321429	2.017857	1.839286	1.910714	2.625	3.535714	4

Factors		SNRZ	PZ	RZ	ORZ	IUZ	SUZ	OUZ
8. Tribal village/ settlements	Stdev	1.069045	1.034314	1.135038	1.32005	1.285281	1.210211	1.244077
	Mean	1.857143	1.803571	1.857143	2.696429	3.642857	4.089286	3.625
9. Shifting cultivation/ cultivation area	Stdev	1.26645	1.292837	1.297225	0.950735	1.096482	0.964129	1.188691
	Mean	3.321429	2.964286	3.089286	1.571429	1.875	1.625	2.928571
10. Slope a. Steep slope (>55%) area	Stdev	1.150945	1.385336	1.179781	1.489247	1.286165	1.194685	1.150804
	Mean	3.142857	2.160714	2.089286	2.517857	2.732143	3.75	3.053571
b. Moderate Slope (25-35 %)	Stdev	1.254473	1.468169	1.239894	1.143587	1.205911	1.167609	1.245772
	Mean	3.339286	2.339286	3.339286	3.035714	3.482143	2.982143	2.607143
c. Gentle slope (<25%) area	Stdev	1.227261	1.354166	1.245772	1.540682	1.318081	1.214496	1.261699
	Mean	2.946429	2.142857	2.107143	2.339286	2.410714	2.375	2.839286
11. Reforestation/ Restoration	Stdev	1.499784	1.367408	1.277172	1.406732	1.254473	1.347316	1.124549
	Mean	3.428571	2.053571	2.071429	2.053571	2.089286	2.303571	2.160714
12. Elevation a. High elevation area (>1200 m)	Stdev	1.393864	1.374985	1.220496	1.3484	1.249286	1.216232	1.239894
	Mean	3.142857	3.482143	2.964286	3	2.303571	2.107143	2.089286
