USER REQUIREMENTS STUDY

SPATIAL DATA REQUIREMENTS IN SUSTAINABLE FOREST MANAGEMENT
A STUDY IN FOUR TROPICAL COUNTRIES

Contents **Page**

Foreword

This document is the result of the country studies conducted for the project "Country Studies for User Requirements Study for Forest Assessment and Monitoring Environment", executed by the Food and Agriculture Organization of the United Nations (FAO) in the framework of a User Requirements Study for Remote Sensing based Spatial Information for the Sustainable Management of Forests (URS)", undertaken by the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands. The URS is the first executive phase of the development of the concept of "Forest Assessment and Monitoring Environment" (FAME), which is a cooperative undertaking of a number of technical institutions in The Netherlands, supported by the Ministries of Development Co-operation, Agriculture, Fisheries and Nature Management and Economic Affairs.

Summary

Four studies have been executed in tropical countries possessing a large amount of forest: Brazil, Costa Rica, Malaysia and Nepal. Each of these countries presents a specific type of forest, forest use and forest management, which are studied in detail with respect to spatial data requirements for sustainable forest management (SFM).

The extensive differences between the forest management systems studied revealed substantial differences in spatial data requirements, either in form, content or presentation. Spatial data derived from remote sensing is unanimously regarded as the data source of choice for synoptic data on the forest and related resources. Unfortunately, the use of such data is restricted to central government agencies and research institutes. The use of spatial data at local level is limited due to political and operational constraints.

Spatial data from remote sensing does not cover all the data requirements for SFM. The holistic view of the forest and its associated resources makes the use of terrestrial observations imperative. Improved sensors and analytical methods may substitute some of these in the future, but it is most likely that terrestrial observations will always be required to supplement remotely sensed data.

The increasing complexity of forest management under the current paradigm of multi-purpose, sustainable use of the forest mandates the analysis of large amounts of data of diverse nature and content. Clearly the local forest manager can not be expected to possess all the qualities required for this task. A (semi-) automated tool has to be supplied to shield the local manager from the complexities of spatial data management and (pre-)processing, such that he can concentrate on specific forest management tasks using a standard, uniform set of thematic data.

The absence of current, comprehensive spatial data on the forest and other geo-physical features is impairing an adequate management, to optimize use of the forest while maintaining its integrity in the long run. Spatial data is not the only problem, however. The lack of clear government policies regarding SFM, inter-institutional strife over competence, lack of qualified personnel, lack of financial resources, lack of uniform procedures and methods, absence of devolution of authority to local managers, lack of analytical tools, etc., together form a complex that seems impossible to untangle. Nevertheless, the availability of affordable, good quality, comprehensive spatial data and the associated analytical tools would make a tremendous difference with the current situation, if not for all, then at least for many local forest managers.

Acronyms

In this list only the most important acronyms are listed. Those acronyms that are very specific to a detail of one of the country studies are mentioned in the text only.

AIFM	ASEAN Institute for Forest Management
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CCT	Centro Científico Tropical (Costa Rica)
CFI	Continuous Forest Inventory (Malaysia)
CIEDES	Centro de Investigaciones en Desarrollo Sostenible (Costa Rica)
DANIDA	Danish International Development Agency
dbh	diameter at breast height
DEM	Digital Elevation Model
DFO	District Forest Office (Nepal)
DOF	Department of Forest (Nepal)
DSCO	District Soil Conservation Office (Nepal)
DSCWM	Department of Soil Conservation and Watershed Management (Nepal)
FAME	Forest Assessment and Monitoring Environment
FAO	Food and Agriculture Organization of the United Nations
FCCC	Framework Convention for Climate Change
FD	Forest(ry) Department
FINNIDA	Finnish International Development Agency
FIS	Forest Information System
FONAFIFO	Fondo Nacional de Financiamento Forestal (Costa Rica)
FORESC	Forest Research and Survey Centre (Nepal)
FRIS	Forest Resource Information System (Nepal)
FSD	Forest Survey Division (Nepal)
FUG	Forest User Group (Nepal)
GIS	Geographical Information System
GTZ	Gezellschaft für Technische Zusammenarbeit (Germany)
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazil)
IBGE	Instituto Brasileiro de Geografia e Estatística
ICIMOD	International Center for Integrated Mountain Development
IDA	International Development Agency
IGN	Instituto Geográfico Nacional (Costa Rica)
INBio	Instituto Nacional de Biodiversidad (Costa Rica)
INPA	Instituto Nacional de Pesquisas da Amazônia (Brazil)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IOF	Institute of Forestry (Nepal)
IPAAM	Instituto para a Proteção Ambiental do Amazônas (Brazil)
ITC	International Institute for Aerospace Survey and Earth Sciences
JICA	Japan International Cooperation Agency
LRMP	Land Resources Mapping Project (Nepal)
LUCC	Land-use / land-cover change
MAG	Ministerio de Agricultura y Ganadería (Costa Rica)
MFSC	Ministry of Forest and Soil Conservation (Nepal)
MINAE	Ministerio del Ambiente y Energía (Costa Rica)
MIS	Management Information System
MPFS	Master Plan for the Forestry Sector (Nepal)
MSS	Landsat Multi-Spectral Scanner
NDVI	Normalized difference vegetation index
NFI	National Forest Inventory (Malaysia)
NFIS	National Forestry Information System (Malaysia)
NGO	Non-governmental Organization
NRSC	National Remote Sensing Centre (Nepal)

NWFP	Non-wood Forest Product
PGAI	Projeto de Gestão Ambiental Integrada (Brazil)
PP-G7	Programa Piloto para a Proteção das Florestas Tropicais do Brasil
PRF	Permanent Reserved Forest (Malaysia)
RCFM	Regional Centre for Forest Management (Malaysia)
RFO	Regional Forest Office (Nepal)
RRA	Rapid Rural Appraisal
RTEC	Regional Training and Extension Centre (Nepal)
SAR	Synthetic Aperture Radar
SFM	Sustainable Forest Management
SINAC	Sistema Nacional de Areas de Conservación (Costa Rica)
SIVAM	Sistema de Vigilância da Amazônia (Brazil)
TM	Landsat Thematic Mapper
UNDP	United Nations Development Program
URS	User Requirements Study
USAID	United States Agency for International Development
VDC	Village Development Committee (Nepal)
WWF	World Wildlife Fund

1. INTRODUCTION

The guiding principle behind the development of the concept of "Forest Assessment and Monitoring Environment" (FAME) is the recognition of the serious lack of appropriate basic biophysical data for supporting sustainable forest management (SFM) at the local and sub-national level. The FAME Programme aims at the acquisition and processing of such basic data, as well as dissemination and implementation of associated tools for improving SFM within the broader context of sustainable land management. SFM is described here as "managing forest resources and associated lands to meet the social, economic, ecological, cultural and spiritual needs of present and future generations" (Forest Stewardship Council). Thus defined, sustainable management implies the involvement of stakeholders at all levels, a knowledge of the forest as an ecosystem and a production system, its inter-relations with other land use systems and the role the forest plays in the socio-cultural consciousness of the population in and close to it.

For the purpose of this study a distinction is made between stakeholders, or beneficiaries, and users of spatial data. Stakeholders are those people or organizations that have a (direct) relation to the forest, such as the people living in or near the forest, rural and urban communities extracting fuel wood and other products from the forest, private forest owners, industries processing forest products and tourists. Users are those people or organizations that use (spatial) data on the forest for management and monitoring purposes. Users could be government agencies involved in policy formulation, large scale monitoring and planning, down to the field office of the forest department or land bureau, but it might also be a private, commercial company or an NGO monitoring the local environment. The emphasis of the study is on spatial data requirements by these users and the tools required for their processing and interpretation to achieve a sustainable management of the forest.

Forest ecosystems can be analyzed from many perspectives, the major ones of which are: 1) spatial focus at various scales, 2) goods and services provided by the forest, and 3) beneficiaries of these goods and services. These perspectives interact and influence one another. In order to identify information needs for sustainable management of forests it is imperative to identify and understand the demands that different stakeholders lay on the goods and services the forest can provide, but also the land on which the forest is growing and the interactions with the other perspectives.

Timber, fuel wood, non-wood forest products (NWFP) and game can be harvested, managed and quantified easily. Biodiversity, recreation, climate moderation and soil and water conservation are indirect: they are the product of an ecosystem interaction of the biosphere with the geosphere and the atmosphere and usually require a certain critical mass of forest to manifest themselves in a visible way. Since they are not easily quantifiable or attributable to the forest they are often overlooked or disregarded in management and planning, even while they provide valuable input to the sustenance of the forest and the wellbeing of the population inside and close to the forest. Cultural aspects are more in the realm of anthropologists than foresters or ecologists, but its consideration is vital for the active participation of the local population in management and conservation.

The following people-forest interactions are important in forest management:

- <u>Local communities and shifting cultivators living inside the forest.</u>
  These people are directly dependent on a particular forest and are usually well adapted to the conditions presented by the forest. The forest provides them directly and indirectly with their sustenance, through hunting and gathering and shifting cultivation, respectively. Often the tribal communities have a spiritual relationship with the forest or some of its components leading to culturally mandated behaviour tending to forest conservation. Increasing population pressure can lead in the long term to degradation of the forest, particularly in the case of shifting cultivation when the rotation cycle becomes too short. Inversely, a reduction of the forest area through exogenous processes (mainly conversion to agricultural land and large-scale logging of natural forest) will lead to a smaller amount of forest available to the local population, with similar results.

- Agricultural communities close to the forest (frontier communities).
  These communities remove parts of the forest to accommodate agricultural fields or pastures. Because of the limited natural fertility of many forest soils in the tropics and the lack of appropriate land management techniques these soils are rapidly exhausted which leads to further clearance of forest patches. Sometimes this behaviour is encouraged by external factors; i.e. when exhausted ex-forest land is bought and converted to pasture land by cattle breeders.

- Remote influences: rural and urban population, industry, tourists.
  The growing urban population in many countries is placing an ever-increasing demand on forest products and on products raised on (former) forestland (e.g. beef, cattle feed) and is thus creating or satisfying a market for these products. Similarly, industries are using forest products for the production of pulp, paper and timber and serving both domestic and international markets. With the exception of forest plantations, these demands are usually destructive; i.e. the forest is cut to satisfy the demand. On the other hand, the forest as a balanced and diverse ecosystem is also in demand by tourists for its esthetical value, by pharmaceutical industries for the supply of rare plants for the production of medicines and other specialty products, and by the scientific community for the preservation of a broad gene pool.

- Disasters.
  Natural and man-made disasters such as fire, floods and landslides have an immediate and usually destructive effect on the forest ecosystem and occur unexpectedly, although they can be predicted to occur with greater probability under certain circumstances, which often relate to human interference in the ecosystem. As such, proper management contributes to the prevention of disaster or at least decrease the frequency of disasters and/or its impact on the ecosystem.

To reconcile the pressures on the forest and to mitigate detrimental influences users (governmental, non-governmental and private) need comprehensive and timely information on the forest and land resource and the processes governing its status and development. Specifically, data is required to plan, implement and monitor the production and use of the multiple goods and services for the different stakeholders without compromising the regenerative capacity of the forest and the soil.

Forest ecosystems are highly dynamic in nature (at least in the hyperthermic and megathermic climate zones of the Earth) with complex associations of and interaction between species. The knowledge of forest ecosystems still shows large gaps. The sustainable management of forests, therefore, implies a (semi)continuous monitoring of the forest and its dynamic processes to be able to assess the impact of any given management operation. Undisturbed forest usually has a high resilience and it is the task of the manager to maintain that resilience while simultaneously generating the goods and services that the stakeholders demand.

Forest planning, management and monitoring takes place at different levels with different scope, purposes and time frames. Each of these planning and monitoring situations requires a specific set of information. Much of the required information has to come from the interpretation of spatially referenced data. Data may come from remotely sensed images, particularly in the case of large forest areas, but these should be complemented by and integrated with ground observations to compile the complete set of required data, much of which cannot be inferred from satellite imagery. This includes ground truthing for the remotely sensed data and data regarding population and markets for forest products, species composition and distribution and physical resource base.

Technical expertise in the acquisition, processing and interpretation of raw data – from satellites for instance – can not be expected to be available to every user of spatial data in forest management and sustainable development. The timely and cheap delivery of raw or even pre-processed satellite imagery to every user will, therefore, not be sufficient. It will have to be regarded as part of a complex of data inputs, thematic pre-processing and interpretation of data and information outputs, where every planning and monitoring situation requires a unique combination of data, information and tools.

Within the context of the operational environment in which forest management takes place the organizations and users have specific data requirements to meet the information needs of their activities, whether it be for planning or monitoring, both in operational and developmental contexts. In forestry, synoptic spatial data will almost inevitably come from remotely sensed images, either from aircraft or satellites, the latter particularly if the data is to be used for planning or repetitive monitoring of large areas.

The country studies will include all of the above aspects of forest management and sustainable development and their associated information requirements. Who are the stakeholders and how do they interact with the forest and each other? What are current information requirements and how are they met? How can the information requirements be met in the future? What spatial information do the users need to optimize their management of the forest? How do users currently access spatial data, how do they process the data and in what ways would they like to see this improved from the perspective of sustainable forest management?

2. THE COUNTRY STUDIES

In order to investigate the spatial data requirements in SFM in tropical countries, as discussed in the previous chapter, four country studies were conducted. In each of these four countries the specific management styles and the associated spatial data requirements were studied. These four country studies are chosen such that they represent the major ecological zones, forest types and forest functions. In many aspects this selection of countries and subjects does not provide an exhaustive picture of spatial data requirements. It does, however, demonstrate the difficulties and opportunities in the use of (remotely sensed) spatial data and information systems in SFM at the local level in tropical countries.

2.1 Methodology

The emphasis of the country studies was on the spatial data requirements of baseline organizations, i.e. the forest manager in the field, provincial or regional offices or NGOs serving a particular rural area, and the functions/services that this spatial data needs to support. In order to effectively identify current and possible future spatial data requirements the country studies were executed with the active involvement of the users of spatial data at the various levels.

The interactions that exist between the different users of spatial data at local, national and sectoral levels were described, both in terms of data requirements and influences/interactions at the level of policy formulation and implementation, information flows, academic and applied research in the fields of forestry, land management and the environment, and extension. The role and position of the local stakeholders of the forest – e.g. forest dwellers, rural population, local forest authorities, private forest owners – was central in the description of these interactions, as it is at this level that the results of spatial data analysis become of truly operational use.

Equally important though is the role that (spatial) information, relating to forest and land resources, plays in the formulation of policies at higher levels, e.g. how does the application and analysis of spatial data at the local level influence the decision-making process at regional or national levels. Is there a clear link between the levels extending from the 'bottom' upward through the hierarchy, or does each level compile and analyze its own information?

The country studies include at least the following:

1. Description of the environment in which the use of spatial data takes place.
2. Organizations and users of spatial data in forest management.
   - Identification of the involved organizations (Governmental/ NGO/private, profit/non-profit, policy/planning/execution).
   - The kind of operations/activities they execute (planning, conservation, protection, production, monitoring).
   - Level of operation: national/provincial/local.
   - Interaction with other organizations/Government (as far as data exchange is concerned).
3. Description of the organizations and users of spatial data:
   - What are the main forest or land management or monitoring objectives of the organization?
   - Which of the tasks in the organization require spatial data on forests and land?
   - What is the availability of skilled (wo)manpower, and/or what are the training needs to achieve an adequate level of spatial data analytical capabilities?
   - What type(s) of spatial data on forests or land are currently being used?
   - Which are the constraints (technical, political, operational) on the present use of (or impediments to use) spatial data?
   - How are spatial data presently obtained and what facilities do presently exist for handling of spatial data? Are GIS facilities being used or are they planned to be used? Is modeling of spatial data applied? Is there any cooperation with research institutes or universities?
   - How can the supply and use of spatial data be improved?

- What additional spatial data is required for better decision-making on forest and land management or better monitoring?

The country studies were concluded with a national workshop, in which all resource persons involved in the study were invited to participate and discuss the findings of the study team. The final reports produced by the study teams include the recommendations made at the national workshop.

2.2 Selection of the countries

The country studies have been conducted in four countries, which have been selected by FAO, in consultation with ITC. This section presents these four countries (core data taken from State of the World's Forests 1997 (extent and percentage) and Forestry Papers 112 (ecological distribution) and 128 (plantation data)).

Each country study provides a global overview of the forestry sector in the country and adds a detailed section on a specific subject (forest function). Combined, the four country studies should provide a body of information that covers the entire range of major ecological zones, forest formations and forest functions. It is obvious that not all combinations could be studied, given the constraints present in the project. The four presented countries are believed to provide an optimal mix to approach a representative coverage.

Brazil	possesses the largest body of tropical rainforest in the world. The rainforest is largely uninhabited and inaccessible. On the fringes there are large-scale processes that increasingly threaten the forest, mainly through conversion into agricultural land, resulting frequently in large-scale fires and 'ecological deserts'. The study concentrated on (the protection of) natural forest formations and was conducted in the State of Amazonas. Core data: $551*10^6$ha of forest (65% of total land area), of which 52% in the tropical rainforest zone and 35% in the moist deciduous forest zone. The State of Amazonas has 93% forest cover in the tropical rainforest zone.
Malaysia	has a forest management system based on the colonial English system. The peninsular part has a large presence of commercial plantations for the production of timber, palm oil and rubber. Sabah and Sarawak have large amounts of pristine rainforest that are being exploited for commercial timber extraction. Due to international pressure to conserve the pristine forest Malaysia is setting up plantations and reafforestation schemes for timber species. The study concentrated on plantations on Peninsular Malaysia. Core data: $15.5*10^6$ha of forest (47% of total land area), of which 93% in the tropical rainforest zone. There are some 116,000ha of plantations for industrial wood production, $1.9*10^6$ha of rubber tree and $1.6*10^6$ha of oil palm.

Costa Rica	has a wide variety of natural resources and related (bio-)physical parameters over a relatively small area, due to its location between two oceans and the recent tectonic formations. The country presents a dry to wet gradient and a hot to temperate vertical gradient. The extreme diversity in ecosystems gives the country one of the highest degrees of biodiversity worldwide. Most of the forest is concentrated in National parks and (biological) reserves. The Government is committed to conservation and sustainable management and exploits its ecological richness to attract tourists. The study concentrated on the experience gained with sustainable management (particularly on private land) and the effect of Government policies regarding sustainable management. Core data: $1.2*10^6$ha of forest (24% of total land area), of which 44% in the tropical rainforest zone and 56% in the hill and montane zone.
Nepal	has predominantly montane forest, which is largely accessible only on foot and with animal traction. Much of the montane forest has been brought under the management of the local population or under watershed protection through the Ministry of Forestry and Soil Conservation. Potentially there are conflicts between the objectives and management decisions made by the local population and those that are made for the protection of the watershed. The study concentrated on the local management and protection of the watershed, the potential conflicts and the tools required for both types of management. Core data: $4.8*10^6$ha of forest (35% of total land area), of which 47% in the hill and montane zone and 26% in the moist deciduous forest zone.

The results of the individual country studies are presented in the following Chapters. In 0 a compound analysis is made of the spatial data requirements and institutional considerations in the selected countries and a generalization is made that should be applicable to SFM in tropical countries at large.

3. BRAZIL

3.1. Study organization

The Brazil country study was executed in the State of Amazonas, in the north-west of the Federal Republic of Brazil. The study was undertaken by the Instituto para a Proteção Ambiental do Amazônas (IPAAM), the Environmental Protection Agency of the State of Amazonas.
The following staff of IPAAM participated in the study: René Levy Aguiar, Rui Moura Bananeira, Stefan Keppler, Neliton Marques da Silva and Artemísia Souza do Valle, and they were assisted by the consultant Wim Sombroek.

3.2. Study location

The State of Amazonas is “landlocked”, being bordered to the west and north by the Andes and the Guyana Plateau, respectively, and by the Brazilian State of Pará to the east. The port of Itacoatiara, on the Amazon river, provides the only transit route for bulk products to and from the State.

Of the total area of the state of Amazonas 97% of the natural vegetation is in its natural form (dense or open humid tropical forests; various types of edaphic savannas). About 35% of the State’s surface, which is $1.6*10^6 km^2$, has already one or another form of protection or defined direct use, as Reserve, Park, National Forest or another category of protected area.

There is an increasing interest at the three governmental levels (federal, state and municipal), of the local society and of local entrepreneurs, to conserve this natural resource, in one form or another, by total protection of the vegetational biomass and the floristic and faunistic biodiversity (access permitted only for scientific or eco-touristic purposes); by sustained exploitation of non-timber forest-products (extractivism); by forest management proper (production of timber on a sustained basis, without destroying the structure of the forest and facilitating the recuperation of the tree species concerned); or by agricultural occupation by small-holders with agro-forestry practices. There is also a major ongoing federal programme to demarcate and protect Indigenous (Indian) Reserves. All these activities require georeferenced databases of socio-economic-cultural, juridic-administrative and biophysical features, not only during the planning phase, but also during the long-term execution (monitoring, control and law enforcement). This country study deals only with the bio-physical data required for zoning and management at local level, considering that the stakeholders are many and very diverse.

Even at (inter-)municipal level, one first needs to determine the minimum acreage to be considered for a specific use. Areas of biodiversity protection require at least 100,000ha to be effective. Guided settlement of small-holders with agro-forestry orientation requires similar areas if adequate social and technical support is to be ensured; organized extractive reserves normally are in order of 500,000ha; forest management undertakings of an industrial nature, to be sustainable – in other words: to allow sufficient time for the useful timber to recuperate –, also require a minimum acreage of 100,000ha, though not necessarily as one continuous stretch of land. In the Amazonian context, most indigenous reserves, natural parks and other types of conservation areas normally will comprise more than 500,000ha. One also needs to keep in mind that the form of protection or sustainable use is intrinsically different for the always accessible uplands (*terra firme*) from that of the seasonally inundated lands (*várzeas* and *igapós*), where the seasonality of access, the presence of fisheries and the prohibition of private land ownership are preponderant.

For this country study, therefore, only areas between 100,000ha and 300,000ha will be considered as to the spatial data requirements for their management, and the examples will be either from the *terra firme*, the *várzeas* or a combination of these two major ecosystems.

3.3. Forest resources, usage and spatial data requirements

3.3.1. Requirements of an initial exploratory inventory

In large areas of primary tropical forest, such as Amazonia, when still little is known about the resource, one starts with the exploratory inventory, provisionally in regions that have a potential for one or another human use (direct use) or form of protection (indirect use). Indirect use in this context means all forms of protection of the primary forest or savanna vegetation and their biodiversity. The density of georeferenced data to be produced, is still low, which translates in scales of cartographic presentation in the order of 1:1,000,000. The great historic example for Amazonia is the major undertaking of RADAMBRASIL during the years 1970-1980 and the method still merits to be applied in other countries with tropical forests.

Because of the difficult terrestrial access and the sheer expanse of such unexplored areas, the availability of remotely sensed images is essential, whether from satellite or aircraft, and in the optical spectrum (MSS) or the microwave (radar) sphere.

Normally, only one set of satellite imagery is needed, but it should cover the entire region under consideration, during the same season of one year. The processing of the original RS tapes of necessity takes place in a central GIS facility in the country itself or elsewhere. The interpretation of the resulting images, the ground-truthing and the presentation in final reports and maps, should, as much as possible, be an integrated multi- and inter-disciplinary effort. The technical coordination is often carried out by an experienced physical-geographer, who can distinguish and denominate the main landform units (the "land system" approach). Also the terrestrial verification of the remotely sensed data needs to be multidisciplinary – if only because of the high costs of access (by river or any existing road; through transects cut specifically for this purpose; openings for the landing of helicopters, etc.). The verifications will normally take place concentrated in time (when the hydrological and weather conditions permit access). Geologists, geo-morphologists/ topographers, hydrologists, soil scientists/agronomists, foresters and biologists preferably examine the same sample points, for reasons of economy and better interdisciplinary correlation; presence of anthropologists and archeologists may be desirable. Nowadays, the methods to quantify the biodiversity and biomass in relation to the fluxes of CO_2 at landscape-level deserve special attention of the multidisciplinary teams.

The required intensity of the sampling sites varies with the pattern and the complexity of the landscape units, but in general will be around 1 per 1,000km^2 (samples of 1ha for forest inventory purposes; soil pits of 2m depth for description and measurement in loco, sampling for laboratory analysis). Acknowledging that each participating discipline has its own preferred observational methods, one needs to give sufficient attention to compatibility in time and space, for instance in function of seasonality, population dynamics of the fauna and the floristic phenology.

Even if the ground-truthing can never be completely representative, one has to keep in mind that the points of easy access will also be the ones with the highest human influence – former indigenous occupation, hunting of wildlife, selective cutting of valuable timber, or any full-scale clearing in the past (the edges of the Solimões/Amazon rivers and the federal/state roads are examples of clearing for agro-pastoral purposes).

3.3.2. Requirements for a general Ecologic-Economic Zoning

To arrive at a consensus between all authentic stakeholders, about the use or non-use of the land and water resources in a given primary forest area, one needs basic georeferenced and georelational data on biophysical aspects, on socio-economic-cultural conditions and dynamics and on the juridical-administrative situation (land ownership, governmental jurisdiction, traditional indigenous ownership, etc.). These together form the criteria to delineate homogeneous geographic domains that could have a specific form of management to be ultimately formalized in state laws. An example is the ecologic-economic zoning of the southeastern region of Amazonas state (Vale do Rio Madeira), now ongoing and intended to serve as a basic tool for the

Integrated Environmental Management Project (Projeto de Gestão Ambiental Integrada, PGAI) of the PP-G7 pilot programme for Amazonas.

The required intensity of georeferenced biophysical data is low to medium, translating itself in maps at scale 1:500,000/1:250,000. As in the previous case, the availability of one set of recent RS products is essential, as well as a multi- and interdisciplinary cooperation on the remotely sensed images, the ground-truthing and the presentation in the form of maps and reports. The delineations and legend descriptions preferably are at the level of more detailed landscape units, with quantified digital indication of the characteristics of the various facets that compose these units (SOTER (Soil and Terrain database) approach of FAO/UNEP/ISRIC).

The intensity and representativeness of the field observations and sampling should be in the order of 5-10 sites per 1,000km^2. The geologic aspects will include the feasibility of ore extraction; the forest inventories will give attention to the total vegetation biomass; the biologists will give attention to endemism features; the soil scientists will include soil faunal studies and measurement of physical parameters of the soils for purposes of assessing the erosion risk upon deforestation; etc. For each of these disciplines, the type and form of the survey and the evaluation of the results has to be specified in advance (terms-of-reference). Much attention has to be given to the description of the land units in a popular language, using simple terminology that can be easily understood by local people – thereby facilitating the discussions for consensus reach on the use or non-use per zoning domain.

To maximize the use of RS, it will be advantageous to avail of the material in digital form (CD-ROM), of both radar (for topography) and Landsat type (for vegetation), the latter in at least two time sets (one during the rainy season and another one at the end of the dry season). The hard- and software for the processing of the digital material should be available at state or regional level, with well-trained technicians. The multidisciplinary teams for the ground-truthing would preferably reside in the region/state itself, if there exists a policy and real outlook that zoning work will be carried out in other parts of the state as well – providing some guarantee of continued employment.

It should be mentioned that continuous monitoring of the change in environmental conditions and land uses, subsequent to the completion of the zoning process, forms an essential part of the PGAI approach in reaching an effective and sustainable integrated environmental management.

3.3.3. Requirements for Municipal Master-Plans and for Management Plans for Areas that Have Already a Specific Direct or Indirect Use

Municipal level authorities and civil society organizations need, within an already approved general zonation, rather detailed bio-physical data for the preparation or actualization of master-plans for territorial settlement and conservation. Management plans for intra- or inter-municipal areas that have already a destiny for a specific direct or indirect use also need georeferenced data. Most municipalities of Amazonas state have a surface size , comparable with provinces or whole countries in Europe. Even so they have a human population that rarely surpasses 50,000 persons. Formally, the municipal authorities have the right to territorial management – for instance the issue of land titles – in only a small square area (20x20km around the center of the town, when there are less than 1,000 families, or 34x34km when the population is higher. The remaining territory of the municipality is either under federal jurisdiction (FUNAI, INCRA, IBAMA, Forças Armadas), part of state level concessions (for instance the traditional rubber exploitation), or is open land (*terra devoluta*), the responsibility for which is in the process of being transferred from the federal to the state level. The federal institute for land reform and settlement (INCRA) has formally the right to establish new agricultural settlements in bands of 50km width at both sites of federal roads, existing or (erstwhile) planned.

The density of data is in the order of cartographic presentation at scale 1:100,000 or 1:50,000. Also in these cases, remotely sensed data (by airplane or satellite) are very useful as a planning instrument, if it has sufficient spatial resolution. Aerial photographs would be an alternative, even if their production would be very expensive if to be paid by municipalities or companies, this because of the small chance for days without clouds, fog or smoke from forest fires.

The collection of ground data for calibration has normally an orientation towards only one or a few bio-physical aspects: major attention to topography (for access); hydrology (for water storage); qualities and limitations of the soils (for agroforestry settlements); mineralogy (for mining); aquatic biology (for sustained fishery); timber resources (for sustained forestry); floral and faunal diversity (for non-timber forest products or complete protection); scenic aspects or archeological sites (for eco-tourism), or evidences of permanent or nomadic occupation by indigenous groups (for demarcation of Indian reserves).
In the case of forest or soil inventories, the sampling intensity will be in the order of 100 samples per 1,000km^2. Especially when the elaboration of a company- or community-level management plan is concerned it will be very useful to know the history of the land use. The early history can be reconstructed through interviews with the present-day riverside people and scanning of the municipal and state archives, and through the identification of biophysical traces of past Indian occupation and archeological sites (occurrence of *Terra-Preta-do-Índio* areas, or high spatial concentrations of herbs and trees known by ethnobotanists, to have been of traditional Indian use). The more recent history can be quantified and georeferenced through comparison of RS images that may be available since the beginning of inventories through the use of aerial photography (in the case of Brazilian Amazon: 1942).

The feasibility of processing of old, recent or future RS material at municipal or company level, for the purpose of master plans and management plans, depends on the infrastructural conditions and the on-the-spot availability of trained personnel. Required are: an unequivocal administrative constellation (for instance the municipal secretary for planning or environmental matters); climatized buildings; secure telephone, electricity and water supply; sufficient financial resources with a long-term guarantee (independent from electoral upheavals), and living standards that are acceptable for specialists in RS and GIS. In general, such conditions can be found or realized only in municipalities with an urban population above 25,000. In all other cases, facilities will have to be provided at state level or combinations of districts or municipalities. (IPAAM is right now planning to have sub-agencies in Humaitá and Parintins).

In the case of major natural resources exploitation companies, their field headquarters can serve as venue for RS processing (Itacoatiara for sustainable timber extraction companies; Pitinga for industrial mining of tin; Balbina for hydropower generation). In the case of preparation of management plans for extractive reserves or environmental protection areas, reserves for sustainable development or forest reserves, there are usually Foundations or major Civil Societies (NGOs) with a well equipped seat or sub-seat in the region that accept management responsibilities on behalf of governmental entities. Mentioned here are: Foundation Victoria Amazônica, IMAFLORA, IMAZON, IPAM, S.C.Mamirauá, Projeto Waimiri-Atroari, SOS-Amazonia, etc., with headquarters in Belém, Manaus or Rio Branco and sub-seats in the interior of the state (Tefé, Presidente Figueiredo, Novo Airão, São Gabriel da Cachoeira, etc.). The international PP-G7 and LBA programmes for the Amazon, now in operation, may create more NGOs. Guaranteed long-term support for such environmental NGOs, is in fact the best way to ensure a market for new RS materials.

3.3.4. Requirements for Improved Digital and Analogue Topographic Maps

In all three above described cases, there is an acute need for planimetrically controlled topographic maps, in digital and analogue form, with a resolution/scale ranging from 1:1,000,000 to 1:50,000 or even more detailed. RS material would make their production much easier, considering that there already exists a basic triangulation, and that Global Position Systems (GPS) are becoming of common use.

It may be noted, that SIVAM – Sistema de Vigilância da Amazônia (military monitoring) and IBGE – Instituto Brasileiro de Geografia e Estatística (federal mapping agency) recently signed an agreement to produce digital topographic maps at 1:250,000, of the entire Brazilian Amazonia, during the next 5 years. The grid-sheets Manaus, Purús and Porto Velho would be ready in October 1998.

Existing digital topographic map sheets are already of fair quality, but the topographic base data of municipal maps is in many cases much out of date, showing topographic discrepancies in the order of tens of kilometers.

3.4. Requirements for the Management of an already defined and Approved Land Use

The type and frequency of georeferenced biophysical data that the manager (person or institution) may need for an area that has already a defined direct or indirect use, depends on the intensity of this use or protection. When the necessary data for a management plan are already available, then the monitoring, enforcement and control functions remain, to ensure then the management is carried out in accordance with the approved plan.

In the following section the major management types are described, ranging from rigid protection to intense human use of any defined area.

3.4.1. Private Reserves of National Patrimonial Importance (RPPN)

These are areas of complete protection, normally of private (person or company) ownership. Most of them are of small size (up to 100ha) and in the neighborhood of major towns, and their owners can monitor any infraction through field inspection. There exists one notable exception in Amazonas state: the "Novo Destino" reserve, founded by the German NGO "Forever Green", in 1994. It consists of 104,000ha, directly north of the Humaita-Lábrea highway and once constituted a rubber-tapping forest (*seringal*). Monitoring of any infraction of the bio-physical integrity of the area will require repeated RS imagery, from time to time complemented by ground control of any timber extraction or slash-and-burn agricultural activity.

It is to be expected that other RPPNs of major size will be created in the near future by owners of abandoned *seringais* in the Purús-Juruá area.

3.4.2. Biological or Ecological Reserves and Stations, of Federal or State Jurisdiction

A number of government-owned conservation units (UCs) with absolute protection exist within the state of Amazonas. Some of them are more than 500,000ha in size, such as those of Uatumã (560,000ha) and Juami-Japurá (573,000ha). There are also a number of minor ones, such as the UC of Anavilhanas (350,000ha) and Morro dos Sete Lagos (37,000ha). Seven of the UC have federal supervision, one is statal (Morro dos Sete Lagos). Their total surface is $2.3*10^6$ha or 1.5% of the State territory.

In general the UCs owe their absolute protection status due to their high biodiversity value. The public has no access and any human occupation or activity is prohibited (slash-and-burn, timber extraction, collection of floral or faunal species).

To maintain the integrity of the UCs it is indispensable to monitor and control any infractions with the use of RS (especially in the visible spectrum), repeatedly over the year, to be accompanied by vigilance, law enforcement and control along all the limits of the area, the latter often a pious wish rather than reality.

It should be noted that the UC areas have thus far only a rudimentary bio-physical characterization, and that the georeferenced terrestrial demarcation in the form of maps and benchmarks is still precarious, making it easy for the small-holder farmer, the individual ore digger, the individual forest product extractor, hunter or fisherman to enter accidentally or surreptively without being detected.

Biophysical characterization studies are still necessary within UCs, to define which parts will need absolute protection infinitely, with the other parts possibly to be transformed in UCs of controlled use, as Sustainable Development Reserves (see below).

3.4.3. Indigenous Lands and Parks

These are areas reserved exclusively for indigenous groups (Amerindians) for their physical and cultural survival. They are in various phases of regularization (identification, delineation, demarcation on the ground, formalization by federal law, registration in the official cadaster). The majority of the individual reserves is between 200,000ha and $8*10^6$ha in size, totaling $27.2*10^6$ha or 17.2% of the state's territory.

The control of the integrity of theses areas is in the hands of the Federal Government through its FUNAI (Fundação Nacional do Índio). Some registered reserves have the benefit of a local civil society under the patronage of the Confederation of Indigenous Organizations of Brazilian Amazon (COIAB). An example is the NGO "Programma Waimiri-Atroari", which has well equipped offices and trained personnel, both in Manaus and at the spot (approx. 200km north of Manaus).

FUNAI, as well as the societies for local support, repeatedly require RS products, in digital or photographic form, as well as hard- and software for GIS and image processing. This to monitor spatial changes in the dwellings of the indigenous groups (the present or recently deserted Indian villages are mostly easily identified on Landsat images!) and to control illegal activities of non-indigenous people. RS products will also facilitate the biophysical characterization of the land and water conditions inside the Reserve, as part of an ecological-environmental and cultural-anthropological rapid initial survey (Rapid Rural Appraisal - RRA). Later on, RS will be required for a more complete survey, to be able to make a prognosis of the needs in the future to support growth of the Indian population and its living style.

With the support of the PP-G7 programme, the FUNAI organization already avails of some interdisciplinary groups to carry out RRAs, but it will need more specialized technicians, including young indigenous ones, for the future.

3.4.4. National or State-Managed Parks

These are protected areas with a varied natural vegetation pattern, high scenic value and absence of recent anthropic action, where environmental studies and eco-tourism can be combined. The major examples of Amazonas are the National Park (PARNA) of Pico da Neblina ($2.2*10^6$ha) the State Park (PARES) of Serra do Araçá ($1.8*10^6$ha), both in the extreme north of the State, and the PARNA of Jaú ($2.3*10^6$ha), relatively near to Manaus. The total area of Amazonas Parks is $6.8*10^6$ha or 4.3% of the State's surface.

Consultation of RS data is required on annual basis, to avoid any new human occupation. The Jaú park is at present object of intensive multidisciplinary inventories and site studies, organized by the NGO "Victôria Amazônica" and with active participation of the National Institute for Amazonian Studies (Instituto Nacional de Pesquisas da Amazônia, INPA), both seated in Manaus, using digital and analogue RS products and organizing terrestrial expeditions that constitute a considerable investment.

It is to be expected that natural environmental changes in the Parks and their surroundings, (such as those caused by the El Niño) will be monitored by local ecological scientific groups of national and international composition (such as the LBA - Large-scale Biosphere/Atmosphere project of INPE/INPA/NASA/ EC). They will want to use repetitive RS material, such as Landsat and satellite radar, the latter especially to assess the seasonal dynamics of the surface hydrology.

3.4.5. National or State-Managed Forest (For Sustained Yield or Conservation)

These are lands of public or private ownership with homogeneous forest cover, earmarked for a sustained timber extraction or for conservation (for instance as store or sequestration mechanism for atmospheric CO_2: a form of indirect use).

Within the state of Amazonas, there are two main National Forests (FLONAs): one south of Tefé ($1*10^6$ha) and another one north of Barcelos (FLONA do Amazonas; $1.6*10^6$ha). There are thirteen other FLONAs with sizes varying between 20,000 and $3.7*10^6$ha, many times alongside or overlapping Indigenous Lands (upper Rio Purús, upper Rio Negro). Recently one more was added to the list: south-east of Humaitá (469,000ha), through the conversion of an old military reserve. Including the Rio Negro forest reserve ($3.8*10^6$ha), the total area of National Forests is $11.6*10^6$ha or 7.4% of the state territory.

The IPAAM institute is studying the possibility and feasibility to establish also State Forests. One of them would be the Rio Capitão area (about $3*10^6$ha of *terra firme*, between the medium courses of the Purús and Juruá rivers). Another prospective area for such purposes would be the Rio Abacaxis one, south of Maués. The federal IBAMA is responsible for the national forests, as well as the state-level IPAAM, will periodically require RS material to verify the non-violation of the above mentioned forest areas. They will also need to avail of technical teams for detailed terrestrial forest inventories as these will be needed for a decision on complete conservation or sustained commercial timber production (see below).

3.4.6. Areas of Environmental Protection (APAs) of Federal, Statal or Municipal Management

These are areas of high environmental fragility and low human population density, but located near to urban centers, with high scenic value, which could specifically be used for eco-tourism development. There are no examples of federal APAs in Amazonas state. At state level there are five, of which the more important ones are: Lago Ayapuá (lower Purús river, 610,000ha, an old floodplain area); Cueiras-Apuaú (directly northwest of Manaus, 741,000ha, upland with high biodiversity) and Cavernas de Maroaga (100km north of Manaus and west of Balbina hydropower lake, 375,000ha, with caves caverns, rapids and sources of mineral water). The latter two form part of IPAAM's priority area for integrated environmental management (PGAI-AM). The institute has the responsibility to ensure the environmental protection of these areas, in cooperation with the environmental entities of the municipalities of Presidente Figueiredo and Manaus and the rural people that happen to live in that area. Vigilance and control in the field is taking place to avoid new burnings, new small-holder occupation and timber extraction, especially along the road to Balbina and around the headwater parts of the micro-catchments. The total area of state-managed APAs is $2.5*10^6$ha or 1,6% of Amazonas state.

Also at municipal level there are some examples: The recently declared Rio Marmelos area (840,000ha), between Manicoré and the Transamazônica, with a very high biodiversity (many stretches of edaphic savannas and savanna forests, several spectacular rapids and waterfalls), which also forms part of the PGAI-AM/PP-G7 priority area. Others are located in Barcelos (Mariuá area; 500,000ha), Benjamin Constant (Jatinama) and Presidente Figueiredo (Urubuí, 37,000ha). More are likely to follow in the PGAI-AM context, especially if such municipal initiatives are to be supported by a long-term environment fund.

It is obvious that RS material will be very useful to control any human induced degradation of the environmental values of the APAs, whether of federal, state or municipal jurisdiction.

3.4.7. Sustainable Development Reserves (RDS), State-Managed

These are areas of public ownership, without specified federal jurisdiction and absence of indigenous groups, where it is being tried to harmonize conservation and sustained use of their natural resources, with the active participation and co-decision of the local traditional population, especially the riverside people (*caboclos*). It is a state initiative, with the daily management entrusted to a NGO of good standing and funding. The best known RDS is the Mamirauá area, located alongside the middle Solimões river ($1.1*10^6$ha of heterogenic *várzea* floodplains, with relatively dense traditional population). Another is located between the RDS Mamirauá and the PARNA Jaú, called RDS do Amaná ($2.3*10^6$ha, sparsely populated *terra firme*).

The management entities for the RDSs, such as the "Sociedade Civil Mamirauá" (seats in Belém and Tefé) need annual, if not seasonal, RS data, and a permanent team of technicians to monitor and carry out the ground control of the changes, with processing through an adapted GIS - along with the organizing of platforms of decision-making on sustainable use, with the local population.

The total area of sustainable development reserves stands at $3.4*10^6$ha or 2.2% of the State's territory. One of the results of the ecologic-economical zoning, ongoing in the south-eastern part of the State, could be the designation, together with the sizable local population, of a RDS of Novo Aripuanã - Manicoré, which is an area of high biodiversity (including new monkey species) an apparently rich Indian heritage; a high vulnerability to erosion, but also considerable potential for extraction of non-timber products. Because of the latter, the creation of an Extractive Reserve (see below) may be an alternative. In any case it will require substantial NGO support, in the form of the annual proceeds of an endowment fund, or else.

3.4.8. Extractive Reserves (RESEX), Federally Managed

These are areas of intensive traditional latex extraction, since the late nineteenth century, a type of exploitation which conserves the forest coverage with the passive or active participation of the rubber-trapping rural community. Therefore, several of these areas are being declared and registered as community property, receiving support for the marketing of the products (latex and associated non-timber products) and for the improvement of the living conditions of the rubber-tapping families, through the PP-G7 programme.

In the state of Amazonas there exists, thus far only one example, the RESEX Carauari in the lower Rio Juruá area (253,000ha). This one as well as future other extractive reserves, will need controlling by RS and ground control of invasions of non-associated people and any type of deforestation.

3.4.9. Mining and Gold-Digging Areas

These are areas that have mineral extraction entitlements, given by the federal government to companies, individuals or groups, with as objective the industrial mining of mineral ore (iron, copper, tin, aluminum, etc.) or of material for civil construction (pebbles, sand, clay for brick and tile making, limestone for cement or agricultural lime). Included in this discussion is the mostly illegal digging up of gold and other (semi)-precious minerals in land surface layers or in river sediments by free-roaming gold-diggers (*garimpeiros*).

In comparison with the situation in Pará state, these kinds of natural resource exploitation are very restricted in Amazonas state: around and north of Manaus (Pitinga, Nhamundá); some in the upper Rio Negro areas and others in the extreme southeast of the State. Even so, many mining title deeds were issued (see also a map produced by the Instituto Sócio-Ambiental in Brasília.

It is unlikely that individual gold diggers will ever refer to RS, when looking for new digging sites; mouth-to-mouth transfer of information is the common practice. The few large mining companies, such as Paranapanema (exploiting the Pitinga tin mine at 300km north of Manaus) or PETROBRAS (exploiting oil and gas in Urucu), avail of own aerial prospecting and monitoring facilities.

The task of the institutions that belong to the National System for the Environment (Sistema Nacional do Meio Ambiente), and IPAAM in the case of Amazonas, is to license, inspect and fiscalize all the mining activities, and to monitor and control their environmental effects.

RS products are helpful at the proper execution of these functions. As demonstrated clearly on Landsat TM images of the southeastern corner of the State (upper Ríos Abacaxi and Maués-açú), the activities of the gold diggers in that crystalline basement area can be easily detected through RS, by the whitish color of the fluvial sediments (instead the regular black or dark-blue color).

A finer geographic resolution with seasonal repetitions – hence radar – would be necessary to monitor the extent of extraction of construction materials, as prevalent in the surroundings of the metropole Manaus (1.5 million habitants).