b. Medium Elevation (600-1200 m)	Stdev	1.26645	1.340672	1.361817	1.317219	1.293214	1.296849	1.305334
	Mean	2.178571	2.642857	3.5	3.785714	3.517857	3.25	3.571429
c. Low elevation area (< 600m)	Stdev	1.221028	1.228318	1.466066	1.285155	1.294845	1.302844	1.277172
	Mean	3	3.267857	2.178571	3.196429	2.821429	3.392857	2.928571
13. Souvenir shop, food shop and parking area	Stdev	0.56115	0.798809	0.883715	0.915475	0.723747	1.175139	0.6759
	Mean	1.733333	2.066667	1.933333	3.533333	4.333333	2.666667	2.333333
14. Tourist attraction sites	Stdev	1.205911	1.227261	1.245772	1.29133	1.41559	1.242118	1.159797
	Mean	2.482143	3.053571	1.892857	2.071429	2.178571	2.357143	3.767857
15. Dormitories and other tourists facilities	Stdev	1.166636	1.3329	1.222622	1.271056	1.365151	1.250325	1.241987
	Mean	3.142857	2.071429	2.178571	2.142857	2.75	3.517857	3.053571
16. Temple	Stdev	1.290198	1.410535	1.23254	1.313145	1.252011	1.221958	1.244077
	Mean	3.160714	2.214286	3.160714	2.803571	3.321429	2.875	2.625
17. Research stations	Stdev	1.222622	1.243033	1.063564	1.344059	1.20173	1.192509	1.365507
	Mean	2.821429	2.017857	1.821429	2.107143	2.285714	2.321429	2.660714

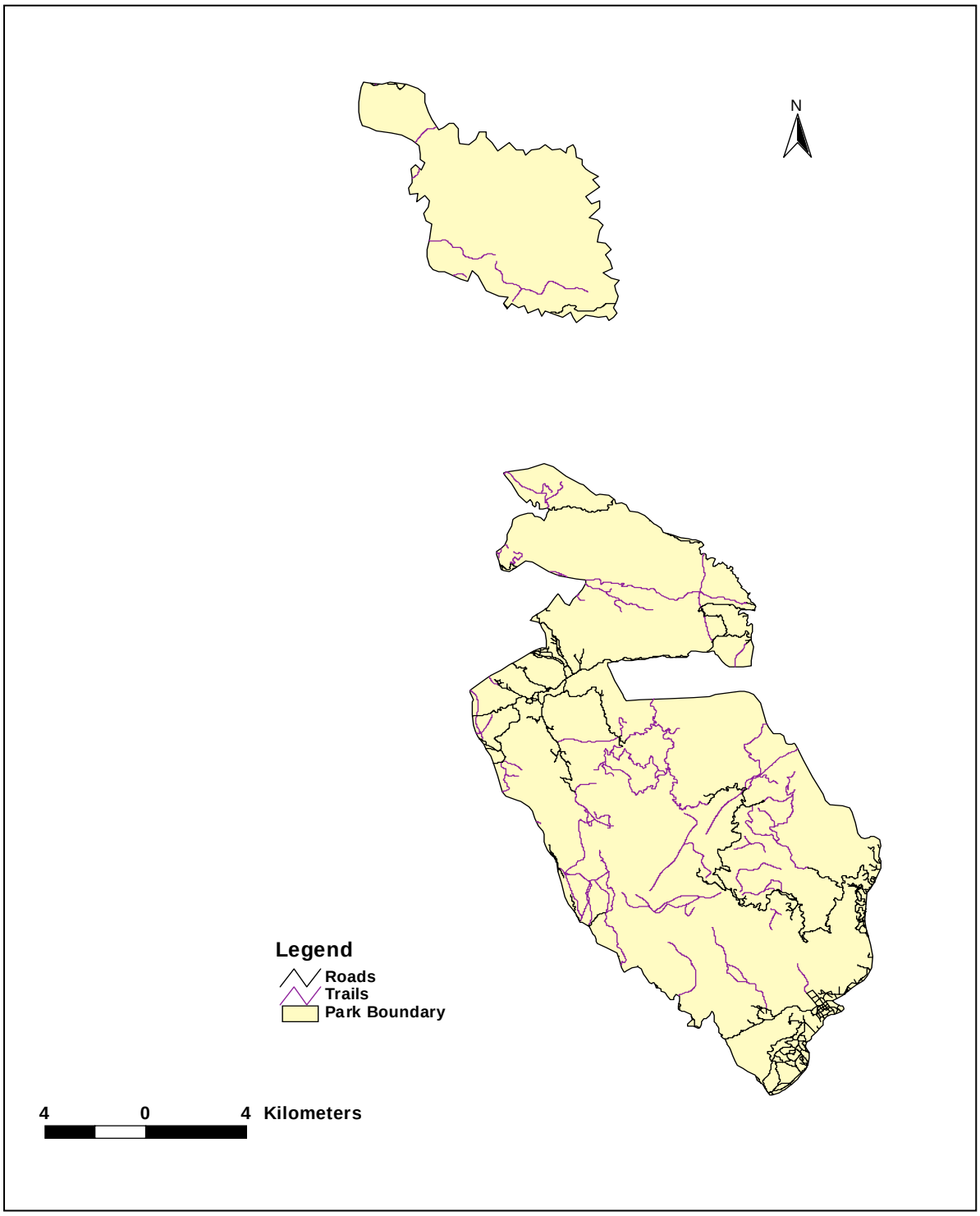
Researchers + Park Official/Staffs + NGO

Factors		SNRZ	PZ	RZ	ORZ	IUZ	SUZ	OUZ
1.Land Cover	Stdev	0.507093	0.589592	0.538958	0.889087	1.146423	1.154701	0.920662