3.4.10. Areas with a License to Extract Timber from the Primary Forest

At the moment, the State has seven large timber extraction and processing companies (Pará state has about 300!) and about 50 small ones. Most of them are licensed to log and utilize timber through a management plan, approved by the federal IBAMA agency, which is related to the sustainability of the forest as timber resource. This implies that a system of selective logging of low impact should be applied, which preserves the structure of the forest and the reproductive capacity of its individual species. Such forest management activities, require moreover an environmental license by IPAAM, with subsequent verification, to ensure that the off-site environmental effects, such as river pollution, remain to acceptable low levels. Spatial databases on approved management plans and environmental licenses for logging and processing of timber by industrial companies, large or small, exist in the offices of IBAMA and IPAAM respectively.

The great majority of the companies concerned is active in the floodable areas (recent *várzea*; old or high *várzea* terrains; low-terrace lands), preponderantly in the middle reaches of the Purús and Juruá rivers and the upper Solimões. They extract only a few soft-wooded species (Samaúma, Muriatinga, Virola), with cutting being done in the dry season and the transport by floating in the high-water season.

The majority of the individual floodplain concessions falls in the category between 100 and 10,000ha (a few ones are between 25,000 and 35,000ha), and the local managers will not normally make use of RS to control the annual extraction (in fact, the frequency of the mentioned species is often such that clear-cutting becomes very tempting). However, the big timber processing companies, most of them with their headquarters in Itacoatiara with its sea-faring port facilities, would be wise to obtain basic data and to monitor stocks in the large *várzea* areas mentioned above, with the help of RS and permanently available forest inventory teams. In such a way, they would convince themselves of the sustainability of their undertakings and investments in the long run.

The only large company that utilizes timber resources of the *terra firme*, is Mil Madeireiras (of the Swiss Precious Wood company), with a present-day concession of 81,000ha near Itacoatiara. It has received an international seal of good forestry practices. The monitoring of the effect of long-term selective timber extraction on a rotational basis is already in execution, through an arrangement with EMBRAPA in Manaus, using RS of high resolution and ground verification (conditions in felling gaps and skid trails; type and speed of timber regrowth).

There are numerous cases in all parts of the State and either on *várzea* or *terra firme* land, where timber extraction takes place without any license, whether as a by-product of slash-and-burn activities or within the primary forest. The illegal extraction of Mahogany and Cedro in the southwestern part of the State is a blatant case-in-point. The IBAMA organization is responsible for the monitoring and controlling for such situations, through caption of the products and the application of heavy fines. In practice, this is only sporadically done, due to the sheer expanse of the areas involved and the intricacy of the fluvial transport network. However, it is to be expected that in the priority areas for Integrated Environmental Management as promoted by IPAAM, the monitoring and control can become more complete and effective, in cooperation arrangements between IBAMA, IPAAM and Municipalities.

It should be noted that at regional Amazonian level, IBAMA is responsible for the execution of a major sub-programme of PP-G7, to promote the exploitation of timber products from primary forest on a sustained basis (PROMANEJO).

The monitoring and control of timber extraction and transport in any of the forms described above, requires frequently RS products of high resolution.

3.4.11. Other Areas (Cropping, Animal Husbandry, Fishery and Associated Land and Water Degradation Hazards)

This report deals with the conservation and management of the natural vegetation. In comparison with the neighboring States, the areas within Amazonas that have been deforested for any form of agriculture, are relatively small, (totalling about 3% of the statal territory). Within the confines of Amazonas state, the practice of "slash-and-burn" of forest in large units for cattle ranging or commercial production of grain crops (rice, soja) is taking place in modest form only. The majority of the experiments with industrial plantation of perennials (rubber, oil palm) where negative. Exceptions are the cultivation of guaraná (Maués), sugarcane (Presidente Figueiredo), both supported by refrigerant drink companies. Maybe the recent undertakings with the palm Pupunha (fruits and palm-hearts) and Paranut tree plantations will become successful as well.

The reasons are in part socio-economic (employment in the industrial center of the Tax-free Zone of Manaus; precarious terrestrial and fluvial rural infrastructure; lack of rural extension and credit), in part of bio-physical nature (absence of a well defined dry season, making slash-burning difficult, facilitating the proliferation of crop diseases and pests, and causing molding instead of proper drying of crop grains; majority of the soils being very acid, of inferior structure, of imperfect drainage and/or very sandy).

Even so, the areas of substantial anthropogenic influence deserve attention as to their geographic expansion in the course of years. Specifically concerned are the margins of the middle Amazon river, between Manaus and Parintins and stretches along the federal or state highways. The control of agricultural occupation along the federal highways, existing or planned, formally belongs to the federal institute for settlement and land reform (INCRA) of the ministry of Agrarian Reform. This boils down to the creation of formal settlement schemes of small-holders in virgin forest; each lot should contain a forest reserve part of 50%, when the size of the lot is more than 100 ha and of 20% when smaller; this results in extreme forest fragmentation, with moreover little control. Recently, the official settlement policy in the Amazonas region was changed in the sense that future settlements should be located on already deforested and degraded land. Even so, INCRA officials continue to justify the practice of occupation of primary forest areas with the argument that it concerns a "land ownership regularization" of areas that where occupied spontaneously and/or clandestinely.

In principle, any degradation of deforested land, the vigor of growth of secondary vegetation (with its carbon storage potential), and the benefits of conscious agro-forestry practices (for future timber and fruit supply) can be quantified and monitored using RS products of high resolution and frequent production. Main forms of physical erosion on the few existing cattle ranches and perennial plantations can be evaluated by aerial and ground-level monitoring.

The quality of the open waters – the incidence of pollution in relation to aquatic biodiversity and the stock of fish for food or ornamental purposes – is another aspect in which RS monitoring can be useful. IPAAM is to be the principal organizer of such a type of monitoring, applying methods (to be) developed in cooperation with scientists of INPA, EMBRAPA and the Federal University of Amazonas. Once again, the efforts are likely to be concentrated in the priority areas of PGAI-AM: Right now, these are the southeastern part of the State (Valley of the Madeira river) as well as the northeastern part (Valley of the Uatumã river and the zone of influence of the highway to Venezuela). In the near future, probably also the area of the upper Purús and Juruá rivers, adjoining Acre state, will be a major focus of attention.

The overall monitoring and control of deforestation and large-scale burnings is about to become part of two pilot sub-programmes of the international PP-G7 initiative: PRODESQUE and PROARCO (the latter specifically for the southern fringe of the region), both to be executed by the federal IBAMA institute. These projects will be major and frequent users of digital and analogue RS products, to be supplied by INPE. The storage and processing of the relevant data will be done through a national GIS and data bank.

3.5. Spatial data requirements and the operational environment

For the Legal Amazon Region as a whole, three recent inventories were carried out on the existing installations for RS and GIS, including the available or soon to be installed hard- and software, and the requirements for training of technicians. This was done with the proper execution of the various sub-programmes of PP-G7 in mind, and with special attention to the state-level natural resource policies (SPRN sub-programme).

A specific programme within the federal Ministry of the Environment and the Legal Amazon in Brasília, that aims to establish a system of shared databases on Amazonia already avails of rather detailed information on state level RS/GIS facilities and staffing.

3.5.1. Remote Sensing Products

The overview of the requirements on biophysical data, to identify and manage large areas of forest and other natural vegetation in Amazonas, as given in sections 0 and 0, provides the elements to specify the required RS materials. The RS products that are available at present are the following, in chronological order:

- Trimetrogon aerial photographs, scale 1:40,000, flown in 1942 by the American Air Force. AAF preliminary base maps, scale 1:250,000 were prepared on the basis of these photographs, and both the photos and the maps should still be in the archives of SUDAM, Belém. They give a rather detailed first overview of the occurrence of natural savannas in the region, as well as of the extent of deforestation at the time.
- Vertical aerial photographs, flown by the Brazilian Air Force (FAB) or national companies in the period between 1950-1980 for strategic areas, such as the broad stretches where federal highways were to be located. The majority of these photographs are at a scale of 1:100,000 and the negatives are archived by Aerofoto-Cruzeiro in Rio de Janeiro or the Geographic Service of the Military in Olinda.
- Individual images and semi-controlled photo-mosaics of airborne radar, flown by the Brazilian Air Force for the RADAMBRASIL project in 1971-72, covering the whole Brazilian Amazon (and beyond). The negatives are at scale 1:40,000 (resolution of 100m) and the mosaics at 1:250,000 or 1:100,000 scale. The originals are with IBGE in Salvador and Aerofoto-Cruzeiro in Rio de Janeiro. IPAAM avails of a full set of the semi-controlled mosaics in map sheet form.
- Satellite images in the optical spectrum at 1:250,000 of the US Landsat Thematic Mapper, functioning since 1972 and still operational. Images taken every 18 days, spatial resolution 30m. The quality for the Amazon region varies with cloudiness and fogginess.
  The Center for Promulgation of INPE in Cachoeira Paulista (SP) has copies of all original electronic tapes and full processing facilities. Copies in the form of CD-ROMs or as 1:250,000 scale false-color photo images can be bought there, but the price is high and waiting time is several months.
  IPAAM avails of a complete state-wide coverage of such images (bands 3, 4, 5), most of them of july-august 1995, when atmospheric conditions were exceptionally good. For the PGAI priority areas, also CD-ROMs of these images are available, as well as a few more recent ones with bands 1, 2, 3, 4, 5 and 7 combined (for drought prone areas, geologic features and recent land-use changes). Other institutions in Manaus (INPA, IBAMA, NGOs) have partial coverage at best.
- As from 1987, INPE is also the distributing agent for the French produced SPOT images. They are also in the visible spectrum, but with a higher resolution, but very expensive. IPAAM, did not acquire this material thus far.
- The National Metereologic Center in Brasília (linked to the Ministry of Agriculture) receives from time to time NOAA satellite imagery. It has a coarse resolution, but is useful for overview purposes. IPAAM does not avail of such material.
- Satellite radar products in digital or analogue form can be bought from the Japanese (JERS-I/SAR). The cycle is every 48 days and the resolution 12.5m. IPAAM does not have these, but some INPA scientists can use them free-of-charge, for experimental purposes, such as studying the seasonal surface water dynamics in the *várzea*.

Potentially the following radar products could be used in the (near) future:

- Satellite radar products of the Canadian RADARSAT programme. Every 24 days, since 1996. Resolution is variable (on demand). Prices are high. The RS unit of the University can make use of some of the material for experimental purposes.
- Satellite radar products of the German AEROSENSING programme. Radar bands X and P. Prices unknown. The company is calibrating its products in the Tapajóz National Forest (Pará state), together with INPE, and in the upper Negro river area of Amazonas state, in cooperation with the Geographic Service of the Military.
- Airborne radar of the US/Brazilian SIVAM programme, meant for vigilance purpose of the whole Brazilian Amazon by the Military, but also to be available for improving topographic base maps, natural resources evaluation and environmental management. About to become operational, with a main field office in Manaus. Close cooperation with IPAAM is foreseen, but the costs involved are still unknown.
- A Chino-Brazilian satellite, for observations in the optical spectrum on land cover and land-use conditions in tropical countries is planned to be launched in 1999.

As discussed in section 0, only one set of Landsat TM and/or Radar, in digital (CD-ROM) or analogue form (photographs, mosaics or false color images) will be needed for one-time activities, such as initial general reconnaissance surveys, zoning, or the preparation of master plans or management plans. Such a complete set of RS products is relatively expensive thus far, but it still is very modest in comparison to the cost of the required associated ground validation.

In contrast to this, the requirements to facilitate the continuous activities by the management unit of areas of already defined use, are much more demanding. The RS materials in this case should be:

- produced repeatedly (short global flight cycles);
- of constant high quality;
- to be made available without interruptions and within the shortest time-laps (if possible at near real-time);
- available at modest costs, if not for free to the governmental users (municipal-, district-, state- or federal level) and the associated environmental NGOs;
- accessible with the least possible limitations on the national security side, while avoiding use of the material for natural resource predatory purposes;
- the guaranteed minimum period of the availability of the products should be in the order of 25 years. This condition may be more realistic for the recent RS initiatives as described above, than for the ongoing programmes of scientific technical cooperation (PP-G7, LBA, TFAB, etc.) that should ensure the modest pricing of the RS products for the local Amazonian users.

3.5.2. Infrastructure for Geoprocessing

Geoprocessing facilities for RS material and associated ground-truth data can be modest or very sophisticated, depending on the type or characterization or management of the bio-physical and/or other conditions that one has in mind. When a center needs to process one or more time series of digital format quickly, then the necessities are large. Such processing can take place in the capital or some major municipality of the State, linked with federal or state entities, major NGOs or private companies.

At present, the Manaus-located RS/GIS laboratories are the following: IPAAM, INPA, FUA, CPRM, IPT, FVA, SUPEZ-AM of IBAMA and 4DL/SGM (Military).

Considering the present infra-structural and socio-economic conditions of the interior of Amazonas state, geoprocessing units at municipal level can have modest forms only, with few exceptions. These exceptions are Tefé (S.C.Mamirauá), Itacoatiara (Mil Madeireiras, a.o.), Rio Preto da Eva (prefecture, with SUDAM support) and Presidente Figueiredo (idem). The latter three have daily terrestrial transport facilities with Manaus. Even in these few cases, one cannot realistically plan for a local infrastructure that can receive or process raw digital RS data in real or near-real time. In all cases it will be wise to keep and maintain traditional cartographic and photographic equipment – allowing continuation of the work on already acquired RS material.

3.5.3. Facilities for Ground Truthing, on-the-spot Fiscalization and Control

The terrestrial survey and monitoring activities will always be the most critical and costly element for the user or local manager. This because of the disciplinary and institutional complexity of the work, the extremely difficult physical access to the forest, the costly and precarious transport facilities, the seasonal irregularities and the poor working and living conditions in the Amazon forest in general.
The number of qualified national technicians, who are prepared to work for several years away from the capital or the few major towns in the interior of central Amazonia, are rare indeed. The guarantee of a financial compensation in the form of a hardship allowance could be a stimulating measure. At the same time, a special effort will be needed to strengthen a spirit of pioneering and civil responsibility among technicians to want to serve the community in remote places.

Investment in qualified technicians of the region itself is needed, and any potential commercial supplier of RS/GIS hard- and software should be prepared to support, financially or otherwise, the drudgy and expensive ground-based activities locally.

3.5.4. Training and Capacity Building of Personnel

There is a need to train staff and auxiliary personnel for the established or foreseen laboratories for RS/GIS. Both for the natural resource inventory work and for the adequate management of major geographic units for conservation and/or development purposes, a substantial increase in the number of scientific-technical staff will be required as well.

Limiting ourselves to the biophysical aspects, there is a need for multidisciplinary teams that cover aspects such as: geology, geomorphology, hydrology, agro-climatology, pedology, forest biomass and species composition assessment, floristic and faunal biodiversity assessment and their interrelationships with ecology and environmental assessment in general.

In Manaus, the following technical-educational establishments exist, which can provide a good part of the training-requirements:

- Five private schools of higher education
- The Federal Agrotechnical School (EAF), which includes an orientation on forest management – medium level
- The Technological Institute of Amazonas (UTAM), also with an orientation on forest inventory and forest-management – higher level (B.Sc.)
- The Federal University of Amazonas Foundation (FUA), with courses at B.Sc. and M.Sc. levels in the subjects geology, biology, forest engineering, fisheries, agronomy, as well as various graduate and post-graduate courses in the social science area. Within the University there is also a Center for Environmental Studies, which has a broad interdisciplinary orientation for M.Sc. graduation. The University can confer Ph.D. titles in Entomology, Botany, Ecology and Forest Management, through the scientific guidance and facilities of post-doctorate staff of INPA.
- The National Council for Research (CNPq) of the Federal Ministry of Education (MEC), provides quite a number of research grants, either in Manaus (FUA-INPA) or at Universities in north America and Europe (partly in cooperation with local entities). Also international research orientated cooperation programmes of INPA, such as the German SHIFT, the Japanese JACARANDA, the French ORSTOM-linked, the British BIONTE and the US Smithsonian-linked programmes, are providing some facilities for overseas post-graduate training.

Additional international training facilities at graduate and post-graduate level would be most useful, especially:

- to build-up and strengthen a cadre of leading staff members for inter- and multidisciplinary groups;
- to increase the quality of the university and sub-university level education;
- to improve the orientation and practical output of mixed teams for inventory/zoning/monitoring of the natural resources and their environmental management.

The following objects can be mentioned specifically: integrated survey, rural survey, modern forest inventory and management (selective and sustainable), assessment of forest-land biomass in relation to global climate change, techniques to map and evaluate the various aspects of biodiversity, and the assessment of land and water resources in conjunction – all, of course, with ample use of the various types of RS data.

3.6. Problems related to spatial data use

Thematic data

- There have been several comprehensive studies of the natural resources of the Amazon basin, some of which have been based on remotely sensed data ranging from aerial photography (1942) to radar and optical imagery. There is however a lack of ground validation of remotely sensed images, due to the sheer size and inaccessibility of large parts of the Amazon basin. The result is an often poor correlation between different parameters, such as soil and vegetation.
- The international community has shown great interest in the study and the protection of the natural vegetation of the Amazon, which is evident from the many (pilot) projects taking place. These projects usually generate large quantities of (spatial) data, but they are frequently not comprehensive (area-wise) and specific to a particular application or field of applied research (e.g. pilot projects from JERS and RADARSAT, and upcoming project from AEROSENSING). The current PP-G7 project aims at providing remotely sensed data for monitoring and control, but this has yet to be effected.

Institutional weaknesses

- There are quite a few institutes at federal, state and municipal levels that have jurisdiction over a particular territory or natural resource. In some cases the interests (and not necessarily the objectives) of different institutes are overlapping and/or conflicting. For instance, throughout the Legal Amazonia IBAMA has to endorse management plans involving forests, while in the State of Amazonas IPAAM has to endorse management plans for their environmental soundness. Similarly, the military is proclaiming certain areas to be of national security interest (thus prohibiting any trespassing or economic activity), while these may have been allotted to other uses (as was the case with the officially established Yanomani tribal area in north-western Amazonas).
- With respect to remotely sensed data, INPE is the federal agency dealing with its distribution to other federal institutes and state governments. This rather stringent procedure is being criticized by many people throughout Brazil as being too expensive and taking too long to deliver.

4. COSTA RICA

4.1. Study organization

The Costa Rica country study was undertaken by independent consultants with ample experience in the fields of forestry and RS:

- Dr. G. Arturo Sánchez-Azofeifa.
  Assistant Professor, Department of Earth and Atmospheric Sciences, University of Alberta, Canada. Formerly head of the Geomatics unit of the Centro de Investigaciones en Desarrollo Sostenible (CIEDES), Costa Rica. Lead scientist in the recent deforestation study of Costa Rica.

- Carlos León-Perez, MSc, MPA.
  GIS and land evaluation expert. Formerly with the Ministerio de Agricultura y Ganadería (MAG).

Since the study concentrated on policies and spatial data use for SFM little fieldwork (i.e. down to the local branch office of the FD or local NGOs) was undertaken. Instead, all the major institutes involved in forest and land management were visited and invited to participate in the study.

4.2. Forest usage and management

In 1992, Costa Rica's Strategy for Sustainable Development indicated that, if unchanged, the trend of unsustainable management of the country's forest resources in the last 50 years would deplete all primary forest of commercial timber by 1995. Costa Rica's deforestation rate between 1976 and 1990 had been estimated at 3.2% per year, the fifth highest in the world. Reforestation efforts were estimated as being negligible before 1979, and had increased at a slow rate since then.
Table 4.1 presents past trends of forest loss in Costa Rica and its deforestation rates.

Table 4.1 Tropical deforestation and deforestation rates for Costa Rica.

Year	Forest Cover (ha)	% of the Country	Deforestation rate (ha/yr)	Author
1940	3,420,600	67%	N.D.	Sader y Joyce, 1988
1950	2,864,200	56%	55,640	Sader y Joyce, 1988
1961	2,303,500	45%	50,972	Sader y Joyce, 1988
1977	2,085,900	41%	52,000	Sylvander, 1977
1983	1,330,000	26%	43,350	Junkov, 1985
1992	1,359,000	27%	44,994	Sánchez-Azofeifa, 1996
1997	2,063,487	40%	16,424	FONAFIFO, 1997

N.D. means 'no data'.

Different methodologies and minimum mapping units make comparisons between different studies difficult to achieve from Table 4.1. One obvious conclusion is that during the last 50 years deforestation has been the most important force driving land cover change in Costa Rica. Differences such as 13% between the 1992 and 1997 figures are, for example, the result of impossible task of producing cloud free estimates of forest cover and deforestation rates in a country with high cloud cover. These situations will be explored further in this report.

The dynamics of land-use / land-cover change (LUCC) in Costa Rica during the last 30 years have generally been driven by the expansion of the agricultural and cattle frontier. This LUCC process was encouraged by legislation which placed a low value on forest lands and a high value on agricultural development. Tropical deforestation was also considered to be important to the expansion of meat production, and was strongly supported through national and international loans. Deforestation was used as a tool to expand grazing land without regard for potential environmental degradation. By 1980, the Centro Científico Tropical (CCT) indicated that up to 76% of all land with potential for crop production was occupied by pastures. Furthermore, it was concluded that during the earlier stages of the country's deforestation, the demand for agricultural land (usually for pasture), rather than the demand for timber, was the main force driving deforestation.

Sanchez-Azofeifa and Quesada-Mateo (1995) indicated that the deforestation rates in Costa Rica have decreased significantly in the last decade. Deforestation rates may have been reduced as result of a combination of factors such as the following:

- An increase in the cost of wood, thereby reducing per capita demand.
- The increase in the efficiency of harvest, by reducing wood volumes burned or wasted, as well as the increase in the number of exploitable species and the implementation of new concepts related with sustainable forest management.
- Increased efficiency at the industrial level, including improvement in the exploitable yields at saw mills.
- A greater desire to protect forests by an organized rural population.
- The increase of private reserve areas for the purpose of exploiting eco-tourism, or as protection estates located in buffer areas around national parks with a view of maintaining options for a future sustainable exploitation.
- The development of financial incentives by the central government for the preservation of forest and payment of environmental services provided by them (i.e. the creation of the National Forestry Fund (FONAFIFO) and the new forestry law 7575).
- The presence of several Activities Implemented Jointly (AIJ) as part of projects dealing with carbon sequestration and the Framework Convention for Climate Change (FCCC)

The combinations of these events have contributed to the reduction of tropical deforestation rates in the last 10 years. By 1998, FONAFIFO indicated that the total net forest lost between 1986 and 1997 was only 32,000ha, and the deforestation rate was less than 1.0% per year for the study period. It also reported that Costa Rica had a total of 2,063,487ha of forest cover (forest units with a minimum-mapping unit of 3ha). This is equivalent to more than 40% of the country's total territory. FONAFIFO's study is the first of its kind in Costa Rica, which had a comprehensive wall-to-wall coverage of relatively cloud free data for the country. FONAFIFO's data set was certified by International Conservation.