a. Dry Dipterocarp Forest	Mean	4.428571	4.380952	1.238095	3.238095	3.285714	3.333333	3.047619
b. Hill Evergreen Forest	Stdev	0.497613	0.679636	0.57735	0.749603	0.507093	0.86465	0.910259
	Mean	4.380952	4.190476	1.333333	1.809524	1.428571	3.047619	2.857143
c. Mixed deciduous Forest	Stdev	0.436436	0.740013	0.57735	0.889087	0.597614	0.507093	0.920662
	Mean	3.761905	3.952381	1.333333	3.238095	4.428571	4.428571	3.047619
d. Agricultural Area	Stdev	0.436436	0.560612	0.830949	0.507093	0.601585	0.601585	0.920662
	Mean	1.238095	1.285714	1.761905	1.428571	1.47619	1.52381	3.047619
e. Old Clearings	Stdev	0.402374	0.46291	0.497613	0.749603	0.597614	0.963624	0.920662
	Mean	1.190476	1.285714	4.619048	1.809524	4.428571	2.142857	3.047619
f. Secondary Growth Forest	Stdev	0.804748	0.768424	0.813575	0.845154	0.658281	0.507093	0.830949
	Mean	1.619048	3.238095	3.190476	3.285714	4.333333	4.428571	3.095238
g. Plantation	Stdev	1.095445	1	1.095445	0.889087	0.717137	0.511766	0.830949
	Mean	1.8	2	1.8	3.238095	4.285714	4.47619	3.095238
h. Built Up Area	Stdev	0.483046	0.57735	0.497613	0.810643	0.601585	0.511766	0.920662
	Mean	1.333333	1.333333	1.380952	3.428571	4.52381	4.47619	3.047619
i. Water Body	Stdev	0.46291	0.597614	0.511766	0.856349	0.669043	0.497613	0.973457
	Mean	1.285714	1.428571	1.47619	3.333333	4.380952	4.380952	3.047619