4.3. Overview of RS and GIS Studies in Costa Rica

The first attempts to implement a nationwide natural resources inventory in Costa Rica dates back to the late 1970s early 1980s. The Costa Rican Government and USAID coordinated this first attempt. The study was prompted by concerns of Costa Rica's Government regarding accelerated rates of land use change and their associated impacts on the national environment. Campbell et al. (1979) implemented a three-phase project to design an operational natural resource inventory and data system for Costa Rica. This system used aerial photography and Landsat MSS satellite imagery.

Sader's (1979) project was also part of the national natural resource inventory sponsored by USAID. The main goal of this project was to evaluate the applicability of Landsat MSS data for resource management in Costa Rica. Landsat MSS data was used as the primary source to estimate the area of coffee lands in the Naranjo region. This study used a GIS and a stratified database to improve coffee detection. Sader concluded that RS derived data was able to estimate coffee areas within 8% error. In addition, this study reported that Landsat MSS was able to identify mangrove and grassland classes reasonably well, but was considerably less accurate in the identification of forest and brush. RS results were compared with aerial photography derived data. Even though Sader's study provided important insights regarding the application of RS technologies in Costa Rica, it was suggested that aerial photography was better suited for Costa Rica's interests at that time.

In 1988 Sader conducted a second study related to application of RS and GIS technology in Costa Rica. This study focussed on the use of multi-temporal Landsat MSS to monitor and map forest change dynamics. Satellite image analysis was compared to aerial photography interpretation. An NDVI was computed for a subset of a satellite scene in north-eastern Costa Rica (La Selva Research Station). Sader's conclusions indicated that the use of multi-temporal NDVI, without cross reference to aerial photography, was not recommended for operational forest inventory programs where the objective is to update forest maps or forest area statistics. The study also suggested that a combination of two dates of imagery was adequate to detect forest change using NDVI.

The only comprehensive country-wide forest cover and deforestation study for Costa Rica has been presented by Sader and Joyce (1988). Their study attempted to measure relatively undisturbed natural forest with an upper canopy cover of 80% of more. The study period was between 1940 and 1983. This country study involved aerial photography interpretation and digitizing of available forest cover maps. Maps provided by several Costa Rican institutions and aerial photography interpretation were integrated into a GIS with other spatial databases (i.e. roads, slope ranges, etc.). The minimum mapping unit was 55ha (750m grid). The study reported that total primary forest remaining in 1940, 1950, 1961, 1977, and 1983 was 67, 56, 45, 32, and 17 percent of Costa Rica's territory, respectively. This paper concluded that:

- deforestation had initially occurred in tropical dry and moist life zones; during intermediate periods, tropical and premontane moist and wet zones were more affected;
- by 1983, only the less accessible high rainfall zones in rugged terrain retained relatively undisturbed forest; and
- the reported forest areas estimates pertained only to primary forest as portrayed by the source maps, indicating that total forest area in Costa Rica could be higher than what they figured. The authors concluded that there was a need for future development of quantitative estimates of deforestation and afforestation for Costa Rica using RS techniques.

RS and GIS technology has also been implemented in Costa Rica to monitor migratory bird habitats (Sader et al., 1991). This project was implemented in north-eastern Costa Rica, in the vicinity of La Selva Research Station and the Braulio Carrillo National Park. Results indicated an overall accuracy of the forest and non-forest map was 70%. Forest class accuracy was reported to be 93%. The study concluded that satellite RS was able to provide information about habitat availability and habitat conversion that could not be obtained by other means at that time. The study reported problems in classifying successional and secondary growth habitats when the unsupervised classification technique was used. Unsupervised classifications were unable to distinguish between major vegetation groups that are important for migratory birds. The authors concluded that the use of a supervised classification, where plots are selected using aerial photography in successional and secondary growth would improve the classification of habitat types.

Several regional studies integrating RS and other socio-economic data using GIS were conducted in Costa Rica during the 1990s. Velkamp (1992) presented a clear example of the potential of GIS for studying and monitoring deforestation at the regional level in Costa Rica. This study links a quantitative inventory of deforestation to possible factors driving forest clearing, like accessibility and soil quality. Aerial photography taken in 1952, 1960, 1971 and 1973 for a 395km^2 area in the Atlantic region was used. This study integrated several data layers of data such as soil fertility, river networks and road distribution. The integration of the former layers of data made it possible to understand some of the dynamics of deforestation in the Atlantic region. The study concluded that aerial photography offers a good means for deforestation analysis in Costa Rica.

The Timber and Forest Sector Cooperation Project performed a comprehensive mapping of deforestation at regional scale. This project is part of a Costa Rican and German Government conservation project. The German Agency for International Development (GTZ) funded this project. The project focussed on the northern region of Costa Rica (5,600km^2). The study's objective was to create a geographic database to support a regional plan for forest development in San Carlos. The result of this project was a 1:50,000 scale map, using six different kinds of forest disturbance. This project did not provide information regarding the state of forest fragmentation in the study area, nor the rate of tropical deforestation in the region.

During the first part of the 1990s two key studies related to tropical deforestation in Costa Rica using RS and GIS were implemented.

The NASA Tropical Deforestation Project used Landsat TM to have a first wall-to-wall estimation of forest cover and deforestation rates between 1986 and 1991/92. Findings from this report indicate that tropical deforestation is slowing as a result of new conservation policies established by the national government. Final map scale was selected to be 1:250,000. The scale was selected because of the use of satellite false color composite photos for comparison and definition of classes. For the 1:250,000 scale, minimum mapping unit is approximately 3ha.

Four Landsat TM scenes with less than 20% cloud cover were used to map 1991 forest cover. These four scenes represent 93% of Costa Rica's territory. The analysis for 1991 showed that 29% ($1.4*10^6$ha) of the country was covered with primary forest with a canopy density of 80%, 54% ($2.6*10^6$ha) was identified as non-forest, and 17% (800,687ha) was covered with clouds. Highest cloud cover was in the northern zone and the Peninsula de Osa.

Results were significantly different from those of Sader and Joyce (1988). Sader and Joyce reported that only 17% forest cover was present in 1983, in contrast with the 29% reported in this study. There are some possible explanations for the differences. First, the Sader and Joyce (1988) study was based on digitized maps from different sources (which can contain important classification errors). Second, the minimum-mapping unit selected for the 1983 study was 55ha, in contrast with 3ha in this study. Sader and Joyce were aware of this potential difference and suggested that their reported forest area could be underestimated.

By overlaying the new 1991 forest cover image on maps of national parks, the study reported that of the total primary forest mapped, 29% percent of the mapped primary forest is protected by national parks, and 71% is outside of these protected areas. Existing forest cover is spatially concentrated along the central cordillera, where high slopes and accesses are difficult.

The most up-to-date study on tropical deforestation and with direct implications to SFM was implemented by FONAFIFO. This work was performed by CIEDES and CCT. Conservation International certified the study. FONAFIFO’s report indicates that by 1997 the country possessed 40% forest cover.

4.4. Forest Management in Costa Rica

SFM is not a new concept for Costa Rica. The first step on conservation and use of Costa Rica’s forest resources came from policies aimed to set aside 25% of the country for conservation and protection. This was done by means of the National System of Conservation Areas (SINAC). Unfortunately, at the same time that national parks were created by the national government, an uncontrolled process of tropical deforestation took place outside of these conservation areas. In general, no policies aimed at SFM were followed and little regard toward the existing forestry legislation existed.

CCT indicated that “from 1970 to 1990 the protected area system became firmly established, and the forestry industry continued to rise. Financial incentives for reforestation became government’s main policy tool in forestry. These incentives mostly benefited larger landowners and were generally insensitive to people’s motivations for forest management and conservation. The main losers were the small holders, who collectively own about two-thirds of the country’s land.” Government incentives ranged form: forest conservation, tax exemption incentives, and SFM.

The reduction of deforestation rates in Costa Rica has not come without cost. It has been estimated that a total of US$115 million has been expended during the process. It is also estimated that more than US$800 million has been contributed by private investment. Contribution from the private sector has helped to reforest 145,000ha during the last 10 years. Most of the investment has come in the form of different types of financial incentives (rent tax exceptions, forest management incentives, conservation certificates, and forest protection incentives).

4.4.1. Forestry Law 7575

One of the most important outcomes is the implementation of a new forestry law (Law No. 7575). With the passage in 1995 of the Law 7575, the forestry sector was provided with a new legal framework. One of the most important contributions of the Forestry Law 7575 is related with forest management on private lands. The new law indicates that on forest lands, land cover or land use change will not be permitted. In addition the law indicates the forestlands can only be exploited if there is a management plan preventing adverse environmental impacts. The effectiveness of this practice stills under discussion. The following are the four main points of the law:

- <u>Recognition of payment of environmental services provided by forest.</u>
  The law recognizes that forest and forest plantations provide important environmental services that directly affect the protection and improvement of the environment. The following are the main environmental services recognized by the Law: Mitigation of greenhouse gases (reduction, sequestration, absorption and storage); protection of water resources for urban and rural use, as well as hydropower generation; biodiversity protection so it used and preserved as part of national sustainable development goals (scientific studies, pharmaceutics use, and genetic improvement); ecosystem protection; and landscape protection (scientific and tourism goals).

- <u>Definition of a new role for the central government concerning its responsibility to protect and oversee forest lands, and its role in promoting and facilitating private actions.</u>
  The law indicates that the central government has the following responsibilities when dealing with sustainable forestry issues:
  - To preserve the country’s forest resources at all levels (private and state owned lands).
  - To approve forest management plans based on the forestry law.
  - To indicate the main conditions that are part of a forest management plan based on the law and the monitoring of that those conditions are met.
  - To administer FONAFIFO.
  - To establish protection guidelines for endangered species or those species that because of their nature can affect the survival of other plant or animal communities.
  - To implement a national forest inventory with the goal of evaluating the status of the country’s forest resources.
  - To keep an inventory of all research on forestry at the national level.
  - To promote and standardize distribution, education and training related to SFM.
  - To develop and promote programs aimed to the sustainable management of forest resources.
  - To promote the acquisition of financial resources to support activities related to SFM.
  - Delegate duties and responsibilities to other actors such as Forestry regents, Municipalities and Regional Forestry Councils
  - Deregulation of tree plantations, agro-forestry systems and the industry, in order to favor decision-making by the business sector.

- <u>Renovation of an obsolete institutional structure.</u>
  Responsibilities are delegated, so specialized institutions and organizations are best prepared to do what has been assigned to them. For several years the responsibility of the forestry sectors was in hands of the General Directorate of Forestry (DGF). This organism was in charge of monitoring and controlling tropical deforestation at the national level with not much success. Under the new forestry law a new organization was created so there is a close coordination with the vertical and horizontal levels, as well between the private, public and international sectors. At this time is difficult to try to present a flow diagram regarding SFM and institutional responsibilities in the country since the new forestry law make important changes that still under implementation.

4.4.2. Constraints and degree of success for SFM policies in Costa Rica

CCT has prepared a comprehensive study regarding constraints and successes of SFM in Costa Rica. The most important constraints to SFM are being identified as:

- The macro-economy, particularly structural adjustment, which has a large part in determining forest policy.
- Excessive influence on policy of some actors, particularly sections of government, forest industry, and more recently the advocates of forest protection.
- Limited policy analysis capabilities amongst key actors.
- A high level of regulation that, in effect, protects the existing large-scale forest industry.
- Forestry financial incentives benefitting only the large landholders.
- The integration of forest management and forest product processing is not yet perceived to be profitable by small-scale and medium-scale enterprises.
- Uncommunicative and unresponsive state agencies, and capacity weaknesses in local government.
- Existing mechanisms for regionalization do not coincide with coherent socio-cultural areas.

Additionally the same study reports that the most important policies and policy processes with some degree of success are:

- Costa Rica's natural strength with regard to policy for forests and people lies in its high level of education, its history of social organization and its relatively democratic governance systems.
- Cross-sectional policy analyses, when well targeted, have brought sector actors together and given impetus to policy debates.
- Economic incentives increase capacity amongst large-scale producers, and increase levels of organization amongst small-holders, if government can afford them.
- Linking local success to regional alliances and national associations generates considerable "political space" for improving policy.
- Public/private collaboration for forestry technical assistance has raised standards, for example, through the 'forest regents' program.
- Initiatives ensuring that local groups benefit more from conservation are beginning a necessary 'socializing' of the protected area system.
- Progressive land taxation can be an effective tool for redistributing land to those that need it, and for providing locally controlled resources for better land use.
- New 'green policies' can secure international finance. Eco-tourism is already providing high returns, while bio-prospecting and carbon fixing both offer much potential. However, distribution of the benefits is an issue requiring negotiation.
- Constitutional guarantees on the environment, through the Constitutional Chamber of the Supreme Court and the Ombudsman's Office, have provided new means for citizen participation in environmental management.
- Innovative bilateral support, for example through the National Council of Non-governmental Organizations, can create effective space for negotiation of differences between actors.

4.5. GIS and RS for SFM in Costa Rica

The development of GIS in Costa Rica is relatively recent (approximately 5 to 10 years) and its application is still essentially limited to the academic and government institutions, with the private sector undertaking modest investment in the technology.

The use of GIS for SFM has developed as a function of policy changes and new legislation. Until about 1990 GIS was used by DGF to extend and monitor licenses for logging only, an activity that was compromised by corruption and the sale of illegal concessions, etc. Thus, forest management was empirical and the damage

done to ecosystems by logging was enormous. Nobody seemed interested in the use of technology for optimizing the use of the forest resources, let alone GIS.
In 1986 some incentives were introduced for forest plantations, since the elevated deforestation rate (more than 1%) was causing extreme events of precipitation and inundation, landslides and severe soil erosion. The implementation of various programmes for the mitigation and reduction of the high deforestation rate met with a variety of problems related to logistics and verification. Often the incentives were extended to reforested areas, and the efficiency could not be established. Field surveys were forged and silvicultural management was insufficient. Under these circumstances and with the maturity of commercially available GIS systems some technicians and international scientists started using GIS to estimate the true extent of the problem of deforestation and its possible solutions.

4.5.1. CATIE and the first experiences

One of the factors affecting the use of GIS was the absence of suitable computers. Early in the 1980s there was only one mainframe computer in the country available for analyzing digital RS imagery, at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE).

The mission of CATIE, aided by the “boom” in sustainable development, facilitated the resources required to undertake the first activities in image analysis, digital orthophotography and other new technologies. Most activities focussed on land cover and land use in different areas of Central America, for comparison with studies executed by American universities.

At that time, CATIE possessed perhaps the most powerful GIS facility of Central America, established with international assistance. The activities concentrated on the analysis of Landsat imagery and also included some SPOT imagery. Later on, with the implementation of the Regional Programmes for the Management of Watersheds and the Management of Natural Forests, a strategy was developed using PC-based software. Through the academic program in CATIE geo-spatial modeling was used for the identification of critical areas for agriculture, land evaluation, etc.

Through these experiences the academic and government institutions became interested, although the high costs associated with installation and maintenance provoked caution. The following problems caused additional caution:

- Inconsistency in spectral signatures in scenes for similar forest coverages;
- Absence of good quality satellite imagery and elevated cost;
- Shortage of qualified staff
- Limitations in analytical power, due to lacking computer power.

Currently CATIE is involved in the development of user-oriented tools for spatial analysis, creating specific applications for specific users. The most successful of these are:

- Models for precision agriculture for ecological management of banana;
- Optimization of sustainable management for extraction of timber from forests, focussing on access and transportation;
- Municipal management systems for water distribution, environmental monitoring, waste management, etc.

The programmes Management of Secondary Forests and Forest Seeds are increasingly using GIS for their activities. Use of GIS in an operational context is foreseen for activities like:

- Digital cartography of project areas and land use;
- Inventory of silvicultural resources;
- Thematic maps: precipitation, temperature, etc.
- Location of seed banks and other resources;
- Access roads.

Being a regional institute, CATIE is developing activities in all its member states, but GIS is mainly limited to Costa Rica.

4.5.2. GIS and data currency

Costa Rica can not be regarded as being in the vanguard of data management. Despite having a National Statistics and Census Directorate and IGN, the resources are so limited and the political support so low, that the integrity and quality of the available data has to be questioned. For example, the agricultural censuses are based on declarations of the farmers and have little or no geographical or cadastral verification. The same holds true for forest plantations and protected areas, where scientifically derived and verified data are missing. The last national census is from 1984 and the next will not take place until the year 2000.

The previous situation reflects the organizational culture not only found in the public sector, but also the private sector shows no intention of using current, verified spatial data for decision-making. Only in 1997 some public and private companies involved in forest plantation management recognized the need for good quality data. The system "Natural resources of Costa Rica" is exemplary in this context. Developed in 1988 by the Ministry of Agriculture and Livestock (MAG) and DGF with the assistance of FAO, the system is still the major database for data on climate, soil, life zones, erosion risk, etc, and has all data georeferenced. Paradoxically, the system has been kept almost in secrecy without updating the stored data and with virtually no access to users outside of the two ministries.

The development of GIS in Costa Rica has focussed too much on equipment and materials (imagery), forgetting to establish the databases that would lend substance to the systems.

4.5.3. Public Sector

In the public sector, the actual and potential users benefitting most from GIS technology are the Soil Conservation Service in MAG and the Sistema Nacional de Areas de Conservación (SINAC). Both organizations have built modest GIS facilities with external assistance. Both have about five years of experience and some useful systems.

<u>Ministry of Agriculture and Livestock (MAG)</u>

MAG is considering forest management as a land use type in a production system, located in a forest on any unit, whether that is a drainage basin, a micro-watershed or administrative unit.

The agricultural land capability classification requires a large amount of spatial data on soils, geology, hydrology, meteorological, etc. The MAG is aware that for management plans it requires data of sufficient detail. At the moment a country-wide spatial database at a scale of 1:200,000 is available with thematic layers on soils, climate and elevation. For the Atlantic zone a spatial database at a scale of 1:50,000 is available. In 1999 a study will be finished covering 70% of the country with various thematic layers at detailed scale that can be used for agriculture and forestry purposes.

MAG requires the following spatial data sets:

- Soils (being elaborated);
- Land use capability;
- Climatic parameters;
- Digital Elevation Model;
- Infrastructure;
- Socio-economic data (per capita income, land tenure, etc.).

Much of the data sets mentioned above are in fact not generated by the MAG itself, instead they should be produced by other (government) institutions.

National System for the Conservation of Protected Areas (SINAC)

The establishment of the National System for the Conservation of Protected Areas (SINAC) in the Ministry of the Environment and Energy (MINAE) and the adoption of "sustainability" policies requires the Government to generate or acquire and process data for SFM in a systematic way. In reality, but a few technicians in MINAE/SINAC are trained in the use of GIS and most of the available data is not georeferenced and of coarse detail. Simultaneously the Comisión Terra, a commission linked to the President of the Republic, was formed with large amounts of financial resources and the objective to compile spatial data for the whole country. This commission created friction between the different public institutes using GIS and has left SINAC with little resources and possibilities.

Despite the fact that MINAE by law must maintain a series of data sets for SFM the data that is actually available is little and often is derived from data sets of other institutes, such as CATIE and IGN. There are no clear policies regarding spatial data management. MINAEC should have at least the following data georeferenced:

- Timber extraction sites/ concessions;
- Buffer zones;
- Protected areas for hydrological resources and biodiversity;
- Fragmented areas.

The precarious situation in which spatial data management is currently can be blamed entirely on the political leadership, which is unaware of the nature of spatial data management and the benefits it can bring to the organization; hence no clear directives are given for operational management.

Instituto Geografico Nacional (IGN)

IGN is by law the institute that compiles, publishes and processes geographical data in the country. IGN has well-trained technicians in the fields of cartography, geodetics, etc. It has a wealth of data of good quality, and although it is also suffering from budget constraints it recently acquired powerful equipment for image analysis, with the assistance of JICA. The Comisión Terra has usurped part of the mandate of IGN, even while the former does not have the expertise of the latter.

IGN is in general cooperating with other government institutes in the analysis and processing of spatial data. For SFM it provides geological and hydrological data and it produces climatological data in cooperation with the National Meteorological Institute.

Dirección de Catastro y Registro

Part of the Ministry of Justice, the Directorate of Cadaster and Registry possesses perhaps the best equipment in the country for orthophoto-interpretation and large databases with all registered property, including land. These databases are indispensable in land use planning. Nevertheless, these databases are used relatively little for land use and forest planning, even though the costs associated with queries are moderate.

Universities

The two most important public universities, the Universidad de Costa Rica and the Universidad Nacional, have GIS facilities for various purposes and in differing degrees of development. UCR has a well-developed facility in the Centro de Investigaciones en Desarrollo Sostenible (CIEDES), although it is lacking a sufficient number of technicians. Other facilities have little attention for forest management.

The higher level Forestry Schools do not have a consistent approach towards the use of GIS for SFM, although some inroads have been made.

4.5.4. Non-Governmental Organizations (NGOs)

With the growing popularity of "sustainable development" and in view of the deteriorating environment many civil environmental organizations transformed into NGOs, filling the gaps that the public sector did not fill. Some of these have been very successful in finding external funding, although not all of them can meet with approval from external auditors. Fraud and abuse of funds have made some financiers shy away from Costa Rica, or concentrate on more established NGOs, with an academic focus.

In the field of forest management, reforestation, natural resource management and the environment, there are two NGOs that stand out from the rest. These are the Centro Científico Tropical and the Organización para Estudios Tropicales.

Centro Científico Tropical (CCT)

In the field of forest management CCT is improving the information base through improved technical and academic knowledge. This knowledge refers to forest composition, area, carbon sequestration and the economic value of environmental services provided by the forest. CCT also manages a number of protected areas and functions as a forum for the discussion of natural resources management in general.

CCT maintains a GIS with spatial data on forest, being used to support decision-making by government institutes. The GIS is also used to produce a detailed characterization of the forests. The tendency is towards total protection for the remaining primary forests and rational management of secondary forest and plantations. The spatial data is derived mainly from digitized topographical maps. The data is complemented with field surveys. Lately also satellite imagery is being used.

4.5.5. Private sector

In the private sector some consulting companies are actively offering services in the field of spatial data production and application development, without being specifically oriented to SFM. These companies are operating in the void left by the public sector.

The large agricultural estates (banana) started using GIS around 1995 for the physical characterization of their areas and for prospection potential new areas, with an emphasis on drainage and infrastructure. Commercial plantations of teak and other timber species are not using GIS.