2.Proximity to roads	Stdev	0.813575	0.676123	0.669043	0.810643	0.560612	0.538958	0.749603
a. Close to road (0-1000 m)	Mean	1.52381	1.428571	3.619048	3.428571	3.714286	3.761905	3.47619
b. Away from road (1000-3000 m)	Stdev	0.511766	0.436436	0.87014	0.749603	0.749603	0.560612	0.74642
	Mean	3.809524	3.761905	1.428571	3.47619	3.52381	3.714286	3.428571
c. Far from road (>3000 m)	Stdev	0.497613	0.507093	0.795822	0.768424	0.830949	0.973457	0.928388
	Mean	4.619048	4.571429	1.333333	1.904762	1.761905	2.047619	3.190476
3. Proximity to trails	Stdev	0.676123	0.872872	0.676123	0.856349	0.57735	0.658281	0.795822
a. Close to trail (0-600 m)	Mean	1.571429	1.47619	3.428571	3.333333	3.666667	3.666667	3.333333
b. Away from trail (600-1200 m)	Stdev	0.478091	0.402374	0.795822	0.679636	0.810643	0.669043	0.795822
	Mean	3.857143	3.809524	1.333333	3.52381	3.428571	3.619048	3.333333
c. Far from trail (>1200 m)	Stdev	0.483046	0.46291	0.804748	0.804748	0.783764	1	1.116969
	Mean	4.666667	4.714286	1.380952	1.952381	1.714286	2	3.047619
4. Proximity to permanent stream	Stdev	0.483046	0.795822	0.783764	0.872872	0.845154	0.995227	0.830949
a. Close to per. stream (0-900 m)	Mean	4.666667	4.333333	4.285714	3.47619	3.285714	3.238095	3.238095
b. Away from permanent stream	Stdev	0.94365	0.511766	1.095445	0.86465	1.014185	0.597614	0.853564