4.6. Problems related to spatial data use

Thematic data

- There is a serious lack of good quality spatial data sets, ranging from topography, soils, climate and socio-economic phenomena to forest extent, composition and quality. There is a nation-wide catalog of spatial data sets at 1:200,000 scale (including topography (iso-contour lines and DEM), soils, hydrology, some climate parameters and vegetation), but most of this data is derived from old maps, undocumented and of uncertain geometric and geostatistic quality. For operational forest management these data sets have virtually no significance. Some institutes are digitizing the 1:50,000 scale topographic maps for regional projects, which, although more appropriate for forest management, have the same problems of reliability as the 1:200,000 maps.
- The Instituto Geográfico Nacional (IGN) has acquired georeferenced colour aerial photography at 1:25,000 scale for the whole country, which is currently being digitized. This data set will be made available to selected users and will most likely alleviate the data problem somewhat.
- Most digital data sets that are available are not properly documented, which leads to unusable data or improper use.
- A number of institutes, among which IGN, is studying the installation of a Landsat 7 receiving station that would enable the acquisition of comprehensive and current satellite imagery at a relatively small cost. Initial costs to set up the receiver are a big obstacle however.

Institutional weaknesses

- There are quite a few institutes that have a GIS facility, but there is no standard mechanism for the publication or exchange of spatial data. Worse still, there are no national standards guiding the production of digital spatial data or a standard national format for its exchange. The absence of a regulatory body leads to incompatible data and duplication of effort. IGN has in the past made an attempt at drafting national standards, but the lack of a legal framework has thwarted the attempt.
  Last year the Comisión TERRA was formed, with the objective of making an inventory of available data sets. Many institutes neglected the commission however as it professed an authoritarian approach and was uncommunicative to comments from the institutes involved.
- In many institutes the GIS facility is playing a minor role, is being marginalized, is separate from other institutional structures and activities or is not given adequate support to maintain and exploit the possibilities of the facility.
  There is often a critical lack of skilled personnel and, in the case of Government agencies, skilled people easily leave to take a higher paid job in the private sector.

5. MALAYSIA

5.1. Study organization

The Malaysia country study was executed by the Regional Centre for Forest Management (RCFM), Kuala Lumpur. RCFM is an institute spawned from the Forest Research Institute of Malaysia (FRIM), at the request of the member nations of ASEAN, to address the development and promotion of sustainable forest management in the region. As such it is the successor to the ASEAN Institute for Forest Management (AIFM).

The main contributor to the study was Dr. Khali Aziz Hamzah, a forester with advanced education in the field of remote sensing. Dr. Hamzah is heading the Geomatics unit of RCFM.

5.2. Study location

The emphasis of the Malaysia country study is on plantation forestry, both for timber and non-timber products. Geographically the focus is on the State of Negiri Sembilan.

Negeri Sembilan is located in the central region of Peninsular Malaysia. It is bordered to the east by Pahang and to the south by Malacca and Johore. The state capital Seremban is about 60km south-east from Kuala Lumpur. Seremban is well connected to the major towns and cities in the west Coast of Peninsular Malaysia by the north-south Expressway. The State covers a total area of 664,591ha. The land is comprised of valleys and plains amidst undulating hills and mountains. As the Titiwangsa range of the Peninsula tapers down towards the lowlands of Johore, the mountainous and forested terrain of the eastern part of the State gradually gives way to the gentler, undulating rubber and oil palm plantations of the western region.

Negeri Sembilan has a population of about 780,000 (1995 Population Census). Of this 56% are Malays, 29.7% are Chinese, 16.4% are Indians and 1.4% others. Average population density is 109 persons per km^2.

Negeri Sembilan is mainly an agricultural state. However, the establishment of several industrial estates has enhanced the manufacturing sector as a major contributor towards the State's economy. Agricultural activity includes rubber and oil-palm plantations, livestock, fruit orchards and vegetable farming. About 309,850ha are under rubber and oil palm. Manufacturing activity includes electrical and electronics, textiles, furniture, chemicals, machinery, metalwork and rubber products. Agricultural land occupies the largest portion of the State, comprising 62.2% whilst industrial land occupies only 0.4%. However, in terms of employment, the manufacturing sector employs 28.7% of the labour force and the agricultural sector 20.7%. It is estimated that by the year 2000, 38.5% of the labour force will be in manufacturing and 11.8% in agriculture.

5.3. Forest and Land Resources in Malaysia

Malaysia covers a total land area of approximately $32.9*10^6$ha with $13.2*10^6$ha in Peninsular Malaysia, which comprises eleven states and the Federal Territory of Kuala Lumpur, $7.4*10^6$ha in Sabah and the Federal Territory of Labuan, and $12.3*10^6$ha in Sarawak. Being a tropical country, Malaysia is located north of the Equator within latitudes 1° to 7° north and longitudes l00° to 119° east. Peninsular Malaysia is separated from Sabah and Sarawak by 720km of the south China Sea, giving the country a coastline of almost 4,830km.

The climate of Malaysia is typically humid tropical or wet equatorial and is characterized by year round high temperatures and seasonal heavy rain, especially during the north-east Monsoon from October/November to February/March. The mean temperatures during the day and night are 32°C and 22°C respectively. The average monthly temperature variation is about 2°C while diurnal temperature variation for inland and coastal areas are 8.5°C to 11°C and 5.5°C to 8.5°C respectively. The average annual rainfall is about

2,540mm with a maximum of 5,080mm and a minimum of 1,650mm. Humidity is always high and ranges from 70% to 98%.

5.3.1. Natural forests

Malaysia is well endowed with a relatively large tract of rich and diverse tropical rain forests. The total forested area in Malaysia per ultimo 1996 was estimated to be 18.9*10^6ha or 57% of the total land area. Of this total, it is estimated that some 16.5*10^6ha are the inland dipterocarp forests, with the remaining 1.7, and 0.6 million hectares being fresh water swamp, and mangrove swamp, respectively. The inland dipterocarp forests could be further categorized into lowland dipterocarp, hill dipterocarp, upper dipterocarp, lower montane and upper montane forests, respectively. The distribution and extent of forest areas by major forest types and regions is as shown in Table 5.1.

Table 5.1. Distribution and Extent of Natural Forests by Major Forest Types in Malaysia, 1995 (x10^6ha).

Region	Land Area	Dipterocarp Forest	Swamp Forest	Mangrove Forest	Total	%
Peninsular Malaysia	13.16	5.41	0.30	0.11	5.82	44.2
Sabah	7.37	3.83	0.19	0.32	4.34	58.9
Sarawak	12.33	7.30	1.20	0.20	8.70	70.6
Malaysia	**32.86**	**16.54**	**1.69**	**0.63**	**18.86**	**57.4**

As a national renewable resource, the forest has contributed significantly towards the socio-economic development of Malaysia. For instance, in 1992 the forestry sector provided direct employment for 235,000 people or about 3% of the country's labour force. Apart from its monetary value, forest also plays an important protective function such as in the maintenance of environmental stability, the minimization of damage to rivers and agricultural land by floods and erosion, the conservation of wildlife and the safeguarding of water supplies. In this regards, the forest catchments of Malaysia supply approximately 97% of the fresh water needed for domestic, agricultural, irrigation, industrial and recreational purposes. It must also be stressed that the success and development of the agricultural sector depends on the protective role of the forest.

In view of these crucial roles of forests, Malaysia has set aside a total of 14.3*10^6ha of its natural forests as the Permanent Reserved Forest (PRF) to be managed and developed sustainably. Approximately 10.9*10^6ha or 76% of the PRF are production forests with the remaining 3.4*10^6ha being protection forests. The status of the PRF in Malaysia is summarized in Table 5.2.

Recognizing that the tropical rain forest of Malaysia is a unique heritage, which is rich and diverse in both flora and fauna, Malaysia, over the years, has been establishing a network of protected areas for the conservation of biological diversity. These comprise primarily national parks, wildlife reserves and sanctuaries, nature parks, bird sanctuaries and marine parks. Some of these parks have been established since the 1930s. Malaysia's largest national park covering 434,351ha was gazetted as early as 1939. Currently, Malaysia has 2.1*10^6ha of conservation areas protected by legislation (Table 5.3). Of these, 1.80*10^6ha are located outside the PRF, whilst another 0.33*10^6ha are located within the PRF.

Table 5.2. Permanent Reserved Forest (PRF)in Malaysia, 1995 (x10^6ha).

Region	Protection Forest	Production Forest	Total	%
Peninsular Malaysia	1.90	2.78	4.68	35.6
Sabah	0.53	3.07	3.60	48.8
Sarawak	1.00	5.00	6.00	48.7
Malaysia	**3.43**	**10.85**	**14.28**	**43.5**

Table 5.3. Areas under National Parks, Wildlife and Bird Sanctuaries in Malaysia, 1995 (x10^6ha).

Region	National Park	Wildlife & Bird Sanctuary	Total
Peninsular Malaysia	0.43	0.31	0.74
Sabah	0.25	0.14	0.39
Sarawak	0.68	0.32	1.00
Malaysia	**1.36**	**0.77**	**2.13**

5.3.2. Plantations

Currently, Peninsular Malaysia also has $3.72*10^6$ha of agricultural tree crops which are mainly rubber, oil palm and coconut (Table 5.4). These agricultural plantations are similar to reforested land and increasingly these crops can be looked upon as alternative sources of wood supply especially that of rubberwood. In fact, the total amount of timber obtained from rubber plantations had increased tremendously from about 100,000m^3 in the early 1980's to about $1.84*10^6m^3$ in 1992. Rubberwood trees (commonly known as rubber trees) are felled when their economic life span of 25 to 30 years of latex production is over and replanting is necessary. Research and development has been largely responsible for the commercial development of rubberwood as a new source of timber: 80% of furniture made in Malaysia comes from rubberwood. Likewise, research and development is showing promising results in the utilization of oil palm trees, using trunks and empty fruit bunches in the manufacturing of furniture and particle board.

Table 5.4. Area of main industrial tree crops in Peninsular Malaysia, 1996 (ha).

State	*Hevea* (Rubber)	Oil palm	Coconut
Johor	284,739	597,085	38,199
Kedah	241,256	37,672	3,039
Kelantan	155,820	77,735	8,322
Melaka	58,842	29,820	3,061
Negeri Sembilan	223,146	103,945	1,211
Pahang	269,299	576,970	4,428
Penang	13,487	15,158	2,479
Perak	205,764	297,647	25,095
Perlis	8,693	-	513
Selangor	40.090	146,478	30,082
Terengganu	85,464	138,517	5,076
TOTAL	**1,586,600**	**2,021,027**	**121,505**

Forest industries in Malaysia are dominated by primary processing activities of sawmilling, veneer, and plywood production. However, in recent years, downstream processing activities such as the manufacture of mouldings, furniture and joinery have increased significantly. In addition, Peninsular Malaysia also produces a variety of wood-based panels, which include blockboard, chipboard and fibreboard. Except for a number of integrated timber complexes that had been established and owned by the State Economic Development Corporations, most of the timber industries are owned by the private sector.

With regards to the wood utilization, about 90% of the logs are derived from natural forests. Timber from rubber plantation constituted about one million m^3 per annum while the utilization of forest plantation logs is at the moment insignificant. In Peninsular Malaysia, the first commercial harvesting of forest plantation planted with *Acacia mangium* is expected to occur in the year 1999 in the state of Selangor, although thinning of these plantations are currently being undertaken but the quantum is very minimal. Hence, the utilization of wood resources from forest plantation is relatively low at the present moment.

In the near future the supply of logs from the natural forests is projected to decline from the current $28.3*10^6m^3$ to a sustainable level of around $18*10^6m^3$ per year from PRF. However, approximately another $4*10^6m^3$ are expected to be produced by the rubber replanting programme and the forest plantation. Thus, the total log supply is expected to remain around $22*10^6m^3$.

As resource scarcity becomes more and more severe, increasing number of lesser-known or under-utilized timber species will be promoted and traded as commercial timber. Similarly, plantation logs will also become more important as a source of industrial wood raw materials. As stated above, the amount of forest plantation logs, mainly that of *A. mangium, Gmelina arborea* and *Paraserianthes falcataria*, will be amounting to about $2*10^6m^3$ per annum. However, forest plantation establishment, especially by the private sector, is expected to enhance in the future. This is due mainly to the following reasons, namely:

- Current research findings which concluded that these forest plantation logs are suitable for the production of plywood, fibreboard, particleboard and other reconstituted wood products.
- The provision and enhancement of incentive schemes by both the federal and state governments; and,
- The anticipated increase in the market share of the reconstituted wood products.

In addition, high quality timber species such as Teak and other new species like Sentang are also expected to be planted. Thus, the quantum of forest plantation logs may well exceed $2*10^6m^3$, making it even more significant as a new source of raw material for forest industry and as an alternative to logs from the natural forests.

Another source of raw material, which will become even more significant in the future, is that of rubberwood, which is currently used in the furniture industry. Although the expected input of rubberwood into the industry is projected on average to be $2*10^6m^3$ annually, this is confined to the utilization of the trunk portion of the rubber tree only. On the contrary, the actual availability of rubberwood logs of 5cm diameter and above, including tree branches is close to $9.3*10^6m^3$ per annum. However, most of the potential supply plantations are owned by small-holders and scattered. The accessibility is poor and logistic arrangements are costly and problematic. Nevertheless, with improved co-ordination and planning, these constraints in rubberwood utilization could be significantly reduced. Thus, coupled with improved processing capability through the innovation of modern technology, the actual amount of utilizable rubberwood logs may well be over the projected $2*10^6m^3$.

Thus far, rubberwood logs are generally obtained as a by-product of the agricultural rubber estate, established for latex production. However, rubberwood can also be derived from rubber tree plantation established solely for timber production. Significant research had been carried out to identify new clones or species that will increase its timber yield. Already, new clones such as the RRIM 900, RRIM 2000 and the PB Series which can produce as much as 3 times more timber than the current RRIM 600 series and harvestable in a shorter rotation of 12-15 year have been discovered. Furthermore, new species of higher potential had also being researched. Other than *Hevea brasiliensis, H. pauciflora, H. nitida* and *H. guianensis* have been found to have potential to produce 9 times more timber than the RRIM 600 clone. Consequently, rubberwood logs would become even more significant in the future as a timber plantation species rather than a by-product of agriculture farming.

Other than rubberwood, oil palm trunks and fronds also have great potential as a source of raw material in the future, although very little use is currently made of the timber fibres from the palms. The palm oil industry produces an estimated $20*10^6 m^3$ of trunks, $24*10^6$ tonnes of fronds and $2.4*10^6$ tonnes of fruit bunches a year which can be used to produce panel products such as MDF, particleboard and cement bonded board. As studies and tests carried out had shown that palm fibres can be used to produce good quality panel products, its potential as a raw material for the commercial production of timber and fibre-based products in the future cannot be under-estimated.

5.3.3. Institutional Provisions and Development

In Malaysia, land and forestry are under the jurisdiction of the respective State Governments. To ensure the effectiveness and efficiency in the management and development of its forest resources towards sustainability, the National Forestry Council (NFC) was established in 1971. The NFC serves as a vital platform for the formulation of coordinated forest policies that are in line with the national goals of sustainable forest management and development, as well as for the resolution of conflicts and issues amongst the various States.

A National Forestry Policy (NFP) was promulgated and approved by the NFC in 1978. This policy fostered greater uniformity in the implementation of strategies for the achievement of forest conservation, management and development. It defines that forest management must fulfill environmental and conservation needs besides meeting rational economic production goals. However, in response to the recent global emphasis on the conservation of biological diversity and sustainable utilization of genetic resources, as well as the role of local communities in forest development, the NFP was revised in 1992 to include these important aspects of forestry. The salient points of the revised NFP are as follows:

- to dedicate as PRF sufficient areas strategically located throughout the country in accordance with the concept of rational land use. The PRF will be managed and classified under four major functions: Protection forest; Production forest; Amenity forest (recreation, eco-tourism and in promoting public awareness in forestry); and Research and education forest.
- to manage the PRF in order to maximize social, economic and environmental benefits for the nation and its people in accordance with the principles of sustainable management;
- to implement a planned programme of forest development through forest regeneration and rehabilitation operations in accordance with appropriate silvicultural practices, as well as the establishment of forest plantations of indigenous and exotic species to supplement timber supply from the natural forest;
- to promote efficient harvesting and utilization within the production forest for maximum economic benefits from all form of forest produce and to stimulate the development of appropriate forest industries commensurate with the resource flow, especially in the production of more value-added finished and semi-finished products for local consumption and export, and to create employment opportunities;
- to increase the production of non-wood forest products through scientific and sustainable management practices to supplement local demands and the requirements of related industries;
- to undertake and support a comprehensive programme of forestry education and training at all levels in the public and private sectors in order to ensure adequate supply of trained manpower to meet the requirements of the forestry sector, including the forest-based industries;
- to undertake publicity and extension services in order to generate better understanding among the community on the multiple values of forests and to encourage private sector investment in forest development through the establishment of forest plantations on private lands;
- to provide for the conservation of biological diversity and areas with unique species of flora and fauna, including specific areas for the purpose of forestry education and other scientific studies;
- to develop a comprehensive programme in community forestry to cater for the needs of the rural and urban communities and to promote active local community involvement in forestry development projects, including agro-forestry projects; and
- to undertake and support intensive research programmes in forestry and forest products aimed at enhancing maximum benefits from the forest.

To further strengthen the country's capacity to implement sustainable forestry practices the various enactments and rules that were formerly formulated in Peninsular Malaysia were found to be inadequate. A National Forestry Act was implemented in 1984 in all the States in Peninsular Malaysia. In Sabah, the Sabah Forest Enactment 1968 provides the legal backing to ensure that the status of the PRF is secured while in Sarawak, the Sarawak Forest Ordinance 1954 provides the necessary legal framework. The National Forestry Act was amended in 1993 to further strengthen its effectiveness in dealing with forest encroachment and illegal logging. Amongst others, the penalties for offences have been increased and the Police and Armed Forces undertake surveillance of forestry activities, which together has helped to curb illegal logging and forest encroachment.

Recognizing the potential impacts of forest harvesting operation on the environment, the Environment Quality Act of 1974 was amended in 1985 to include Environmental Impact Assessment (EIA). The Act applies to the following:

- land development schemes converting an area of 500ha or more of forest land into a different land use;
- drainage of wetland, wildlife habitat or virgin forest covering an area of 100ha or more;
- land-based aquaculture projects accompanied by clearing of mangrove swamp forest an area of 50ha or more;
- conversion of hill forest land to other land use covering an area of 50ha or more;
- logging or conversion of forested land to other land use within the catchment area or reservoirs used for municipal water supply, irrigation or hydro-power generation or areas adjacent to state and national parks and national marine parks;
- logging covering an area of 500ha or more;
- conversion of mangrove swamp for industrial, housing or agricultural use covering an area of 50ha or more;
- clearing of mangrove swamps on island adjacent to national marine parks, and
- other activities, which may affect forest, such as coastal reclamation, and hydropower projects.

5.3.4. Forest Inventory

Macro level forest inventory

Forest inventory at macro level aims to collect and generate the following data on the forest resource base:

- to determine the acreage and location of forest areas according to the forest type stratification;
- to assess changes in forest resources with respect to distribution, composition, forest stocking, forest stand and total tree volume according to its quality and productivity;
- to determine the standing volume of forest areas in accordance with the forest type stratification;
- to estimate the net and gross standing volumes of specific diameter classes according to species groups/types and areas with potentials for exploitation; and
- to determine the location and assess both the quality and quantity of rattan, bamboo, palm and *pandanus* resources.

For instance, as a follow up of the first two NFIs, the Third NFI in Peninsular Malaysia was carried out from 1991 to 1993. The aim was to collect the most recent and up-to-date data on the forest resources to be used in the present and future planning, management and development of the forest resources.

Operational level Forest Inventory

At the operational level, there are three types of forest inventory in which all of them involve field survey. They are:

- Linear enumeration of big trees (EN), being carried out with 10% sampling intensity with the objective to estimate timber volume in a given area prior to logging.
- Pre-felling forest inventory, being carried out to determine an appropriate management regime (felling) based on the stand structure of the forest prior to harvesting.
- Post-felling forest inventory, with the objective to determine the regeneration status of the harvested forest in terms of stocking, composition, size and distribution. The information will be used to design appropriate silvicultural treatments of the forest.

5.3.5. Forest Plantations

Commercial tree planting in Malaysia started with *Hevea brasiliensis* (common name: rubber tree) in the early 1900s after it was introduced into the country in 1877. The rubber tree was mainly planted for its latex. Malaysia has commercial plantations also of *Elaeis guineensis* (common name: oil palm) which was introduced in 1870 but commercially planted only in the 1960s.

Although forest tree planting had a similar start as rubber and oil palm with the first planting in early 1900s, it was not managed as intensively as rubber and oil palm. This was probably due to the wealth of natural forest for timber production at that time. The important role of forest plantation in supplementing timber production from the depleting natural forest was only recognized in 1957 with the planting of *Tectona grandis* in the northern states of Peninsular Malaysia. The choice of teak for plantation in those states is mainly due to its favourable climatic conditions and high wood quality. Currently about 2,279ha has been planted with *Tectona grandis*.

In the late 1960s and early 1970s forest plantation efforts in Peninsular Malaysia were directed mainly at establishing fast-growing tropical pines to produce long fibre pulp for the envisaged local pulp and paper industry. With the assistance of FAO, about 5,679ha were established mainly with species such as *Pinus caribaea* var *hondurensis*, *P. merkusii*, and *Araucaria* species in trial plantations in the states of Kedah, Johore, Negeri Sembilan, Pahang and Selangor. However, the planting of these pine species were discontinued in the late 1970s due to lack of viable seed, high establishment and management cost, problems with termites, pests and the poor prospects for the envisaged pulp and paper mill.

The Compensatory Forest Plantation Project (CFPP)

In 1982, the FD of Peninsular Malaysia launched the Compensatory Forest Plantation Program. The project plans to establish about 100,000ha of plantations based on a 15-year rotation, of fast-growing tropical hardwood species, such as *Acacia mangium, Gmelina arborea* and *Paraserianthes falcataria*. However, most of the established areas now consist of *A. mangium* due to its adaptability to almost any planting site. The project saw greater areas being allocated for forest plantation development with proper silviculture and management regime ascribed. Ultimo 1996, about 56,248ha of fast-growing forest plantation had been established under this project.

In 1996 about 70,000ha of forested area had been converted into plantation forests in Peninsular Malaysia. The extent of forest plantation according to the species planted in the respective states is shown in Table 5.5. It is notable that the major portion (about 86%) of the forest plantation areas comprises *A. mangium* planted under CFPP.

Forest plantations in the east Malaysian states of Sabah and Sarawak were established since 1973 and 1981 respectively. In Sarawak, the total forest plantation established is about 10,000ha, which consists of exotic species such *as A mangium, G. arborea, P. falcataria, Swientenia macrophylla* (Mahogany), *A.*

cunninghemii, and some indigenous species such as *Shorea macrophylla* (Engkabang) and *Durio zibenthinus* (Durian). The Sarawak FD has a plan to establish 2,000ha annually in the PRFs that have been affected by shifting cultivation. In the state of Sabah, a total of 113,811ha of forest plantations had been established of which 90,026ha (80%) is covered by fast growing species such as *A. mangium*, *Tectona grandis* and rattan. It is envisaged that by the year 2000, a total of 250,000ha of forest plantations would be established in Sabah.

Table 5.5. Forest Plantations established by the Forestry Department of Peninsular Malaysia according to species, in states of Peninsular Malaysia (1996).

State	*A. mangium P. falcataria G. arborea*	*Tectona grandis*	*Pinus spp.*	*Azadirachta excelsa*	*Hevea*
Kedah	-	1,403	20	-	-
Perlis	-	413	-	-	-
Perak	3,060	234	-	240	-
Selangor	9,022	-	903	-	180
Negeri Sembilan	4,644	118	669	-	30
Johor	18,322	-	1,804	-	-
Pahang	*19,637	-	2,283	-	400
Terengganu	*3,038	-	-	20	40
Kelantan	*3,106	111	-	200	-
TOTAL	****60,149**	**2,279**	**5,679**	**460**	**650**

* Including state plantations
** Area planted under CFPP is 56,248ha.

The serious occurrence of heartrot in *A mangium* plantations that will adversely affect the expected volume and quality of sawlogs production has led to a shift of species choice. The current choice is from three categories of timber species, namely dipterocarps (*Dryobalanops aromatica*, *Hopea odorata*, *S. leprosula* and *S. parvifolia*), non-dipterocarps (*Pterocarpus indicus*, *Dyera costulata* and *Endospermum malaccense*) and exotics (*A. mangium*, *A. auriculiformis* hybrid, *Araucaria hunstenii*, *Flindersia brayleyana*, *Hevea brasiliensis*, *Khaya ivorensis* and *Tectona grandis*). The choice is based on the quality of the timber, growth, planting stock availability and most importantly, the ability of the species (especially the dipterocarps and non-dipterocarps timber species) to adapt to forest plantation conditions. From the limited research data, these species have potential to be planted in plantation.

Rubber Plantations

The Malaysian rubber plantation, originally established for latex, is currently regarded as an important source of timber for the wood-based industry. It is estimated that annually around $2*10^6 m^3$ of rubberwood logs are harvested and utilised for the production of furniture and furniture components. In terms of area, about 30,000ha to 40,000ha are involved yearly.

Most of the rubber plantations either belong to small-holder farmers or estates with the main intention of harvesting latex. With the rapid expansion of the rubberwood-based industry, there appears short supply of rubberwood and this is expected to be serious as more rubber areas are converted into other land use. Measures are in hand to ensure sustainable supply especially by promoting the species as one of the forest plantation species to be planted in the FDs forest plantation program. At present, about 650ha of forest plantation has been planted with rubber.

Logging for rubberwood from agriculture plantation has accelerated over the last ten years. The logs are extracted during replanting, which is normally carried out when the trees reach the end of the 25-30-year economic cycle for latex production. The log yield per hectare varies, but on average the estates and small-holdings produce $190m^3$/ha and $180m^3$/ha of greenwood, respectively. After sawing, the estates and small-holdings can yield around $18m^3$/ha and $11m^3$/ha of sawn-timber respectively.

In view of the pending wood shortage, measures have been initiated to increase timber yield from plantations. The rubber planters are encouraged to plant proven clones that produce high yields of latex and timber. In addition, alternatives that can further ensure adequate supply of wood are considered including promoting rubberwood plantation, plantations solely for production of rubberwood; and rubberwood agro-forestry, mixed rubber plantation for the production of latex, rubberwood, and teakwood.

5.3.6. International Commitment

Currently, various issues on tropical forests have become major concern internationally. This is particularly true with regards to its sustainable management, conservation and development. Consequently, it is envisaged that more intensive forest management will be carried out in the coming years. This is in line with Malaysia's stand as a member country of ITTO and in subscribing to the ITTO “Year 2000 Objective”. The ITTO Year 2000 Objective requires that tropical timber being traded is obtained from sustainably managed forests by the year 2000. In this regard, Malaysia will endeavour to operationalize the “ITTO Guidelines for the Measurement of Sustainable Management of Natural Forests” and its “Criteria for the Measurement of Sustainable Tropical Forest Management” in managing its natural forests. At the same time, the establishment and development of forest plantations will be consistent with the “ITTO Guidelines for the Establishment and Sustainable Management of Planted Tropical Forest”.

A National Committee on SFM in Malaysia comprising representatives from various agencies in the forestry sector was formed in 1994 to ensure that ITTO's Criteria and Indicators are fully implemented. The committee had formulated a total of 92 activities to operationalize the ITTO criteria at the national level and 84 activities at the forest management unit level. In this regards, the due implementation of the “Malaysian Criteria, Indicators and Activities for Sustainable Forest Management” (MC&I) would be critical and of prime priority as Malaysia moves towards achieving the ITTO Year 2000 Objective.

Furthermore, effort is undertaken by Malaysia to facilitate full implementation of the non-legally binding authoritative statement of principles on forests and the commitments as required under the “Convention on Biological Diversity” which was enacted at the UNCED World Summit on Sustainable Development in Rio de Janeiro, 1992.

5.4. Spatial data in forestry

Management of forest resources requires sufficient information about the status of the resource itself. The forest resources need to be regularly mapped, inventoried and monitored. For efficient planning, the data should be kept in a suitable database management system especially when dealing with large quantities of spatial data. It is generally accepted that gathering spatial data through RS techniques offers a sound means for mapping and monitoring forest resources, and a GIS is effective for handling the large quantities of spatial data that are produced.

5.4.1. Early Experience

In Peninsular Malaysia the first attempt at extensive spatial data acquisition based on aerial photographs in forestry was made in 1961. It was to demarcate the upper altitudinal limit of forested lands suitable for inclusion in the production forest. Since there were no standard guidelines on the data requirements, vertical aerial photographs with scales ranging from 1:10,000 to 1:90,000 were used. It was found that stratification of the forest cover was satisfactory up to a photo-scale of 1:60,000. Photographs with scale larger than 1:10,000 proved to be rather tedious for stratification because of the small field of view. The opinion was that aerial photographs with a scale of 1:25,000 was the best compromise for consistency in stratification and forest typing. Hence, the generally accepted range of scale is 1:25,000 to 1:40,000. Aerial photographs are taken in a north-south direction.

Two main reasons for this are:

- Peninsular Malaysia has an undulating land surface. There is a main range known as Banjaran Titiwangsa that runs across from north to the south of Peninsular Malaysia. Flight mission is normally planned to run parallel to the mountain ridges so that relatively constant aircraft flying height above terrain can be maintained.
- Peninsular Malaysia is divided into two zones with different weather pattern on each side of the main range. Flight line needs to be planned not to work against the weather pattern. Being a tropical country, cloud cover poses a big problem in taking aerial photographs in Malaysia. To avoid that it is recommended to take aerial photography in the early morning, possibly before 10:00 hours.

In managing the forest resources, spatial data acquired from aerial photographs has been used widely in various applications. The data is used in NFI, forest resources reconnaissance survey, preparation of working plan for mangrove forest, detecting shifting cultivation areas, planning of national parks and planning and checking of road alignment.

5.4.2. Spatial data in National Forest Inventory

The role of RS in collecting spatial data to be used in National Forest Inventory (NFI) has started since the first inventory was carried out in 1971. The objective was to obtain data on the forest resource for the Forestry and Forest Industries Development Program, implemented with UNDP and FAO. It was based on air-borne RS in which panchromatic vertical aerial photographs of scale 1:25,000 were used. Using the photographs, the mixed tropical forests were stratified into eleven broad forest types (excluding mangrove forest), and maps with a scale of 1:250,000 were prepared. The sampling points for the field survey were selected by superimposing a five-minute grid on the broad forest type maps. The same approach was also carried out in the second NFI in 1981 to check the status and changes of forest areas in Peninsular Malaysia since the first forest inventory was carried out in 1971. In both inventories aerial photographs were successfully used in determining the status of the forested areas in Peninsular Malaysia. The results of the first and second NFI carried out had estimated that the total natural forest were $8.32*10^6$ha and $6.84*10^6$ha respectively.

Recognizing the usefulness of using RS techniques in forestry application, a decision was made to use space-borne RS data in the third NFI. The inventory was carried out in 1991, but the system development program started in 1990 in which the FD Headquarters Peninsular Malaysia purchased and installed hardware and software for the development of an NFIS including mapping capabilities. Under this project the third NFI (1991 - 1993) was carried out using satellite data in replacement of aerial photographs. Landsat TM data for the whole Peninsular Malaysia was acquired from the Malaysia Centre of Remote Sensing (MACRES). Only cloud-free digital data and hard copy print out (image with a scale of 1:250,000) were used.

5.4.3. Spatial data in Forest Mapping

Beside inventory, RS-based spatial data has been used for forest mapping. The first step in forest mapping is to differentiate between forest and non-forest areas. Specifically in Malaysia the non-forest category include agriculture areas (oil palm, rubber and other plantations) and non-vegetated areas. Using Landsat TM data, rubber and oil-palm plantations can be differentiated from forested areas. Generally, the forest registered higher reflectance in TM4 compared to TM5. This is in contrast to logged-over area in which the value in TM5 is higher than in TM4, due to higher soil reflectance in the short-wave infrared.

Based on satellite data the different forest types in Malaysia (peat swamp, mangrove and inland forests) can be differentiated by the different spectral reflectance as a result of the species composition in the respective forests. It is also possible to differentiate between undisturbed forest and recently logged-over forests due to the greater spectral reflectance of the latter seen in the satellite imagery.

5.4.4. Spatial data in Forest Rehabilitation

In general, prior to any forest rehabilitation programs, one needs to have good base-line data. The most critical are data on the extent of the degraded forests, the location of the areas, the severity of the degradation and its potential causes. It has been proven that much of this data can be obtained by performing suitable digital analysis of satellite imagery.

The most promising use of RS-based spatial data for forest rehabilitation is on the delineation and assessment of degraded or disturbed forest areas. Uncontrolled and improper planning of timber harvesting is one of the reasons leading to forest degradation. As a result of forest harvesting, the natural primary forests is disturbed, partly due to road construction, construction of log landing site, as well as due to the impact of the felled trees to the surrounding residual stand. Normally the disturbed forest sites are quite easily recognized because of their linear shapes. In satellite imagery, these areas will show light colour against the dark background of intact forest.

Various studies conducted locally have shown that satellite imagery is very useful for locating degraded forest due to logging activities. This is particularly true for locating forest roads, disturbed areas due to extensive harvest of trees and landing sites. A study has shown that roads, skid trails and forest depletion and disturbances such as abandoned land and bare soil could easily be detected through both digital and visual interpretation of Landsat MSS and SPOT imageries. Another study reported that recent logged-over forest areas especially those that had been intensively harvested could also be detected and mapped from Landsat TM data. By knowing the extent and location of the degraded forest, proper rehabilitation plans can be prepared accordingly.

Satellite imagery also has good potential in determining different degrees of forest disturbance. The data will be of useful in designing a proper forest rehabilitation programme for the different disturbance classes. Landsat TM data has been used to determine peat swamp forest disturbance after logging, providing very useful information for the forest manager and planner to conduct necessary rehabilitation programmes in order to secure future sustainability of the resources in the area. The use of RS techniques in mapping of peat swamp forest is worthwhile in view of the fact that most of the peat swamp forest is not easily accessible. The experience gained so far could be very useful to forest managers and decision-makers in planning proper rehabilitation program of the peat swamp forest.

5.4.5. Spatial data in Forest Monitoring

Due to the dynamic nature of the forest resource, its management must in turn be highly dynamic. Hence, it is important that it is monitored, through repetitive inventories aimed at describing quantitative and qualitative characteristics of the resource area. It is concerning the monitoring process (where forest cover is subject to rapid alteration by either natural or manmade activities) that RS-based spatial data is expected to be of greatest use in forestry. These alterations are widely varied in their nature and causes, ranging from shifting cultivation, forest exploitation, insect infestation and many others.

Previous studies conducted in Malaysia have shown that RS offers good potential in the monitoring of forest resources. Awaya et al. (1989) showed that by using satellite data it was possible to determine some of the changes taking place in the forest as a result of forest harvesting and forest road construction. Forest harvesting and forest road construction are two activities than can be regulated and monitored by the proper authorities, hence theoretically should pose little management problems. Nevertheless, problems such as illegal logging cannot be ignored especially in remote areas where accessibility poses a big hurdle. RS can assist in the efficient monitoring and regulating of timber harvesting areas, hence reducing illegal logging through early detection.

Shifting cultivation by aborigines is another problem faced by the forestry sector although the situation in Peninsular Malaysia is still under control. Most of the aborigines live in the forest and some practice shifting cultivation. Detection and monitoring of these areas can be performed using RS-based spatial data.

Integration of spatial data obtained from RS with other spatial data such as land use maps also prove to be useful in monitoring forest areas. Hamzah et al. (1993) used Landsat TM data and land use map covering Klang Mangrove Forest to detect the forest changes between 1974 to 1991. Results indicated that there has been a steady reduction of mangrove areas between the two dates. During that period about 23.8% of the mangrove forest in the study area has been converted to other land use. Field observation conducted confirmed that on the islands most of the areas has been converted to agriculture, where as along the mainland coast, the changes were mainly due to the development of the mangrove forest into residential areas, ports and related infrastructure.

5.4.6. Spatial data from Microwave Sensor

For tropical forest management in Malaysia, microwave data is considered useful in four major fields: forest cover type mapping, monitoring cutover areas, forest plantation mapping and forest inventory. Among notable advantages of using spatial data obtained from microwave sensors are cloud penetration capability and unrestricted data acquisition time. However, in contrast to optical systems, microwave data are not widely applied in this country. Nevertheless, there are a number of studies related to the use of microwave data (particularly SAR) reported in literature. Hamzah and White (1996) reported significant difference in JERS-1 SAR backscatter between primary and logged over peat swamp forest. Dams et al. (1989) showed that SAR data is very useful for forest cover mapping and cut-over monitoring in Peninsular Malaysia. One important detailed study was conducted by Hamzah (1997) on the utility of L-band JERS-1 SAR data for tropical peat swamp forest inventory in Peninsular Malaysia. Results from quantitative analysis of the SAR data showed that the L-band SAR is sensitive to different peat swamp forest classes due to the vegetation density. There are significant positive relationships between the L-band backscatter coefficients measured by JERS-1 SAR and forest biophysical parameters. This suggests the possibility of using the spatial data obtained from microwave sensor to collect forest-related data. The main conclusion from the study is that L-band SAR data can be a useful adjunct in tropical peat swamp forest management programmes.

5.4.7. Spatial Data – Problems and User Requirements

It is recognized that spatial data from satellite imagery has good potential linkages with forestry-related activities. But the use of satellite imagery in forestry application especially in tropical countries is currently restricted by several problems. Besides the data quality problem (cloud cover, haze, etc.), the coarse spatial resolution of the data is also critical. The full advantage of the data could not be obtained under the current resolution (the best so far 10m resolution of SPOT panchromatic) because, for instance, some of the degraded forest areas, which are small in size, could not be detected. Hence, the true picture on the extent and location of the degraded forest could not be obtained accurately. But the development of RS technology is taking very fast. The most notable improvement, which is expected to give much advantage in forestry, is on the spatial resolution. With the improved resolution, detail and better analysis can be performed. This will lead to more precise mapping and assessing of the forest resources hence proper forest management programmes can be planned and implemented effectively.

Another obvious limitation in this part of the region is acquiring cloud-free images. Cloud cover has largely restricted the opportunities for acquiring relevant data and reduced the advantage of repetitive capabilities of the satellite RS data. Specifically for Malaysia, a mean annual cloud coverage of the region ranges from 80% to 90%. In some cases, it is almost impossible to get cloud-free image of an area throughout the year. This problem has been subdued with the availability of microwave remote sensor in orbit such as ERS, JERS-1, and RADARSAT satellites.

5.5. Organization and Implementation

The implementation of the RS programme in Malaysia is coordinated by the Malaysian Centre for Remote Sensing (MACRES). Policy guidelines regarding RS application, facilities creation, training and manpower development are addressed by MACRES. In the forestry sector, the FD provides coordination and planning services related to the disposition and management of forest resources, and in that capacity it has to interact with central, state and academic institutions and also with industry.

5.5.1. Organizations using spatial data

Three main agencies are currently active in using RS-based spatial data and GIS technologies for forestry applications. They are RCFM, FRIM and FDs that serve three major different roles namely training, research and application.

RCFM

The establishment of AIFM in 1986 has accelerated the use of RS and GIS technologies in forestry. Beginning in January 1998, the institute is known as RCFM. Among others the objective of RCFM is to promote effective transfer and application of modern technologies, such as RS and computer applications, as well as management and information science in forestry. The Centre is fully equipped with digital image processing and GIS software, and its strength is the ability to undertake RS and GIS projects as well as to provide training for scientists in the ASEAN region.

FRIM

FRIM has recognized the importance of RS and GIS technologies in forestry for quite some time. This is in line with FRIM's role in the development of appropriate knowledge and technology for the conservation, management and utilization of the forest resource through research, development and application. FRIM initiated its first proper RS study in 1987 under a joint project with Japanese scientists. Subsequently, many studies related to the use of RS-based spatial data and GIS have been carried out. The availability of systems and a group of scientists in RS and GIS make FRIM capable of performing various RS and GIS related research.

Forestry Departments

Recognizing the usefulness of remotely sensed data, in 1990 the FD Headquarters installed computer hardware and software for the development of an NFIS. A similar system is also available in the FDs in the states of Sarawak and Sabah since 1991. Their intended primary application is for enhancing the decision making process in forest resources management.

5.5.2. The National Forestry Information System (NFIS)

The NFIS comprises three major components, which are the MIS, GIS and Image Processing System (IPS). The development of MIS will involve the use of various types of spatial data such as satellite imagery, as well as thematic maps. The MIS will be used to continuously update the forest resources of Peninsular Malaysia in the GIS database using satellite data analyzed by the IPS.

With the assistance of the UNDP and the FAO the FD Headquarters, Peninsular Malaysia, set up a continuous forest monitoring system integrating RS technology and GIS. The project is further strengthened with the involvement of the European Commission by providing both technical and financial assistance in 1997. The overall objective of developing the MIS is to allow forest managers at all levels to have convenient access to data and information to improve effective planning, management, conservation and sustainable development of forest resources. The MIS will provide sufficient and significant information at

National, State, District, Forest Reserve and even Compartment levels in support of a better and improved decision making in forest management activities. A methodology for the Continuous Forest Resources Monitoring System (CONFORMS) has been developed and made operational. The System is based on a 3-phased approach consisting of:

Satellite Image Preparation and Interpretation

The first objective during this phase is to establish a grid of permanent observation or monitoring points over the entire forested area of Peninsular Malaysia using satellite imagery, basically Landsat TM. Secondly, the imagery is used on a continuous basis for the detection of changes in forestland use and forest type classification based on the stratification described in Phase 2.

For the purpose of establishing permanent monitoring points a 2.5 minute grid was adopted with each intersection point being a future permanent observation point. Each grid represents an area of approximately 2,000ha and the area of a forest type can now be estimated with a higher precision while changes in forest cover can more easily be delineated.

It is planned that other RS data, such a SPOT or radar imagery, or traditional aerial photographs will also be used to supplement the Landsat TM data if the latter are found to be inadequate for certain user purposes.

Geographic Information System and Applications

The objective of this phase is to arrive at a detailed classification of the grid intersection points, established on the satellite imagery during Phase 1, into basic forest types or strata using a GIS. The following activities were considered in this phase:

- Landsat TM imagery as the basic tool.
- SPOT imagery or conventional aerial photography (when available) for specific pilot studies.
- Radar imagery for areas with continuous heavy cloud cover such as south Johor.
- Updated forest type maps at scale 1:250,000, which the mapping section of FD Headquarters produced at regular intervals. It should be noted that this particular type of updating is done from map and tabular data, received from the State FDs, based mostly on administrative decisions such as gazetting and degazetting of forest reserves, issues of logging licenses, etc.
- Data to be extracted and calculated from the First and Second National Forest Inventory and from the Continuous Forest Inventory (CFI) plots started in 1986.
- Specific data on year of logging and other relevant data to be obtained from the State FDs using a specially designed questionnaire.

Most of the additional non-forest data required to complete the GIS format (soil, slope, aspect, forest administration subdivision, protection and environmental aspect etc.), except the field data to be collected during phase 3, must be obtained and entered into the system during phase 2.

Field Survey

This phase concerns data collection in the field, programming and data processing. The results, incorporating the findings of phases 1 and 2, will give updated data on the forest resources and accurate change evaluations. Field sampling on a continuous basis, of all the forest types on randomly selected grid points, according to pre-determined accuracy standards, will be undertaken.

6. NEPAL

6.1. Study organization

In Nepal the study was executed by New ERA, a local NGO with a long experience in educational and socio-cultural development activities, but also with community development at watershed level.

The study team was composed of the following persons:

- Dr. Harka Gurung, team leader.
  Four times Minister in the Government of Nepal. Director, Asian and Pacific Development Centre, Malaysia.

- Mr. Prakash Mathema, research officer.
  Watershed management expert, Ministry of Forest and Soil Conservation.

- Dr. Bal Bopal Baidya, senior research associate.
  Community development expert, New ERA.

The study team was assisted by a Steering Committee, composed of representatives of different government institutions, NGOs and ICIMOD.

6.2. Study location

For the study two watersheds were selected in Kaski district in west central Nepal with its headquarters, Pokhara, located 200 kilometres west of Kathmandu. The selection of Kaski district for field investigation was based on three reasons:

1. It is a hill district with fair representation of sub-tropical and temperate montane forests. Pokhara Valley, in the central part of the district with altitudinal range of 600 m to 2,600m, has a wide variety of vegetation types.
2. Kaski has the largest number of Forest User Groups (FUG) of any district in the country. The district has presently 350 FUGs involving 28,097 households, covering 10,514ha forest area under community management.
3. Phewa Tal (= lake) and Begnas-Rupa Tal watersheds within Pokhara Valley have experienced a number of donor projects in forestry and watershed management. These include both past and on-going projects funded by multi-lateral, bilateral and NGO agencies.

Phewa Tal watershed, in the western section of Pokhara Valley, covers an area of 123km². It covers seven Village Development Committees (VDC) and part of Pokhara municipality with 5,600 households and a total population of 31,578. Since 1974 Phewa Tal has experienced a number of watershed management projects funded by international donors. These studies included a number of studies on dynamics of forest change and siltation of Phewa Tal. One local NGO, Machhapuchhre Development Organization, with support from Norwegian and Japanese NGOs, is also active in some VDCs of Phewa Tal watershed.