(900-1700 m)	Mean	3.238095	3.52381	3	3.380952	3.142857	3.571429	3.142857
c. Far from permanent stream (>1700	Stdev	0.597614	0.597614	0.717137	0.995227	0.783764	1.135991	1.116969
m)	Mean	1.428571	1.571429	1.285714	2.095238	1.714286	2.238095	3.047619
5. Proximity to seasonal stream	Stdev	0.597614	0.912871	0.768424	0.920662	0.902378	0.966092	0.783764
a. Close to seasl stream (0-600 m)	Mean	4.571429	4.333333	4.238095	3.380952	3.285714	3.333333	3.285714
b. Away from seasonal stream (600-	Stdev	0.902378	0.507093	0.963624	0.92582	1.07127	0.74642	0.94365
1200 m)	Mean	3.285714	3.571429	3.142857	3.428571	3.047619	3.428571	3.238095
c. Far from seasonal stream (>1200	Stdev	0.589592	0.601585	0.70034	1.146423	0.889087	1.152637	1.179185
m)	Mean	1.380952	1.52381	1.238095	2.285714	1.761905	2.142857	2.904762
6. Park office/staff quarters	Stdev	0.402374	0.669043	0.57735	1.40068	0.740013	1.123345	1.154701
	Mean	1.190476	1.619048	1.333333	2.52381	4.380952	3.52381	2.666667
7. Tourist Information Centre	Stdev	0.679636	0.830949	0.910259	0.654654	0.872872	1.287301	1.077917
	Mean	1.47619	2.095238	2.142857	4.142857	3.47619	2.428571	3.190476
8. Tribal village/ settlements	Stdev	0.74642	0.669043	0.928388	1.030488	0.792825	1.189237	0.402374
	Mean	1.428571	1.380952	1.52381	1.809524	1.857143	2.714286	4.190476