The watersheds of Begnas Tal and Rupa Tal in the eastern section of Pokhara Valley cover an area of 173km². A watershed management project started in 1984 and covered seven VDCs with a population of 34,884. As of 1995, the project had completed forest plantations in 36 areas totalling 320ha and prepared management plans for 28 localities with 1,042ha under FUGs. 1,681 Hectares of forest area was handed over to 76 FUGs with 620 members.

6.3. Forest and Land Resources

Nepal is a landlocked country situated between China and India. It has a total area of $14.7*10^6$ha and a rectangular shape extending from east to west. Rugged Himalayan terrain makes up more than 80% of the country. Along the southern border, there is a belt of level land, the tarai, as an extension of the Gangetic plain.

Wide attitudinal variation in Nepal gives rise to great ecological diversity, ranging from tropical forests to alpine tundra along a north-south transect of only 150km. The distribution of Nepal's forests generally follows a zonal pattern related to elevation. Below 1,000m are tropical forest predominantly composed of *Shorea robusta*. *Acacia catechu/Dalbergia sissoo* forest replaces *Shorea* along rivers. In the foothills in western Nepal, *Terminalia/Anogeisus forests replace Shorea*.

Sub-tropical forests occur between 1,000-2,000m, which include *Pinus roxburghii*, *Alnus nepalensis*, *Schima wallichii*, *and Castanopsis spp*. Lower temperate forest occurring between 2,000-2,700m consists of *Pinus wallichiana* and several species of *Quercus*. Upper temperate forest (2,700-3,000m) includes *Quercus semecarpifolia*, *Rhododendron sp*., *Acer spp*., *Pinus wallichiana*, etc. Sub-alpine forests are found at around 3,000m to 4,200m. *Abies spectabilis*, *Betula utilis* and *Rhododendron* forests and *Juniperus indica* forest represent this category. Trees do not grow in the alpine zone but shrubby *Rhododendron* and *Juniperus* are found up to 4,500m.

The most comprehensive investigation of Nepal's land resources (including forests) was made under the Land Resources Mapping Project (LRMP) in the early 1980s. LRMP used a countrywide coverage of 1978/79 aerial photographs as its database.

Table 6.1 shows the LRMP estimates for the major land use categories of Nepal.

Table 6.1 Land use in Nepal (x 1,000ha).

Land use Type	Physiographic Zones						
	High Himalaya	High Mountain	Middle Mountain	Siwalik	Tarai	Total	%
Cultivated land	8	244	1,223	269	1,308	3,052	21
Forested land	155	1,639	1,811	1,438	475	5,518	37
Shrub land	67	176	404	29	30	706	5
Grassland	885	508	278	16	58	1,745	12
Non-cultivated inclusions	1	148	667	59	123	998	7
Other land (snow, rocks, rivers, etc.)	2,234	245	59	75	116	2,729	18
Total	3,350	2,960	4,442	1,886	2,110	14,748	100

Source: LRMP (1986)

In the land use classification adopted by LRMP 'forested land' is considered to be land with at least 10% crown cover. 'Non-cultivated inclusions' are small pockets of land (less than 25ha) close to cultivated land, but too small to be mapped at a scale of 1:50,000. A common pattern of forest distribution in the hills of Nepal is for small pockets of forest to occur scattered throughout the agricultural land. Therefore, it is safe to conclude that LRMP data on forest coverage probably under-estimates the actual area of Nepal's woody vegetation cover.

With regard to forest land use change, a total of 103,968ha of forest in the Siwaliks and tarai were cleared under the Government's settlement programme from the 1950s to mid 1980s. A more recent study (1994) conducted by Forest Research and Survey Centre (FORESC) which compares the LRMP maps based on the 1978/79 aereal photographs with Landsat data of 1990/91 shows that the annual deforestation rate is 1.3% for the tarai. This is less pessimistic than the figure of 3.9% estimated by Master Plan for the Forestry Sector (MPFS) (1988).

Table **6.**2 gives a breakdown of the natural forest area by various categories. Hardwoods are the most extensive forest type comprising about 60% of the total.

Table 6.2. Forest by Type (x1,000ha).

Distribution by	Conifer	Hardwood	Mixed	Total	%
Crown cover (%)					
10 – 40	230	876	311	1,417	26
40 – 70	511	1,403	772	3,186	59
70 – 100	186	428	207	321	15
Maturity					
Poles and regeneration	9	33	10	52	1
Small timber	446	2,356	725	3,527	65
Large timber	472	818	555	1,845	34
Total	927	3,207	1,290	5,424	
Percent	17	59	24	100	100

Adapted from MPFS (1988).

More than a quarter of the forests is degraded (less than 40% crown cover). Almost two-thirds is occupied predominantly by small-sized timber, and one-third by large timber. The proportion of pole-sized timber and regeneration is very small. MPFS (1988) estimates the total growing stock as $522*10^6m^3$ over-bark up to 10 cm top diameter, i.e. an average of $96m^3$/ha.

6.4. Forest Usage and Management

The people of Nepal have traditionally depended on forests for the supply of fuelwood, fodder, timber and non-wood forest products. The greatest value of forest in the livelihood of the people is as providers of essential inputs into the farming system. Tree fodder makes up a high proportion of animal feed. Leaf litter collected from forests is used as bedding material in animal stalls and mixed with dung to make compost manure which is the major fertilizer for farmland.

Nearly all rural households depend on fuelwood for cooking and heating. It has been estimated that two-thirds of the fuelwood supplies come from forest and the rest from private trees and crop residues. Compared to fuelwood and fodder, the demand for timber is low. At high altitudes, conifer shingles are used as roofing material.

The rural people also use forests for obtaining products for direct domestic consumption and income generation. These include honey, mushroom, birds, animals, plants (tubers, fruits, seeds, barks, leaves, flowers) used as diet supplement. Forests also support cottage industries like hand-made paper, bamboo products, ropes, brooms, etc.

Forests make a significant contribution to the sustenance of Nepal's farming system. Consequently, the sustainability of the farming system places a heavy demand on forests. In earlier periods, land use policy was to encourage conversion of forested land to agricultural land in order to increase the tax base. It was not until 1942 that a national-level Department of Forest was established. But the government was unable to manage the forest effectively because of the lack of requisite infrastructure. Although several management plans were prepared for commercial management of tarai forests, these plans were not implemented.

In 1988, the Government approved the MPFS. While the plan covers all aspects of forestry, it emphasizes community forestry so much that 47% of total forestry sector investment during the next two decades was earmarked for community forestry. To date, about 13% of Nepal's total potential community forest area of $3.5*10^6$ha is managed by local communities. The national forest areas are virtually unmanaged with government forestry officials merely protecting them. However, illicit felling of timber continues in the tarai for smuggling across the border to India.

6.5. Organization of Services in Forestry and Watershed Management

The Ministry of Forest and Soil Conservation (MFSC) and the four departments under it are the major government forestry institutions. MFSC is responsible for policy formulation in the forestry sector and for providing direction to the departments under it. The four departments under MFSC are:

- Dept. of Forest (DOF)
- Dept. of Soil Conservation and Watershed Management
- Dept. of National Parks and Wildlife Conservation
- Dept. of Plant Resources

The Ministry is also responsible for supervising the operations of the following parastatal and development boards:

- Forest Products Development Board
- Forest Research and Survey Centre
- Herbs Production and Processing Company Limited
- Nepal Rosin and Turpentine Industry.

The DOF has District Forest Offices (DFO) headed by District Forest Officers in 74 of 75 districts. Depending on the extent of forest cover in a district, the DFO may have up to 3 Ilaka Forest Offices headed by an Assistant Forest Officer. The Ilaka Forest Office has several Range Posts under it. Forest User Groups (FUGs) also comprise a prominent institution in the use and management of the forest resource especially in the hills. According to the database of DOF, 6,605 FUGs have been registered as of 16 August 1998. These FUGs are managing 442,336ha of community forests.

The Department of Soil Conservation and Watershed Management has District Soil Conservation Offices (DSCOs) in 55 districts.

The Department of National Parks and Wildlife Conservation has jurisdiction over protected areas covering about $2.4*10^6$ha. The protected areas include eight national parks, three wildlife reserves, three conservation areas and one hunting reserve.

The Forest Survey Division of Forest Research and Survey Centre conducts forest inventory and prepares forest management plans. It has four sections, namely: Cartography and Photography, Remote Sensing, Inventory, and Biometrics.

6.6. Legal and Operational Framework

The main legal instruments relevant to the forestry sector are:

- Conservation Area Management Regulations, 1996
- Buffer Zone Management Regulations, 1995
- Forest Regulations, 1995
- Forest Act, 1993
- Soil and Watershed Conservation Regulation, 1985
- Soil and Watershed Conservation Act, 1982
- Wildlife Reserve Regulations, 1977
- National Parks and Wildlife Conservation Regulations, 1973

- National Parks and Wildlife Conservation Act, 1972
- Himalayan National Parks Regulations, 1971

The Forest Act 1993 defines forestland as all land that is partly or fully covered with trees. It categorizes the national forests into five types:

- Community Forest: forest areas handed over to FUGs for management and sustainable utilization for collective benefit of the users.
- Leasehold Forest: forest areas leased to institutions or groups of people.
- Religious Forest: forests handed over to religious body for its protection and development.
- Protected Forest: declared by the government for special significance in relation to environmental, scientific or cultural value.
- Government-managed Forest: Production forests managed by the government.

The Act also has provisions for registering forests on privately owned land as private forests.

The Forest Act recognizes FUGs as autonomous legal entities that can freely fix price, transport and market forest products obtained from community forests and utilize the fund so generated in forestry and the surplus amount on community development activities.

The Soil and Watershed Conservation Act and its Regulations give authority to the Government to declare any area as a protected watershed and implement various conservation measures in such areas. However, the Act and Regulations have not come into full effect. Nevertheless, land stabilization and productivity improvement programmes along with land use planning are being implemented with community involvement.

The inherent vulnerability of the national forests to degradation has long been recognized and a long-term plan for Nepal’s forest resources was devised in the MPFS. It spells out the following long-term objectives:

- to meet the basic needs of the people for fuelwood, fodder, timber and other forest products, and to contribute to food production through an effective interaction between forestry and farming practices.
- to protect land against degradation by soil erosion, floods, landslides, desertification and other effects of ecological imbalance.
- to conserve the ecosystem and genetic resources.
- to contribute to growth of local and national economies by managing forest resources and developing forest-based industries and also creating opportunities for income generation and employment.

To meet the above objectives, MPFS has put forth the following policies:

- The forest resources of the country will be managed and utilized to give priority to the needs of the people. As such, forests near the villages will be managed with the participation of local people.
- Land and forest resources will be managed and utilized according to their ecological capability so as to conserve forests, soil, water, flora, fauna and scenic beauty.
- Emphasis will be given to multiple utilization of land for integrated farming system by strengthening soil conservation and watershed management, agroforestry and other related activities.
- Land exceeding the needs of the local communities will be allocated for forest management in the following priority sequence: people living below the poverty line, small farmers, and forest-based industries.

The above policies have been operationalised into various types of forestry programmes and projects. International donors that have shown concern on the degradation of the Himalayan environment support many of these projects. Presently a dozen donor agencies are involved in forest and watershed management in Nepal.

Community forestry projects in operation involve more than six donors and are spread over 58 districts. Of these, 37 districts are covered under a project funded by DANIDA and IDA. The districts that have no donor-supported community forestry project are mostly tarai districts and one mountain district (Mustang). Nine donor agencies are involved in watershed management covering 40 districts. 31 Districts have donor-supported activities both in community forestry and watershed management. Besides regional projects like Participatory Watershed Management Training in Asia and Farmer-Centred Agricultural Management Project – both operated by FAO – are also supporting Nepal's forestry sector. Involvement of donors obviously means introduction of new technologies including use of spatial data. However, application of spatial data remains minimal at the operational level in the districts.

6.7. Spatial data use in Nepal

6.7.1. At national level

Department of Forest (DOF)

FORESC and consulting firms prepare forest management plans for DOF. These management plans are based on the most current aerial photographs available. DOF has a computer based Management Information System (MIS) database for the FUGs. This includes information on the size of the group and its committee, type of forest and its condition, area of forest handed over, income and expenditures of the group. Maps of the FUG forests are not included in the MIS. Although the need for a spatial data handling system has been recognized, nothing has been planned. DOF does not have a specialized unit to deal with acquiring, handling and analysis of spatial data.

Department of Soil Conservation and Watershed Management (DSCWM)

The Watershed Planning Section of DSCWM uses spatial data for preparing sub-watershed management plans. The most recent aerial photographs and topographical maps available are used. The land use, land system, land capability and soil maps prepared by LRMP in 1986 are also used. The sub-watershed management plans include different thematic maps (land use, drainage, slope, proposed land use, etc.) at a scale of 1:25,000.

Recently DSCWM has acquired GIS hardware with financial assistance of JICA. Due to lack of appropriate software and some accessories, the system is not operational. DSCWM has three cartographers and several professionals trained in GIS. Many donor-funded projects, both past and on-going, within DSCWM have used diverse spatial technologies for planning their activities.

Forest Survey Division (FSD)

FSD is the specialized unit within MFSC for acquiring, handling, analyzing spatial data on forests for resource assessment and preparing forest management plans. Use of aerial photographs for forest inventory dates back to early 1960s with the establishment of Forest Resources Survey Office (the old name of what is now FSD), funded by USAID. All the staff of FSD received specialized training on handling and analyzing spatial data. Their capacity is increasing with support from Forest Resource Information System (FRIS) project. FSD uses PC-ERDAS, PC-ArcInfo, TOPOS and ArcView GIS software.

Since January 1990 FSD has been supported by the FINNIDA FRIS project. The Cartography and Photography Section of FSD has aerial photographs of 1954 (scale 1:30,000 and 1:60,000), 1964 (1:60,000), 1967 (1:20,000), 1972 (1:12,000), 1978 (1:50,000), 1992 (1:25,000 and 1:50,000), 1996 (1:25,000 and 1:50,000).

The coverage of these aerial photographs is as follows:

1954	All Nepal except Himalayas and parts of eastern and western tarai.		
1964	All Nepal: Some districts of central and eastern hills.		
1972	Far western, Mid western, western Siwaliks, parts of central and eastern Siwaliks and some adjoining areas.		
1978	All Nepal:	Tarai	1:25,000
		Hills	1:50,000
1992	eastern and central Nepal:	Tarai	1:25,000
		Hills	1:50,000

FSD also acquired recent aerial photographs from other agencies required for preparing forest maps. The FRIS project has established a well-equipped GIS laboratory for FSD. Hardware includes: 5 PCs, digitising boards, plotters, printers and different types of mass storage.
The Remote Sensing Section uses satellite data in forest resource assessment. It has been using 1990/91 Landsat TM data and it is planning to acquire the most recent satellite data. The Section also has 1977 Landsat MSS film negatives covering the whole country.

Institute of Forestry (IOF)

IOF is not a user of spatial data itself, but it is mentioned here as it is the prime training institute for forestry officials. The B.Sc. Forestry syllabus includes the following with regard to spatial data handling:

- Remote Sensing and Photo-interpretation I:
  - Introduction to Remote Sensing
  - Fundamentals of Photography
  - Aerial Photography
  - Basic Photogrammetry
  - Rapid Rural Appraisal through Remote Sensing
- Remote Sensing and Photo-interpretation II:
  - Introduction to Satellite Imagery and Radar Imagery
  - Interpretation of Aerial Photographs
  - Aerial Photo-interpretation for Geological and Soil Evaluation
  - Aerial Photo-interpretation for Forestry, Soil Conservation and Wildlife Application
  - Other applications of Aerial Photographs
  - Geographical Information Systems
- Surveying and Engineering course includes units like chain survey, compass survey, plane table survey and levelling.
- Forest/Soil Conservation Engineering course includes soil survey and preparation of soil maps.
- Forest Surveying. This includes units like chain surveying, compass traversing, levelling, transit and theodolite, tachometry and contouring.
- Soil Conservation and Watershed Management includes a unit on watershed inventory and use of spatial data for preparing watershed management plans.

Optional courses like Environmental Resource Management, Environmental Impact Assessment, Soil Conservation in Degraded Areas also incorporate units on spatial data use.

The certificate in forestry includes a course on Survey and Mapping with units like chain surveying, compass traversing, map drawing, map reading. Aerial photograph interpretation is not included in the course.

IOF has a survey and engineering laboratory that is used for the practical sessions of the above courses. IOF also has GIS facilities that are being used for teaching. IOF has a collection of aerial photographs. IOF also has a collection of topographical maps and some satellite images. The JICA Community Development Forest/Watershed Project has also provided IOF with a set of maps prepared for its Development Study.

6.7.2. At regional and district level

Regional Forest Office (RFO)

Although the significance of spatial data for the activities of RFO is recognized, such data are currently not in use. One reason is the unavailability of data. The RFO does not have facilities for handling spatial data. Although the available manpower usually has skills in map and aerial photo interpretation, their present job requirement does not necessitate the use of these skills.

Regional Training and Extension Centre (RTEC)

The RTEC at Pokhara is currently using a political map of districts to categorize the districts and VDCs within them based on the number of FUGs formed. This map aids the RTEC to prioritize the districts and VDCs for conducting various kinds of training programmes. To date spatial data analysis has not been included in any of RTEC's training programmes. The RTEC does not have aerial photographs nor any topographical or thematic maps.

District Forest Office (DFO)

The DFO does not use aerial photographs or other spatial data except the hand-drawn participatory map for community forests. Use of aerial photographs, topographical and other maps is not been standard practice at the district level. The spatial data available at the DFO have either been acquired at the concerned officer's own initiative or deposited there by some project operating in that district.

The DFO has an important role in the development of FUGs. Under the guidance of DFO officers the base map of the FUG is made. The map is prepared by a Ranger by closed traverse compass and tape survey method. The scale of 1:2,500 is generally used for this kind of map. The generally poor spatial fidelity of this map sometimes leads to problems regarding competence and ownership. Improved techniques for demarcating the FUG area would certainly contribute to the alleviation of this problem.

District Soil Conservation Office (DSCO)

The DSCO of Kaski has used the spatial data products developed by the JICA project. The DSCO does not prepare its own spatial data products. Since the JICA project caters to all the spatial data requirements of DSCO of Kaski, it does not have GIS or other facilities. The available manpower is skilled in map tracing, map reading, surveying and preparation of simple maps. The DSCO uses a copy of the topographical map of the district to show the location of the area where a proposed soil conservation activity is planned.

6.7.3. At the local level

Japan International Cooperation Agency (JICA)

JICA has a package project on land productivity and natural environment in the hill areas of Kaski and Parbat districts. Those are:

- Community Development & Forest/Watershed Conservation Project.
- Greenery Promotion Cooperation Project.
- Development Study on Integrated Watershed Management in the western Hills of Nepal.

The project document specifies use of aerial photographs, topographic, land use, vegetation, erosion hazard maps in analysis of socio-economic conditions. In fact, the Development Study Report has produced detailed maps of its five model areas including three in Kaski district. These were based on aerial photographs taken in 1996. These thematic maps show for each model area the situation for ten items at the ward level:

population density, household water shortage, difficulty in fuelwood, access to livestock feed, households in FUG, landslide damage, land use, soil type, hazard degree, and land use improvement scheme. Topographic maps at 1:10,000 scale and five different thematic maps (soil, slope, land use and vegetation, geological, erosion hazard) at 1:25,000 scale have also been prepared. Integrated Watershed Management maps have been prepared at 1:10,000 scale.

Field visit to the Chapakot model area in Kaski west however revealed that these elaborate cartographic exercises had been very scantily applied at the operational level. The only map used was the standard topographic sheet (scale, 1:25,000) with boundaries of ward and location identification of a mini-project site.

Annapurna Conservation Area Project (ACAP)

Although ACAP does not have a collection of aerial photographs of its project area, it uses different thematic maps prepared by LRMP and others. A GIS lab is being set up at ACAP's head office in Pokhara and the staff are being trained in GIS application with assistance from the World Wildlife Fund (WWF). The Project has plans to use the expertise of the Department of Geography for some of its spatial data related work. The Department of Geography has been equipped with computer facilities by a Japanese donor and teaches courses in GIS for students.

Machhapuchhre Development Organization (MDO)

MDO operates activities in environmental conservation with Norwegian support and nurseries with Japanese support. In 1997 MDO received a WWF Award for its conservation work. Field supervision is done through 19 motivators. It uses an orientation map (scale 1:50,000) showing location of the villages covered. There was no evidence of use of any other maps at the project level.

Forest User Group (FUG)

Given the situation of minimal use of spatial data at the district level, it is not surprising that there is no knowledge of aerial photos and thematic maps at the local level. The operational plans of FUGs include a simple map at a scale of 1:2,500 of the forest showing boundary demarcation and its compartments for management.

Some villagers recognize prominent land features, including forests, from aerial photos. They regard aerial photographs to be an authentic representation of reality. Ex-servicemen were found to be able to read topographic maps. Some could even discern change in forest coverage in aerial photographs of different dates. However, aerial photographs are not usually used in FUG planning and management.

Given the size of the average forest area controlled by the FUG the use of spatial tools for management or monitoring is not really justified. The FUG does however require a good base map at large scale, indicating boundaries and prominent geographic features (village, roads, lakes and streams, slopes). On the basis of this map the FUG members can plan their activities.

6.7.4. Interaction Among Institutions

The involvement of numerous donor-funded projects has built a rich depository of spatial data at the central level of MFSC. This refers particularly to FSD that has been providing useful service to other Departments within the MFSC. However, the expertise is limited only at the central level. Due to lack of dissemination, there is virtually no use of modern spatial data beyond the central departments of the Ministry. Therefore, some sophisticated equipment of FORESC remains under-utilized.

The main function of the RFO is to monitor and evaluate programme implementation in the districts under its jurisdiction. However, the western RFO in Pokhara evidenced that no spatial data had ever been used in its work. Similar is the case with the RTEC that includes no courses in map or aerial photograph interpretation.

There is virtually no interaction between central departments and their district offices on spatial data supply or use. Information on availability of such data for the district is not catalogued or made public, but it depends on the individual initiative of the officer at the DFO to find available data. The lack of consistent spatial data sets has resulted in persistent problems, such as forest area boundary conflicts between FUGs and even among districts.

There seems to be adequate data exchange regarding maps and aerial photographs among institutions at the central level. An Aerial Photographs & Satellite Imagery Index was prepared by the National Remote Sensing Centre in 1987. It includes information on aerial photographs available at different institutes. Presently, FORESC, a depository of former Forest Resources Survey aerial photographs, is providing useful service to other organisations and projects. FORESC has also taken initiative to co-ordinate activities to strengthen RS and GIS activities among various agencies in the country.