9. Shifting cultivation/ cultivation	Stdev	0.749603	0.86465	0.813575	0.813575	1.044259	0.547723	0.538958
area	Mean	1.47619	1.380952	1.47619	1.52381	1.904762	4	4.238095

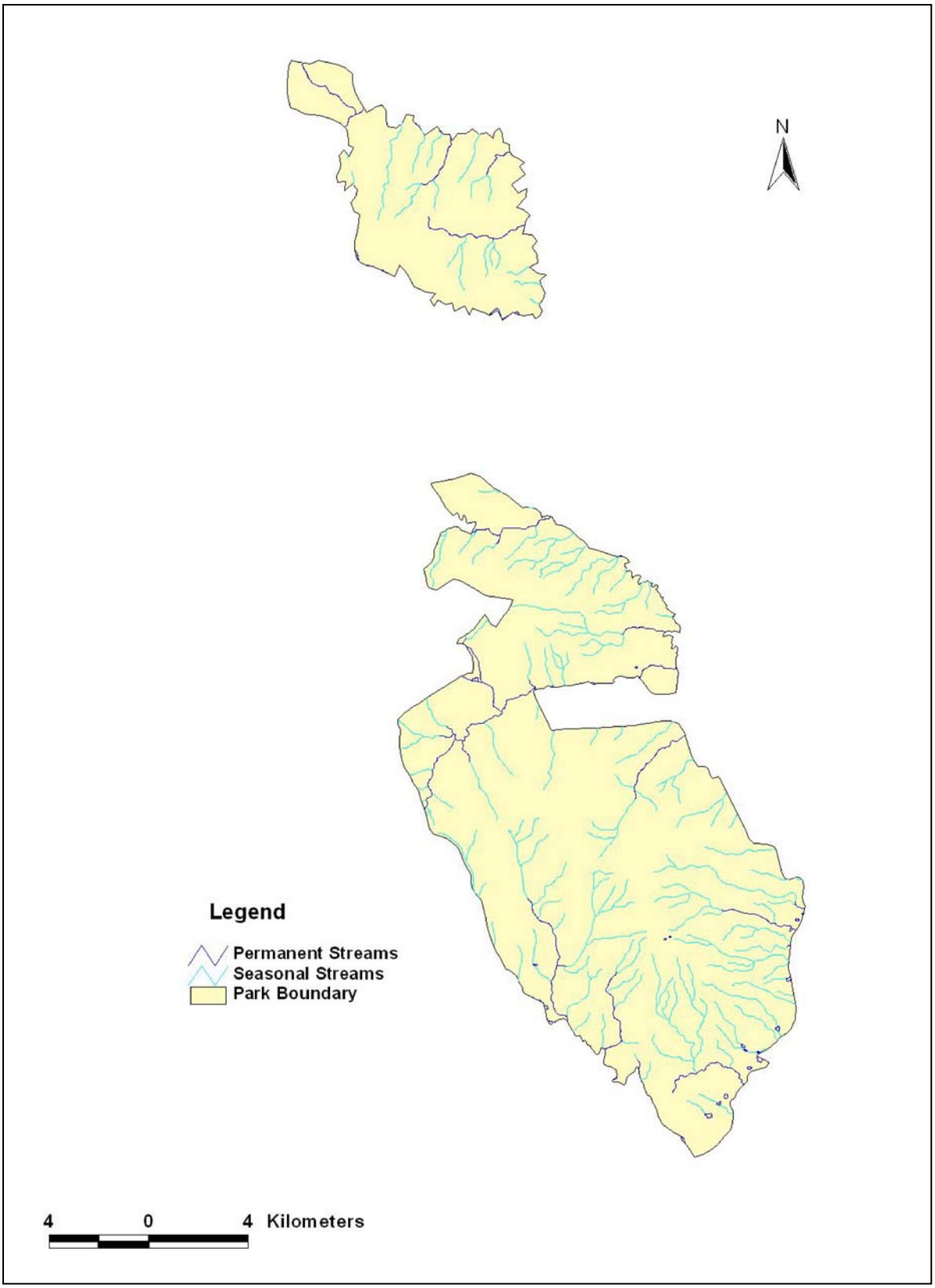
Factors		SNRZ	PZ	RZ	ORZ	IUZ	SUZ	OUZ
10. Slope	Stdev	0.597614	0.768424	1.044259	0.92582	1.023533	0.872872	0.995227
a. Steep slope (>55%) area	Mean	4.571429	3.904762	2.095238	1.571429	1.619048	1.47619	2.095238
b. Moderate Slope (25-35 %)	Stdev	0.920662	0.783764	1.044259	0.92582	1.023533	0.872872	0.995227
	Mean	3.047619	2.714286	2.095238	1.571429	1.619048	1.47619	2.095238
c. Gentle slope (<25%)	Stdev	0.597614	0.597614	0.902378	0.94365	1.167007	0.889087	0.507093
area	Mean	1.428571	1.571429	1.714286	3.904762	3.809524	3.904762	3.571429
11. Reforestation/ Restoration	Stdev	0.717137	0.46291	0.83666	1.338087	1.502379	1.338087	0.872872
	Mean	1.714286	3.285714	4	3.904762	3.428571	3.238095	1.52381
12. a. High elevation area (>1200 m)	Stdev	0.597614	0.872872	0.679636	0.872872	0.872872	0.810643	0.973457
	Mean	4.571429	3.47619	1.47619	1.47619	1.47619	1.428571	1.952381
b. Medium Elevation (600-1200 m)	Stdev	0.894427	0.995227	1.077917	0.963624	1.123345	0.966092	1.101946
	Mean	3	3.761905	2.809524	4.142857	3.52381	3.666667	2.714286
c. Low elevation area	Stdev	0.597614	0.727029	0.507093	1.014185	1.091089	0.872872	0.507093