The situation of interaction among institutions below the central level is very poor. This can be exemplified by Pokhara where there are numerous regional and district level institutions. For example, the Geography Department is equipped with GIS facilities and also teaches courses while the IOF and ACAP offices are in the process of establishing GIS facilities. But none of the regional and district offices under the MFSC have such facilities nor use any spatial data. Forestry offices at Pokhara would greatly benefit if there were a system of accessing the expertise of local institutions. It would even seem logical as the senior management of DOF, DSCWM and FORESC are represented in the Faculty Board of IOF.

6.8. Problems related to spatial data use

Infrastructural problems

- Many Government and non-governmental institutes at district and local level have had little exposure to computer technology and if they do have experience it is usually in the field of text processing and spreadsheets. Consequently, the staff of these institutes is not adequately trained in the use of the technology and the associated procedures for analysis and planning on the basis of digital (spatial) data. In villages and even smaller towns the standards of living are usually such that educated staff would prefer to live elsewhere.
- At local level the facilities for establishing a spatial data-handling unit are usually not available. Humidity and temperature controlled offices, reliable electrical power and telecommunications are all required, while only the first is to a large degree manageable by local institutions.

Thematic data

- There is but little experience with digital spatial data at district and local level in Nepal. The map material used most extensively is the topographic map at intermediate scale and medium to large scale aerial photography. Government officials at local level can generally interpret topographic maps, but aerial photographs usually require a trained person for its interpretation. At the level of village and FUG use is made of topographic maps, large-scale aerial photographs and hand-drawn maps of the area under command of the village development committee or FUG.
- The topography of Nepal makes it difficult to use (optical) satellite imagery. The mountains stretch in east-west direction, which produces long shadows, particularly for satellites passing in the early morning hours. The steep slopes themselves also produce problems in the interpretation of the images.

7. SPATIAL DATA REQUIREMENTS – A SYNTHESIS

Every kind of systematic forest management or monitoring requires some basic set of spatial data on the forest and land resources. Quite often, spatial data is already available, but its usability is primarily restricted to reconnaissance and inventory, rather than management and monitoring.

7.1. Basic spatial data sets

Management of forests for different functions requires different sets of thematic data. There is, however, a substantial amount of thematic data that is required for most managerial operations. Thematic data describing the geo-physical and bio-physical environment in general terms are most widely used.

Soils, topography, geology, hydrology and precipitation and other climate parameters are almost universally used for the description and analysis of the land resources and for the estimation of the supportive capacity of the land. These data are not commonly generated by the forest managers, but acquired from (other) government agencies, either specialized in mapping and cadastral applications or line departments. The quality of the data (age, resolution, geometric precision, descriptive attributes) is often mediocre, or simply unknown.

Forest cover (extent and change), forest type, species composition, volume classes by species and productivity are used in the context of a specific use of the forest. Requirements (content, resolution, etc.) differ by the specific purpose of the data. Synoptic data is generally gathered through the analysis of satellite imagery, although most forest management operations also require a certain amount of data that can not be derived from such imagery (currently). Terrestrial observations play an important role in the data collection strategies of most forest managers. Such observations are highly superior in quality to RS-derived data, but they do not possess the same possibilities for spatial analysis. Geo-statistical techniques for the interpolation of point observations do exist, but they are not adequate for the description of many of the random processes governing forest dynamics. The combination of remotely sensed data with terrestrial observations, however, can provide a good mix between quality and usability, and in this field many advances are currently being made.

In general, forest managers do not have the financial and technical resources to update their (spatial) databases frequently. The application of spatial analysis techniques to operational forest management is still very recent and the few installations that became operational employ a rather static data use, i.e. data is used for inventory purposes and not for day-to-day management. This situation expresses itself in the preponderance of data that is two to five years old. For forest management and continuous monitoring (fire, encroachments, concessions, etc.) this is clearly an unworkable situation.

The scale of the data being employed is 1:50,000 at best, with exceptions for areas with specific local interests (i.e. research plots, plantations, parks and reserves with high numbers of tourists, etc.). This scale corresponds *grosso modo* to the spatial resolution of Landsat TM imagery, when cartographic standards are followed. Improved sensors with higher spatial resolution (such as the operational SPOT and other sensors) will improve the quality of the data, but they will also increase the required processing power quadratically, they require better analytical techniques and they are generally less well available, at a higher cost.

7.2. Spatial data requirements for management and monitoring

From the four country studies elaborated in this report it is clear that there does not exist a uniformly definable set of information requirements for the sustainable management of tropical forests or monitoring of the same. Information requirements differ by forest function, geo-physical and bio-physical condition of the forest, forest type and the extent of forest under the management of a single entity, to name the most important qualifiers. Consequently, there is no standard spatial data requirement for any end-user of spatial data for forest management or monitoring.

There are, however, a number of similarities between the spatial data requirements of different end-users. Foremost is the use of remotely sensed imagery for the assessment of forest cover and, to a lesser extent, forest type. Second is the necessity to complement RS imagery with field observations, for calibration of image interpretation, and for the collection of data not available from RS imagery.

The next two sections describe data sources in the context of forest management and monitoring. The context itself and the implication for information structures is described in the remainder of the chapter.

7.2.1. Spatial data from remote sensing

The sheer size of forests in many countries mandates the use of data sources that provide synoptic data at regular intervals, of comparable quality and content, at manageable cost and effort. The only viable alternative is RS, either using aerial (digital) photography or videography, or satellite sensors.

Despite the unquestionable value of RS for the assessment of forest resources over large areas, especially when repetitive assessment is required (as in monitoring), RS has some distinctive shortcomings in operational forest management, particularly in view of the upcoming non-timber forest uses.

Optical satellite sensors, the most widely available RS data source, have too coarse a resolution for operational management at field level, when the use is other than protection of a large area, or another large-area, data-extensive, management-extensive use. Air-borne optical sensors provide excellent imagery for a wide variety of management purposes, but the operational costs are prohibitive for most end-users of spatial data, if the option is at all available.

Radar imagery has become generally available since 1994 and suitable interpretation and analysis techniques are now available as well. Radar imagery, however, does not have the spectral resolution that some optical sensors have. The interpretation of radar imagery is not as straightforward as optical imagery, and its primary use is in texture analysis and binary classifications, e.g. forest/non-forest, forest/hydrology, etc. The combination of optical and radar imagery has opened new possibilities for analysis that have proven useful for forest type classifications.

In tropical countries the cloud-free season, when optical images are usually acquired because they need to be as cloud-free as possible, often coincides with defoliation of the vegetation in areas that are not in hydrological depressions. This is actually beneficial for soil studies and terrain analysis, but it underestimates living biomass, unless the analysis is calibrated and validated with extensive field inspection, something which is often not feasible (access, time, financial resources, etc.). The cloud-free season also coincided with seasonal fires, more often than not emanating from agricultural operations, that may impair image quality through the presence of smoke. In some areas there is no distinct cloud-free season and good quality optical imagery may be almost impossible to acquire. Radar imagery does not deteriorate from clouds, haze or smoke, but it is sensitive to rain.

Satellite imagery fails to reveal important managerial parameters, such as forest composition, species distribution, minor species, biodiversity and fauna. High-resolution imagery has been used to determine forest composition in terms of major species of mature trees, and assorted forms of dramatically different species (palms, bamboo, etc.). High-resolution radar imagery has been used to extract forest texture.

7.2.2. Ground measurements

Although not an RS technique, the collection of field data through ground measurements is of such importance that it is included here. As a matter of fact, without ground measurements RS analysis would not be feasible for lack of calibration and validation. Furthermore, no RS technique (airborne or space-borne) has yet been useful for the identification of minor species under closed canopy (small and young trees, non-woody vegetation, NWFP) and it is unlikely that this will be achieved in the near future, given the physical characteristics of the forest system versus current measuring techniques. However, with SFM gaining momentum, such data is rapidly becoming an essential ingredient in the management of forest for different functions.

Field observations will remain a necessary instrument to gather all sorts of data not retrievable from RS imagery. There are essentially three types of observations:

- recorded on-site during physical visits to the forest;
- fixed-site recording by automated probes;
- statistics on forest product output (timber, NWFP, game, tourism), generated at collection points, customs/transit check-points or through other means.

Field visits

Field visits are the traditional form of data collection in forestry. For very large areas statistical sampling is employed, for instance by making transects through the forest, rather than executing an exhaustive survey. Through field visits essentially any kind of forest data can be collected, although there are certain problems associated with this technique, such as poor access to certain areas and the overwhelming amount of surveying that needs to be done for large forest areas.

With the advent of spatial data analysis from remotely sensed images, field visits have become necessary for the calibration and validation of spatial analysis through the collection of empirical data in the field. Notwithstanding the enormous contribution that RS has made to synoptical data collection, field observations are indispensable for the collection of data not found in current imagery, such as forest composition by species, production of NWFP, etc.

New technologies, such as GPS and field computers, have greatly contributed to the efficiency and accuracy of field observations. The development of information systems specifically for forest management has helped in the processing and analysis of data collected in the field.

Fixed-site measurements

A number of geo-physical parameters is routine collected in the field by fixed installations of instruments, with data being recorded for later retrieval or transmission via radio to an office. Stream and sediment gauging flumes, weather stations and insect traps have been used for several decades. Recently, there are new installations measuring air quality and carbon sequestration, a.o.

Statistics on forest product outputs

Statistics on forest product outputs provide important insight in the actual use of the forest by the different actors. Although the statistics are usually not very accurately related to spatial features (the forest) they do give a quantitative dimension to forest use. The statistics can relate to official use (concessions, State board for forestry products, number of tourists, etc.), but they should also take into account illegal appropriation of forest products (timber, firewood, game, etc.) that may be tracked through the recording of registered offences.

7.3. The operational environment

The way the users perceive and manage the forest and land resources is determined by the properties of the operational environment in which they operate. Characterization of the operational environment is essential, as it will allow relating the information requirement for each forest manager to the context in which this information needs to be used. The operational environment is determined by:

- Forest and land resources:
  Forest fragmentation; accessibility; physiography, position; climate (e.g. humidity and seasonality); state of the forest (e.g. virgin forest, secondary regrowth, plantations); forest fires, disasters, diseases; protection (e.g. watersheds, wildlife, parks), conservation, tourism; etc.
- Forest usage, stakeholders and management:
  Forest dwellers, hunting/gathering, shifting cultivation; indigenous people; collection of timber, fuel wood and NWFP by local population. Exclusive government Forest Department management, participatory management, community management, private ownership; commercial or industrial extraction or production. Forest policy, forest laws, forest management regulations. Forest/agriculture interactions, conversion, land use, pressure on the land; environmental protection measures, imposed or self-imposed by the local stakeholders or users; etc.
- The organization of services in the country:
  Local and central Governments; national and private institutions; local and national organizations; interaction between these levels; etc.
- The legal and operational framework:
  The ability to organize and undertake activities; the ability to gather, process and use or disseminate (spatial) data (on forests); access to the forest; etc.

This section will elaborate on those parts of the operational environment that do not directly relate to the forest and land resources or the actual use of spatial data, but rather to the setting in which forest management takes place.

7.3.1. The legal and operational framework

The dissemination and use of spatial data is bounded by legal regulations in most, if not all, countries. These regulations limit the use of spatial data to certain institutes, possibly excluding areas that are politically or militarily sensitive, and imposing restrictions on the use that is made of the spatial data. The production and dissemination of spatial data might well be monopolized by a state-controlled organization (i.e. IGN in Costa Rica, although its prerogative is routinely ignored, and INPE in Brazil for remotely sensed data). Government agencies can usually access spatial data through the official channels, but for NGOs it could be difficult, particularly if they oppose the government on certain policies or programmes. Improved distribution of spatial data has to reckon with these national policies and regulations regarding spatial data use.

7.3.2. Culture

Introducing technologies based on spatial data require an organization to adopt and learn new ways. The older the methods used and the more hierarchical the organization, the more painful the process will be. Information flows are shifted from the old-style managers to new-style computer-literate officers. This last category will have access to data and analysis tools previously not available: technical skills are suddenly both and asset and a threat.

Spatial analysis systems are technical by their nature. People operating them used to have a mapping background: cartographers, land surveyors, etc. Increasingly, professionals in the field of the application (e.g. forestry, land management) start working with the tools. These operators are technically interested enthusiasts, with in-service training that more often than not does not extend beyond working with the specific spatial analysis systems available, thus lacking formal knowledge of spatial analysis itself and the applications for which it is intended.

7.3.3. Organizational readiness

The introduction of spatial analysis systems should always include a review of currently used management practices. Large organizations, government or privately owned, tend to have (partially) outdated management systems. Successful use of spatial data, pervading all procedures and reaching all staff, is dependent on the top-level management's awareness of the necessity to change, rather than to append. This is not to say that the whole organization must change, but that automated spatial data use, or information systems in general, dramatically alter the way that data is analyzed and disseminated. This will definitively change the way that many procedures are implemented.

The changing patterns of data management will have a profound effect on the way that tasks are performed. Forest condition can now be determined (to a certain extent) from satellite images, field visits are required less often, taking the form of sample plot investigations to calibrate image classification. New forest roads can be planned from the office, rather than that a forest area has to be meticulously surveyed.
All these new procedures require that staff is trained and enabled to use the new technology. Quite often in developing countries access to computers and other sophisticated tools is still regarded as a status symbol and it may therefore be reserved for staff of specific rank, thus excluding field staff, the prime users and suppliers of baseline data. Obviously this barrier should be removed. It is the field staff that will survey the forests with GPS and data logger. Overcoming these cultural and political obstacles is quintessential to a more widespread, democratic use of spatial data.

7.4. Common problems in spatial data handling

<u>Inadequate training and experience</u>

The spatial analysis system is often run by foresters rather than by geographers or cartographers. Although a profound knowledge of the subject being modeled with the use of spatial data is indispensable, so is a thorough understanding of the implications of the operation itself.

Local staff may not be able to read English or understand the technical language of manuals and help systems. They may have had insufficient exposure to computers and be unfamiliar with modern operating systems or procedures.

<u>Experienced staff leaves the organization</u>

In developing countries it is not unusual that the private sector is more appealing than the public sector because of (much) higher wages for skilled technical personnel.

<u>Inappropriate procedures and (lack of) standards</u>

As mentioned above, inexperienced users may apply inappropriate procedures to address a given problem. The lack of clear and concise standards is another cause for incorrect or unreliable results.

<u>Technology not understood by decision makers</u>

Applying modern technology to solve a problem involves more than buying a powerful computer, installing expensive software on it and training a few operators to perform the magic that is usually expected in return for the investment made. Seldom the changes in the organization or the work procedures are made that would serve to integrate the technology and take advantage of its full potential.

<u>Insufficient resources</u>

Many organizations do not have the resources to acquire the computers and software they actually need for the tasks they have at hand. Even less so do they hire experienced people to operate the system, to build and maintain a library of standard procedures and functions (spatial data, attribute data, data formats, output formats), to cooperate with the foresters to represent their working environment digitally. Furthermore, the recipient organization may not make the necessary provisions (budget!) to maintain a computer system after its installation.

Lack of reliable data

Almost any kind of spatial analysis requires multiple data sets, which are usually in part general and in part specific to the field of application. The specific data sets almost invariably have to be generated by the own organization, while the general data sets may be obtained or purchased from third parties such government mapping agencies or commercial data providers. However, in many cases no digital data sets of a general nature are available and if they are the associated metadata might not be compiled leaving the data set virtually unusable (because of lack of data quality information, projection, currency, et cetera). Also, an organization implementing a GIS does not usually have technically skilled personnel to build the reliable and concise application specific data set required for specific analyses.

7.5. A Forest Information System

With the multitude of available spatial and statistical data sources, analytical procedures and management options some structuring becomes inevitable. In general it can be said that all the components in the information and decision structures need to be integrated, benefiting from recent developments in information technology. Data sources (satellite imagery, field observations, GPS, etc.) are fed into databases; databases are used to supply raw data to analytical and decision-making procedures; and output is presented to the end-user in a variety of ways: thematic maps, reports, action plans. In the field of forestry and forestland management such integration would involve the use of GIS tools, statistical databases and specific business rules supporting management and decision-making. We will baptize such an integrated system a Forest Information System (FIS).

Making the appropriate data available to the right persons at the right time in the right form is the most compelling task in the development of a FIS. It is obvious that designing an integrated FIS requires a thorough knowledge of data flow, the data requirements for the different processes and the way that processes depend on each other and how they interact.

7.5.1. Integrating data sources and decision processes

Spatial databases must be integrated with statistical databases in order to fully achieve their potential for planning, management and, to a lesser degree, monitoring. There is however a friction between the probabilistic nature of many types of spatial data (e.g. boundaries on a soil map, unsupervised classified satellite imagery) and the deterministic nature of most statistical data. Statistical data with a spatial significance usually refer to a quantitative observation at a particular point, whereas spatial data has, at its best, a set of generalized descriptors of the nature of the observed feature over a large area (e.g. forest types from satellite imagery versus species inventory from a sample plot).

This discrepancy between the two data sources is not really an obstacle however; it is rather an aspect of a FIS that requires consideration. Neither database is comprehensive or completely accurate, they can complement each other and cross-validate data.

The unified data structure must itself be integrated with analytical procedures and ‘business rules’ that support the decision-making process. Each function or activity will have its own set of data processing methods to arrive at management decisions. Monitoring of a natural forest area by a NGO requires completely different analyses from a local forest/watershed/community development system or a sustainable timber extraction operation. But also within a particular organization many different functions exist, i.e. higher management in a Forest Department (planning, monitoring) versus a local branch office (operational management plans).

7.5.2. Institutional capacity

The integration of data and decision processes as discussed in the previous section is vital to the proper use of spatial data. In most organizations the spatial data is not handled by geographers or cartographers, but by subject matter specialists having had training to work with specific software. The end-users of the spatial data usually don't have any specific training: foresters, silviculturalists, watershed conservation experts, local office managers, higher management. These two categories, spatial data handlers and end-users, do not necessarily understand each other's functions and associated information requirements.

Ideally a laboratory for spatial data processing procures, analyzes and prepares spatial data required for the different users of the FIS. This may include the production of vectorized forest road networks or supervised and unsupervised classification of satellite imagery for specific purposes, and includes the whole array of spatial data housekeeping such as verification, geometric transformations, mosaicing, generalization and attribute recording. The end-users access the spatial data and associated statistical data through a uniform user interface. Thus, the end-users need to learn to operate a specific tool, focussing on their specific tasks, rather than an array of general tools.
The complexity of spatial analysis systems require that a FIS be supported by a dedicated unit with the capacity, both in equipment and staff, to support requests for spatial analysis from end-users, to adapt the FIS to new procedures and data sets and to maintain the integrity of the whole system.

It is obvious that the requirements of a FIS limit its usefulness to larger, and financially stronger, organizations, serving large areas of forest, supporting multiple objectives or functions. But also for smaller organizations, where a full-scale FIS would be out of place, there is a need to integrate the different components of a spatial analysis system, if only to benefit from increased analysis possibilities.

7.5.3. Introducing new technology

Automated systems for data collection, analysis and planning are often introduced through a project-based approach, either using a local consulting agency or with the help of international development assistance. Unfortunately time and money constraints imply that a 'blue-print solution' is imposed upon a receiving organization, rather than that a system is developed for a particular situation. In the context of forestry the target organization is often the forest department. It is the donor or the funding agency that proposes, or urges, a FIS to be procured and installed. The intention is to 'modernize' working methods. And although computers and remotely sensed images are modern, introducing an information system is a much more complex undertaking than installing some shrink-wrapped applications.

When a FIS is developed for a particular organization the current procedures, if adequate for the contemporary management paradigms, should be conserved and extended or supported with the possibilities offered by new technology. Pushing a reluctant organization in a certain direction is sometimes seen as the only possible way to get things moving, particularly when dealing with such conservative structures as forest departments. But at some point the new technology must be endorsed by the organization and incorporated in working procedures. If this fails, there will be no or inadequate use of the new technology and the spatial data that it produces. It can even be counterproductive, as it may raise resentment against the modernist management styles and methods of today.

As mentioned before, it is imperative that the actual end-user is taken into consideration when new technology is developed and introduced in an organization. This end-user is not the person responsible for the preparation and processing of spatial data, but rather the person going into the field, the person actually implementing management decisions in the forest, and the higher management of the organization itself (i.e. for planning and monitoring).

It must be stressed that preparing the ground for implementing a FIS, by introducing new modus operandi, is difficult. It can take years from initial evaluations to tangible results depending on the counterpart organization. Old methods are often outdated and the field staff often has their own (informal) ways to cut corners established by an obsolete management system. The operational staff sees the advantages a new system offer faster. They often realize it could help them in getting their job done, either faster, or in a less cumbersome way. At higher levels the managers with less hands-on experience depend more on the formal system. They know the existing system by heart. New methods on the other hand, which they have no experience of and no superiority in, pose a threat. Putting the data in the hands of subordinate staff may undermine their position. It is however the higher management that has to take the decision to implement such new procedures.

Superficially, the development of a FIS centers on technical issues of computer system hardware and software, functional requirements and performance standards. But experience has shown that as important as these issues may be, they are not the ones that in the end determine whether a FIS implementation will succeed or fail. The issues responsible for implementation failure are almost always peoples' problems. They are more profound, putting the entire issue at risk. They are also often more difficult to tackle as they involve humans, and their interactions.

Introducing an FIS aims at improving the management practices of an organization, through the availability of data on which management decisions can be based. The FIS is a derivative of the organization and it should therefore be designed with the organization, and the people that work for it, in mind.

8. CONCLUSIONS

In sustainable forest management the use of modern analytical tools and remotely sensed data has become imperative. The amount of data required for adequate management and the ever more intricate relationships between the different processes occurring in forests that are being included in decision-making procedures preclude the use of manual or cognitive methods.

Adequate forest management and monitoring require these tools and data to be in the hands of the forest managers at the lowest possible level, with the authority extended to them to actually apply the information derived from the analysis of the different data sources. Currently, many forest managers at the local level do not have either one of the three required ingredients. Furthermore, at the local level there are very often no qualified personnel, capable of managing the current information systems and analytical tools.

The supply of high quality, affordable spatial data would have a tremendous impact on the quality of forest management, at least if the institutional and infrastructural impediments are cleared.

Sustainable forest use cannot be mandated from the central government, it cannot be enforced by the local forest manager, until the means are established to define what sustainable use is, how it can be monitoring and who is going to reap the benefits from it. Spatial data can play an important role in the processes related to sustainable forest use, but unless its use is embedded in a rational and adequate environment it will not provide a substantial improvement in sustainable forest management, nor will it alleviate the pressure that is currently on the forest.

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