(< 600m)	Mean	1.428571	1.857143	4.571429	3.857143	3.904762	3.809524	3.571429
13. Souvenir shop, food shop and	Stdev	0.872872	0.830949	0.845154	1.055597	0.669043	1.146423	0.978337
parking area	Mean	1.52381	1.761905	1.714286	3.285714	4.380952	2.714286	2.571429
14. Tourist attraction sites	Stdev	0.813575	0.774597	0.74642	0.669043	0.995227	0.980767	1.07127
	Mean	1.52381	4	1.571429	4.380952	4.095238	2.809524	3.047619
15. Dormitories and other tourists	Stdev	0.717137	0.845154	0.872872	1.395571	0.589592	1.390444	1.276155
facilities	Mean	1.285714	1.714286	1.52381	3.380952	4.619048	2.666667	2.857143
16. Temple	Stdev	0.813575	0.74642	0.810643	0.94365	0.973457	0.46291	1.179185
	Mean	1.47619	1.428571	1.571429	1.904762	2.047619	4.285714	3.238095
17. Research stations	Stdev	0.676123	1.327368	1.238278	0.973457	1.327368	0.507093	1.276155
	Mean	1.428571	2.52381	2.333333	2.047619	2.47619	4.428571	3.142857

Appendix -C

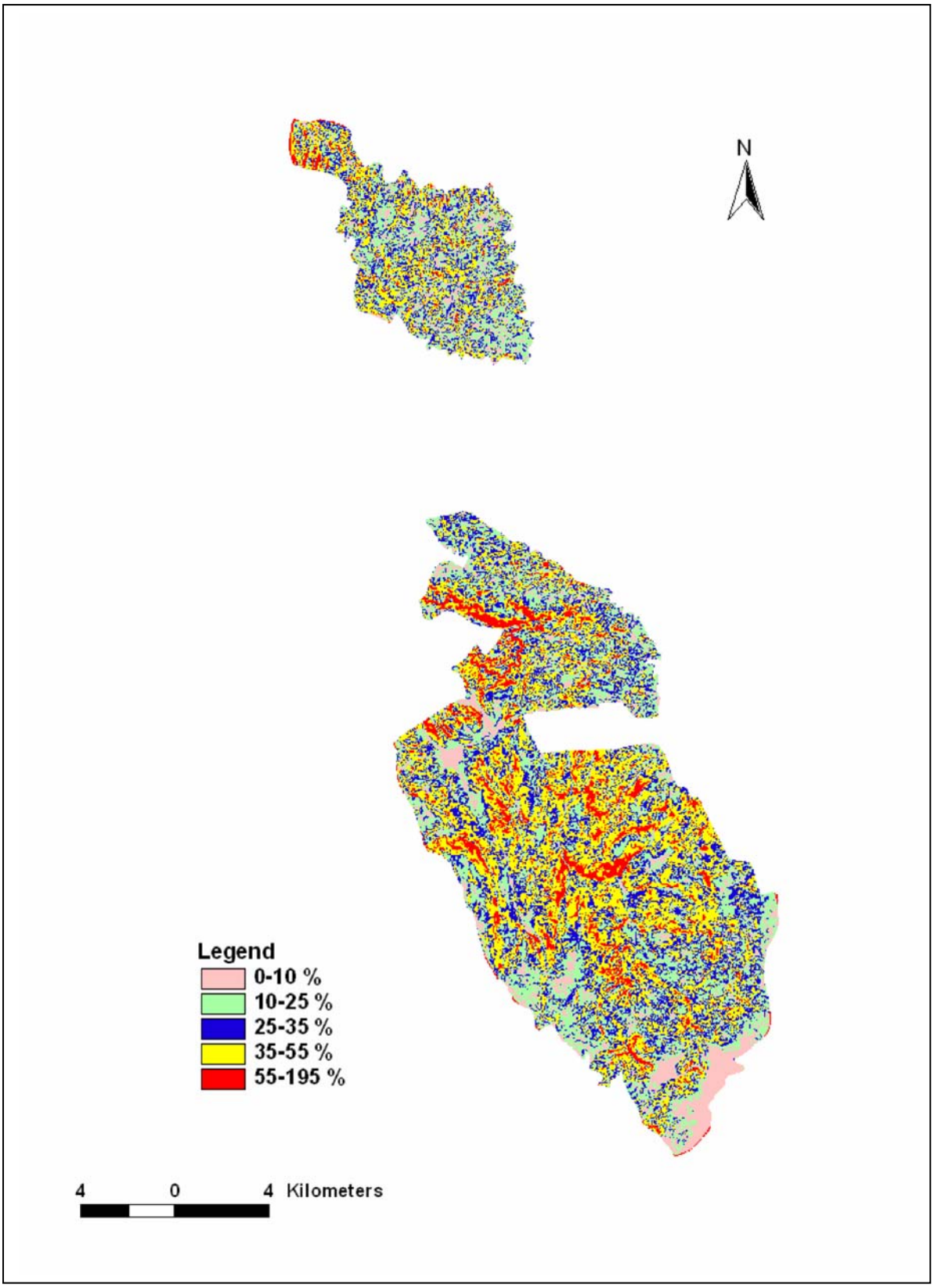
Maps of Road Network, Stream Network, Slope Classes, and Elevation Classes of Doi Suthep-Pui National Park



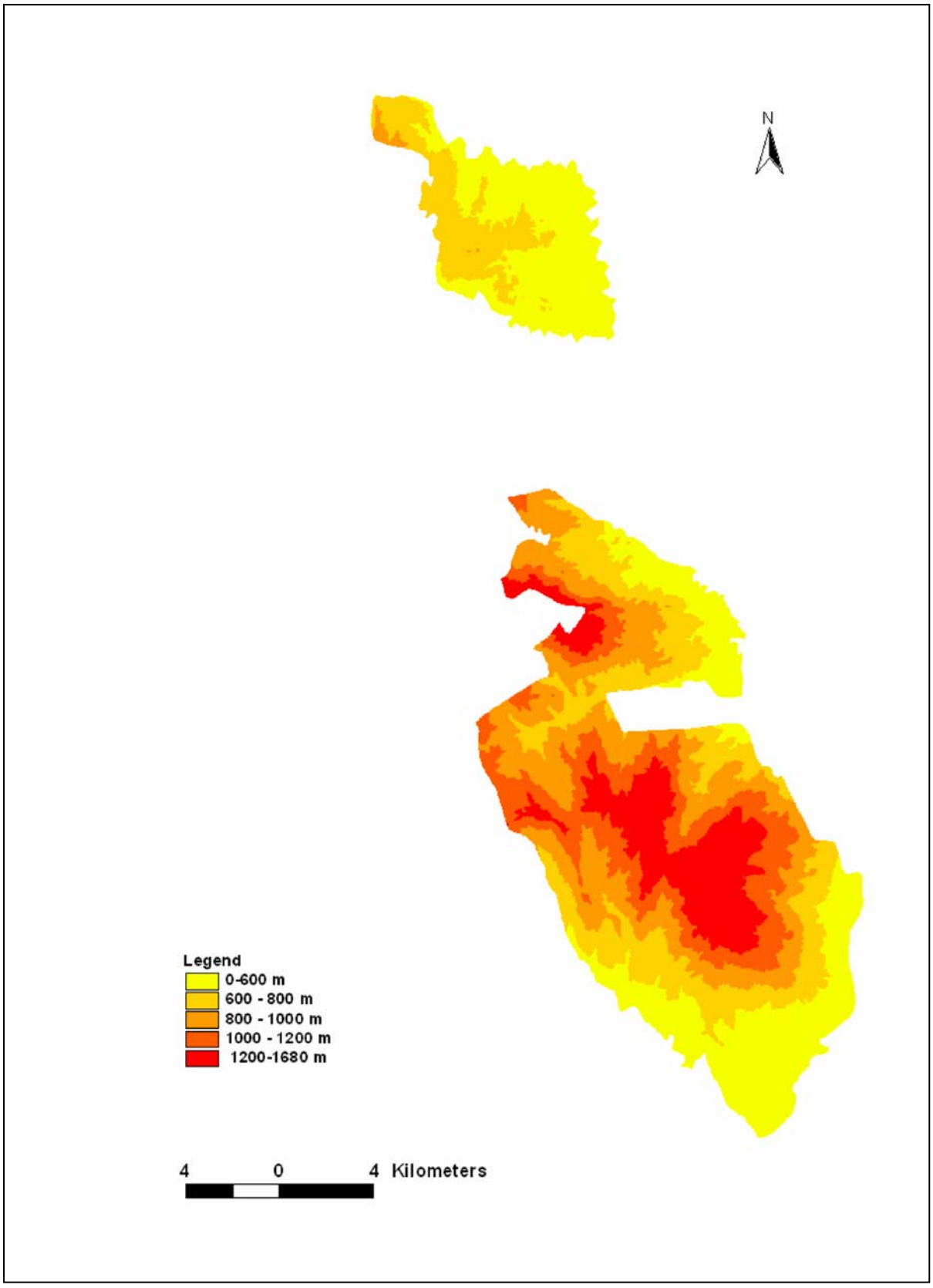
Map of road network of Doi Suthep-Pui Ntional Park



Map of stream network of Doi Suthep-Pui National Park



Map of slope classes of Doi Suthep-Pui National Park



Map of elevation classes of Doi Suthep-Pui National Park